

Veille d'informations sur la pyrale du maïs (*Ostrinia nubilalis*)

Ce document présente une liste d'articles et de rapports de recherches réalisés au Québec ou en dehors du Québec. Dernière mise à jour : 27 février 2017.

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Articles parus en 2017

BERES, P. K., KUCHARCZYK, H., & GÓRSKI, D. (2017). Effects of Insecticides Used against the European Corn Borer on Thrips Abundance on Maize. *Plant Protection Science*, 53(1).

The effect of a single chemical treatment against *Ostrinia nubilalis* (Hbn.) on thrips abundance on maize in south-eastern Poland was evaluated. Two insecticides: Karate Zeon 050 CS, containing lambda-cyhalothrin, and Proteus 110 OD, containing thiacloprid with deltamethrin, were tested. Maize was sprayed in the second ten days of July, during the abundant occurrence of *O. nubilalis* larvae, which coincided with the population peak of thrips on plants. The tested active substances showed high effectiveness against thrips, but a better effect, reflected in a decrease in thrips abundance, was found for the mixture of thiacloprid with deltamethrin. The tested insecticides significantly reduced the population of thrips for up to 14 days after treatment.

EL-SAPPAGH, I. A. Effect of certain bio and chemical insecticides on *Sesamia cretica* Led. and *Ostrinia nubilalis* Hub. in maize field in Qaliubiya Governorate, Egypt.

Field experiments were conducted to determine the comparative efficacies of different bio and chemical insecticides against two lepidopterous species *Sesamia cretica* Led. (Noctuidae) and *Ostrinia nubilalis* Hub. (pyraustidae) in Qaliubiya Governorate, Egypt. All treatments were found effective in reducing the infestation rates by *Sesamia cretica* and *Ostrinia nubilalis* and increasing the yield compared with control. The chemical insecticide Neomyl was found the best against *Sesamia cretica* as it led to minimum percent age of infestation, followed by Bestban and Tempo XI, respectively. While, Dipel 2X resulted the lowest reduction % of infestation compared with control. As for *O. nubilalis* Hub. infestation, Tempo XI was the highest effective in reducing number of both infested plants and number of holes while, Bestban and Neomyl were of moderate efficacy, leading to moderate infestation rates compared to control. Dipel 2X treatment resulted lower infestation percentage than control.

Cette veille bibliographique est réalisée par Nathalie Roullé et Nicolas Chatel-Launay, Pôle d'excellence en lutte intégrée (PELI).

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Georgescu, E., Toader, M., Balaban, N., Rasnoveanu, L., & Cana, L. (2017). TESTING OF THE NEW ACTIVE INGREDIENTS FOR CONTROLLING OF THE OSTRINIA NUBILALIS HBN AT MAIZE CROP, IN CONDITIONS OF ARTIFICIAL INFESTATION, AT NARDI FUNDULEA. *Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series*, 46(2), 121-127.

In this paper, author collective present preliminary results of new active ingredients testing for vegetation treatment against European corn borer at maize crops. Maize plants were artificial infested with *Ostrinia nubilalis* egg batches produced in laboratory conditions, from insects reared consecutive generations, using same artificial diet. Climatic conditions from summer period were favorable for pest evolution in 2016 comparative with 2014. At untreated maize plants, average number of larvae per plant was 3.03 in 2014 and 14.70 in 2016 while average length of the cavities per plants was 13.41 cm in 2014 and 20.18 cm in 2016. At treated variants, in climatic conditions of the summer of 2014 and 2016, higher effectiveness was registered in case of higher dose of indoxacarb active ingredient and chlorantraniliprole active ingredient, in dose of 150 and 200 ml p.c./ha.

Kozak, G. M., Wadsworth, C. B., Kahne, S. C., Bogdanowicz, S. M., Harrison, R. G., Coates, B. S., & Dopman, E. B. (2017). A combination of sexual and ecological divergence contributes to rearrangement spread during initial stages of speciation. *Molecular Ecology*.

Chromosomal rearrangements between sympatric species often contain multiple loci contributing to assortative mating, local adaptation, and hybrid sterility. When and how these associations arise during the process of speciation remains a subject of debate. Here, we address the relative roles of local adaptation and assortative mating on the dynamics of rearrangement evolution by studying how a rearrangement co-varies with sexual and ecological trait divergence within a species. Previously, a chromosomal rearrangement that suppresses recombination on the Z (sex) chromosome was identified in European corn borer moths (*Ostrinia nubilalis*). We further characterize this recombination suppressor and explore its association with variation in sex pheromone communication and seasonal ecological adaptation in pairs of populations that are divergent in one or both of these characteristics. Direct estimates of recombination suppression in pedigree mapping families indicated that more than 39% of the Z chromosome (encompassing up to ~10 megabases and ~300 genes) resides within a non-recombining unit, including pheromone olfactory receptor (OR) genes and a major quantitative trait locus (QTL) that contributes to ecotype differences (Pdd). Combining direct and indirect estimates of recombination suppression, we found that the rearrangement was occasionally present between sexually isolated strains (E versus Z) and between divergent ecotypes (univoltine versus bivoltine). However, it was only consistently present when populations differed in both sexual and ecological traits. Our results suggest that independent of the forces that drove the initial establishment of the rearrangement, a combination of sexual and ecological divergence is required for rearrangement spread during speciation.

Sarajlić, A., Raspudić, E., Majić, I., Josipović, M., Lončarić, Z., & Brmež, M. Vizualna procjena osjetljivosti osječkih hibrida kukuruza na napad kukuruznoga moljca. 52. HRVATSKI I 12. MEĐUNARODNI SIMPOZIJ AGRONOMA, 386.

Tolerantnost hibrida kukuruza na pojavu štetnih kukaca od iznimne je važnosti kod izbora hibrida za sjetvu. Cilj rada bio je utvrditi osjetljivost osječkih hibrida kukuruza na oštećenja koja uzrokuju gusjenice kukuruznoga moljca. Istraživanja su provedena tijekom tri vegetacijske sezone (2012.-2014.) na Poljoprivrednom institutu u Osijeku. Pratilo se oštećenje na listu i stabljici kukuruza od gusjenica kukuruznoga moljca. Istraživanja su provedena na tri varijante gnojidbe dušikom, tri varijante navodnjavanja i četiri hibrida kukuruza. Povećanjem sadržaja vode u tlu te reduciranjem dušične gnojidbe oštećenja od gusjenica na listu i stabljici su smanjena, a hibridi su pokazali različitu osjetljivost prema kukuruznom moljcu.

Siegwart, M., Thibord, J. B., Olivares, J., Hirn, C., Elias, J., Maugin, S., & Lavigne, C. (2017). Biochemical and Molecular Mechanisms Associated With the Resistance of the European Corn Borer (Lepidoptera: Crambidae) to Lambda-Cyhalothrin and First Monitoring Tool. *Journal of Economic Entomology*, tow267.

The European corn borer (*Ostrinia nubilalis* (Hübner)) is one of the most serious corn pest in Europe where it is controlled with pesticides, in particular, pyrethroids. First control failures with this chemical family occurred on the field in 2008 in the center of France, and the first resistance case was described in 2012. In the present study, we investigate resistance mechanisms involved in seven French populations of *O. nubilalis* collected in the field. Resistances to deltamethrin and lambda-cyhalothrin were confirmed, with a higher resistance ratio for lambda-cyhalothrin (63.79 compared to 7.67). Resistance to the two active compounds was correlated except for one population, indicating a high probability of cross-resistance. Analyses of the activity of three major families of detoxification enzymes in resistant individuals showed a significant increase of the average MFO activity in males of four populations (activity ratios of 2.76–5.73) and higher GST activity in females of two other populations (activity ratios 4.48 and 5.21). Molecular investigation of the sodium channel gene sequence showed the presence of the *kdr* mutation in a highly resistant individual. We designed a PCR-RFLP screening tool to search for this mutation in the field, and we found it in five populations but not in the susceptible one. The resistance of *O. nubilalis* to pyrethroids in France seems to result from a combination of resistance mechanisms, possibly as a consequence of a selection pressure with an exceptional duration (almost 40 yr old).

Tancik J. (2017). Natural parasitism of the second generation European corn borer eggs *Ostrinia nubilalis* (Hübner) (Lepidoptera, Pyralidae) by *Trichogramma* spp. in sweet corn fields in Vojvodina, Serbia – short communication. *Plant Protect. Sci.*, 53, 50–54.

Natural parasitism of the European corn borer eggs (Hübner) by *Trichogramma* spp. (Hymenoptera, Trichogrammatidae) was assessed in sweet corn field in north-west Serbia, region Vojvodina at the localities of Ruski Krstur, from 2004 till 2007. The rate of egg parasitism in 2004 varied from 35.89% to 73.58%. The parasitism in 2005 was lower than in 2004. On four different sampling dates in 2005 parasitism varied from 28.48% to 57.05% and averaged 39.4%. In 2006 parasitism fluctuated between 9.31 and 62.9%, averaging 32.15%. In 2007 parasitism varied from 36.8% to 54.54% and averaged 43.48%. The egg parasitoid species was identified as *Trichogramma evanescens* (Westwood). The study showed that this natural enemy occurred constantly in sweet corn fields but its number greatly fluctuated from year to year.

Wu, Z. B., Zhou, X., Ye, Y. Q., Wang, P. Y., & Yang, S. (2017). Design, synthesis and insecticidal activities of novel 1-substituted-5-(trifluoromethyl)-1H-pyrazole-4-carboxamide derivatives. *Chinese Chemical Letters*, 28(1), 121-125.

A series of novel 5-(trifluoromethyl)-1H-pyrazole-4-carboxamide derivatives (6a–6n, 7a, 7b, and 8a–8f) were synthesised by placing the amide bond at the 4-position of the pyrazole ring. These derivatives differed from the structure of chlorantraniliprole analogues with the amide bond at the 5-position of the pyrazole ring. Preliminary bioassay results revealed that a few title compounds exhibited good insecticidal activities against lepidopteran pests, such as *Plutella xylostella*, *Mythimna separate*, *Heliothis armigera*, and *Ostrinia nubilalis*. Some title compounds also elicited broad-spectrum insecticidal activities against dipterous insects including *Culex pipiens pallens* after altering the amide position. Similar to pyrazole-5-carboxamide analogues, compounds 6b and 6e showed 100% insecticidal activity against *P. xylostella*, *C. pipiens pallens*, and *M. separate* at concentrations of 200, 2, and 200 µg/mL, respectively. This finding suggested that 5-(trifluoromethyl)-1H-pyrazole-4-carboxamide derivatives are potential alternative insecticides for management of agriculture pests.

Yao, J., Zhu, Y. C., Lu, N., Buschman, L. L., & Zhu, K. Y. (2017). Comparisons of Transcriptional Profiles of Gut Genes between Cry1Ab-Resistant and Susceptible Strains of *Ostrinia nubilalis* Revealed Genes Possibly Related to the Adaptation of Resistant Larvae to Transgenic Cry1Ab Corn. *International Journal of Molecular Sciences*, 18(2), 301.

A microarray developed on the basis of 2895 unique transcripts from larval gut was used to compare gut gene expression profiles between a laboratory-selected Cry1Ab-resistant (R) strain and its isoline susceptible (S) strain of the European corn borer (*Ostrinia nubilalis*) after the larvae were fed the leaves of transgenic corn (MON810) expressing Cry1Ab or its non-transgenic isoline for 6 h. We revealed 398 gut genes differentially expressed (i.e., either up- or down-regulated genes with expression ratio ≥ 2.0) in S-strain, but only 264 gut genes differentially expressed in R-strain after being fed transgenic corn leaves. Although the percentages of down-regulated genes among the total number of differentially expressed genes (50% in S-strain and 45% in R-strain) were similar between the R- and S-strains, the expression ratios of down-regulated genes were much higher in S-strain than in R-strain. We revealed that 17 and 9 significantly up- or down-regulated gut genes from S and R-strain, respectively, including serine proteases and aminopeptidases. These genes may be associated with Cry1Ab toxicity by degradation, binding, and cellular defense. Overall, our study suggests enhanced adaptation of Cry1Ab-resistant larvae on transgenic Cry1Ab corn as revealed by lower number and lower ratios of differentially expressed genes in R-strain than in S-strain of *O. nubilalis*.

Zhang, T., Sun, Y., Wanner, K. W., Coates, B. S., He, K., & Wang, Z. (2017). Binding affinity of five PBPs to *Ostrinia* sex pheromones. *BMC Molecular Biology*, 18(1), 4.

Background: Pheromone binding proteins (PBPs) of male Lepidoptera function in chemical communication, mate attraction and recognition. Directional selection was previously predicted between PBP3 orthologs of *Ostrinia furnacalis* and *Ostrinia nubilalis* were interpreted as being involved in sexual isolation. Results: In vitro assays show that recombinant male OfurPBP3 bound *O. furnacalis* sex pheromones, Z-12-tetradecenyl acetate (Z12-14:OAc) and E-12-tetradecenyl acetate (E12-14:OAc), as well as to ECB pheromones Z11- and E11-14:OAc. Recombinant OfurPBP4 and OfurPBP5 bound E11- and Z11-14:OAc with greater affinity compared to Z12- and E12-14:OAc, and OfurPBP4 incapable of binding with E12-14:OAc. In silico molecular docking predicted OfurPBP3 residues Phe12, Ile52, Leu94, Ile113 within a hydrophobic ligand-binding pocket and may participate in E12- and Z12-14:OAc binding. Independent site-directed mutagenesis experiments demonstrated that Ser12, Asn52, Arg94, and Asn113 residues variants caused an approximately 1.7- to 4.6-fold reduction in OfurPBP3 affinity for Z12- and E12-14:OAc, and a 2.7- to 8.4-fold decrease in affinity towards E11- and Z11-14:OAc. Conclusions: Five PBPs of *O. furnacalis* play important functions in *Ostrinia* pheromones binding. These four amino acids may play a role in binding of sex pheromone, but this study does not address questions regarding specific response between males of *O. furnacalis* and *O. nubilalis*. Additional studies are required determine the role, if any, PBPs play in the evolution of sex pheromone communication.

Articles parus en 2016

Al-Wathiqui, N. M. (2016). Postcopulatory reproductive processes: The role of female and male reproductive genes and proteins in speciation and sexual selection (Doctoral dissertation, TUFTS UNIVERSITY).

Sexual selection is a powerful force that drives the evolution of reproductive traits and continues after mating is completed. Postcopulatory sexual selection involves molecular interactions between the male ejaculate and the female reproductive tract; these interactions are mediated by male seminal fluid proteins (SFPs), transferred in the male ejaculate, and female reproductive proteins (FRPs), secreted by the female reproductive tract. SFPs have been characterized in numerous species and shown to affect female behavior and physiology. However, they have been

poorly studied in species where males transfer a packaged ejaculate, called a spermatophore. Many insects transfer spermatophores, yet the implication of this type of ejaculate transfer for postcopulatory interactions is unclear. Furthermore, we understand little about FRPs and their roles in postcopulatory sexual selection. Not only are female proteins potential mediators of sexual selection, but may play a role in reproductive isolation due to their potential for rapid evolution. Here, I used a combination of RNA sequencing, proteomics, and metabolomics to characterize SFPs and FRPs in the spermatophore-transferring taxa: *Ostrinia nubilalis* moths, *Tribolium castaneum* beetles, and *Photinus pyralis* fireflies to determine how reproductive genes, proteins, and metabolites differentially regulate postcopulatory interactions between the sexes in different ecological contexts. First, I used these methods to identify male and female reproductive genes that could be mediating a postmating, prezygotic barrier acting between *O. nubilalis* strains. I found that ECB males differentially express peptidases and odorant binding proteins between strains. After mating within- and across-strain, females of *O. nubilalis* also differentially expressed several reproductive genes, many of which are novel. In *T. castaneum*, I used experimentally enforced monandry to examine how relaxed postcopulatory sexual selection could influence reproductive gene expression. Monandrous males showed a shift in gene expression that indicated they may be increasing sperm or production of eggs in female mates. Finally, in *P. pyralis* fireflies I characterized the composition of the male spermatophore, which I found contains a number of peptidases and proteins related to the immune response. Across all three taxa, I found that both sexes express peptidases that may be important mediators of postcopulatory sexual interactions in these spermatophore-producing species.

Bereś, P. K. (2016). EFFICACY OF SPINOSAD AND *Bacillus thuringiensis* var. *kurstaki* IN BIOLOGICAL CONTROL OF THE EUROPEAN CORN BORER ON SWEET CORN.

The European corn borer (*Ostrinia nubilalis* Hbn.) is one of the most dangerous pests of sweet corn in Poland. As indicated in the guidelines for integrated pest management (IPM), harmful organisms on plants should at first be controlled by non-chemical methods and, if these are ineffective, the use of chemical methods is allowed. The aim of this study was to assess the effectiveness of biopesticides containing spinosad and *Bacillus thuringiensis* var. *kurstaki* to reduce the population and harmfulness of *O. nubilalis* caterpillars. The study was carried out in 2013–2015 in southeastern Poland, on 'Candle' sweet corn. Corn plants were sprayed either once or twice in July, when *O. nubilalis* larvae hatched on a mass scale. The pest was controlled with Spintor 240 SC (spinosad A + spinosad D) at doses of 0.2 and 0.4 l ha⁻¹, Dipel WG (*B. thuringiensis* var. *kurstaki*) at doses of 1.0 and 2.0 kg ha⁻¹, Karate Zeon 050 CS (lambda-cyhalothrin) at a dose of 0.2 l ha⁻¹, and Proteus 110 OD (thiacloprid + deltamethrin) at a dose of 0.5 l ha⁻¹. All products reduced the number and harmfulness of larvae, especially on cobs which are a commercial crop. The best effects were achieved after two treatments with biopesticides at higher doses. This reduced nearly by half the number of cobs damaged by the pest. Spinosad was more effective than *B. thuringiensis*. The effectiveness of biopesticides depended on weather conditions. Chemical pest control was found most effective.

Camerini, G., Gropali, R., Tschorsnig, H. P., & Maini, S. (2016). Influence of *Ostrinia nubilalis* larval density and location in the maize plant on the tachinid fly *Lydella thompsoni*. *Bulletin of Insectology*, 69(2), 301-306.

A three years research (2008-2010) was carried out in the Po valley (northern Italy) on *Lydella thompsoni* Herting (Diptera Tachinidae), an important parasitoid of ECB (European corn borer - *Ostrinia nubilalis* Hubner, Lepidoptera Crambidae). Several factors can affect the action of *L. thompsoni* against ECB. This case of study was focused on the influence of ECB larval density and position in maize plant organs. Wintering ECB larvae and parasitoid puparia were sampled from maize plants and reared. *O. nubilalis* density ranged from 0.2 to 3.2 larvae/plant. *L. thompsoni* was the only parasitoid regularly reared from ECB larvae. Parasitisation rates were 17.9, 16 and 11% in 2008, 2009 and 2010 respectively. It was noticed that ECB larvae distribution in the maize plants was related to infestation degree. ECB larvae preferably colonized ears; however, when their density increased, their proportion in the stalk did, as well. The density

of *L. thompsoni* was higher in stalk tissues, below and above the ear. Among the range of ECB densities recorded as a result of this study, it was not observed a density dependent relation between ECB and *L. thompsoni*.

Carrière, Y., Fabrick, J. A., & Tabashnik, B. E. (2016). Advances in managing pest resistance to Bt crops: Pyramids and seed mixtures. In *Advances in Insect Control and Resistance Management* (pp. 263-286). Springer International Publishing.

Transgenic crops producing toxins from the soil bacterium *Bacillus thuringiensis* (Bt) have been widely used for the control of insect pests during the last 20 years. Although Bt crops have provided significant environmental and economic benefits, sustainable use of these crops is threatened by the rapid evolution of resistance. The primary strategy for delaying pest adaptation to Bt crops has been to ensure that sufficient refuges of non-Bt host plants occur near Bt crops. Two relatively new approaches used with refuges are "pyramids", which are plants that produce two or more Bt toxins effective against the same pest, and planting random mixtures of Bt seeds and non-Bt seeds of the same crop within fields. Here we review theory and data about conditions favoring success of pyramids and seed mixtures for delaying evolution of pest resistance to Bt crops. Pyramids of structurally distinct toxins can be exceptionally effective under optimal conditions, particularly when pest populations are highly susceptible to all toxins in the pyramid. Seed mixtures eliminate the problem of farmers who fail to plant separate refuges of non-Bt plants, but may accelerate evolution of resistance when larval movement between plants or pollen-mediated gene flow between plants is extensive. In the many cases where pests are not highly susceptible to the toxins in Bt crops or other conditions are not optimal, we suggest that an effective refuge percentage of at least 20 % is required to substantially delay pest resistance, even when pyramids, seed mixtures, or both are used. We also recommend integrating Bt crops with other management tactics to delay resistance in pests with low susceptibility to Bt toxins.

Coates, B. S. (2016). *Bacillus thuringiensis* toxin resistance mechanisms among Lepidoptera: progress on genomic approaches to uncover causal mutations in the European corn borer, *Ostrinia nubilalis*. *Current Opinion in Insect Science*, 15, 70-77.

Transgenic plants that express *Bacillus thuringiensis* (Bt) crystal (Cry) protein toxins (Bt crops) effectively control feeding by the European corn borer, *Ostrinia nubilalis*, although documented resistance evolution among a number of species in both the laboratory and field has heightened concerns about the durability of this technology. Research has provided major insights into the mutations that alter Bt toxin binding receptor structure and function within the midgut of Lepidoptera that directly impacts the efficacy of Bt toxins, and potentially leads to the evolution of resistance to Bt crops in the field. In this manuscript we provide an overview of available data on the identification of genes involved in high levels of resistance to Cry toxins, with emphasis on resistance described for *O. nubilalis* as the main target of Bt corn.

Gagnon, A. È., Audette, C., Duval, B., & Boisclair, J. (2016). Can the Use of *Trichogramma ostriniae* (Hymenoptera: Trichogrammatidae) to Control *Ostrinia nubilalis* (Lepidoptera: Crambidae) Be Economically Sustainable for Processing Sweet Corn?. *Journal of Economic Entomology*, tow293.

European corn borer, *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae), is the main pest causing damage to sweet corn in North America. Conventional management with multiple use of insecticides is a common practice for processing sweet corn. In Canada, the use of *Trichogramma* spp. began in the 1990s, but the adoption of this approach for European corn borer management is still limited to the fresh market of sweet corn. *Trichogramma ostriniae* (Peng & Chen) has great potential as a biological control agent for large areas such as in processing sweet corn. The objective of this study was to evaluate an economically and environmentally sustainable alternative to insecticides for controlling European corn borer populations in processing sweet corn. During the growing season, the mean number of larvae decreased after insecticide (0.07 ± 0.04) and *Trichogramma* (1.32 ± 0.59) treatments compared with the control (2.42 ± 0.72). At harvest, damages associated with European corn borer were similar after *Trichogramma* ($1.0 \pm 0.7\%$)

and insecticide ($1.0 \pm 0.6\%$) treatments, but significantly lower than the control ($8.7 \pm 3.3\%$). This study showed that the use of *T. ostrinae* can significantly decrease the pressure exerted by European corn borer and its damage on corn ears. This outcome is particularly interesting considering that it was achieved with lower doses of *Trichogramma*, a lower number of releases, and on large crop areas, compared with what is actually done to protect fresh market corn from European corn borer. Under these conditions, the use of *Trichogramma* is an economically and competitive alternative to insecticide applications.

Gauthier, P., & Khelifi, M. (2016). *Trichogramma* pupae spraying technique development for biocontrol of the European corn borer in sweet corn crops.

The European corn borer, *Ostrinia nubilalis* (Hübner), is the major pest insect of sweet corn in Quebec and around the world. Its presence results in important yield decreases and profit losses for farmers. Currently, chemical insecticides are mainly used to control this pest insect. Chemical hazards for human health and the environment are well documented. Despite government efforts to reduce the use of chemicals in agriculture, pesticides sales have steadily increased over the time. Nevertheless, there are some interesting alternatives to chemicals to control the European corn borer, in particular the use of predator insects. Many research studies have demonstrated the effectiveness of using the *trichogramma* to successfully control the corn borer. This biological control method is however more expensive and complex than chemical insecticides. The main objective of this research study was to investigate the technical feasibility of spraying *trichogramma* pupae to facilitate the implementation of this method and reduce the operation cost. For this purpose, many experimental trials using the *Trichogramma ostrinae* were carried out in the laboratory. These trials aimed at finding an adequate aqueous solution to both scatter the pupae in the sprayer tank and stick them to corn leaves once sprayed. A laboratory spraying system was also designed and built to check the viability of *trichogramma* pupae after being immersed in the spray solution and sprayed. Obtained results showed that the sprayed pupae emergence rate exceeded 80% and was comparable to that of unsprayed pupae. The success of this spraying technique to control the corn borer in corn crops is highly valuable and could be generalized to other predator insects.

Gustafsson, O. (2016). European corn borer.

The European Corn Borer (ECB) is one of the most important pests on corn in the world. An increasing interest from the farming community in Sweden, although currently cultivated in a restricted area, a change towards a warmer climate will probably make the ECB more abundant in Sweden. The management methods promoted today with cultural controls such as ploughing and harrowing are, for now, an effective way of control ECB population but an incorporation of insecticides or biological control agents together with scouting and day-degree models before and during the growth season would be beneficial for an effective control of today and future ECB population in Sweden.

Han, P., Velasco-Hernández, M. C., Ramirez-Romero, R., & Desneux, N. (2016). Behavioral effects of insect-resistant genetically modified crops on phytophagous and beneficial arthropods: a review. *Journal of Pest Science*, 89(4), 859-883.

Behavior is a main component of the survival and performance of arthropods. We have witnessed widespread adoption of insect-resistant genetically modified (IRGM) crops nowadays; however, no literature has reviewed the behavioral effects of IRGM crops on phytophagous and beneficial arthropods. In this review, we assessed the current information related to the effects of IRGM crops on arthropod behavior, mainly including locomotion (mobility, escape behavior and dispersal behavior), foraging (orientation, host plant selection/preference and feeding), mating, oviposition and other behaviors (associative learning). Almost all the studies have been conducted on Bt crops. The behavioral effects have been found in 54.2 %, 22 % and 33 % of the case studies on phytophagous arthropods, arthropod natural enemies and pollinators, respectively. Few behavioral studies have been documented on arthropod pollinators. The majority of cases reporting behavioral effects have derived from target phytophagous arthropods. Among them, locomotion and

feeding behavior were the most frequently affected. For arthropod natural enemies, the cases using target prey/host in tri-trophic studies only accounted for a small proportion of behavioral effects observed on foraging behavior (host/prey selection). Overall, the effects through tri-trophic pathways on behaviors of natural enemies are limited. To conclude, while attention needs to be paid to several behavioral effects that may undermine the efficacy of IRGM crops in sustainable pest management, the behavioral effects generally do not disrupt the role of IRGM crops in achieving the goal of integrated pest management and crop production.

Kárpáti, Z., Fejes-Tóth, A., Csengele, B., Szőke, C., Bónis, P., Marton, L. C., & Molnár, B. P. (2016). Pheromone-based monitoring of the European corn borer (*Ostrinia nubilalis*) in Hungary. *MAYDICA: A JOURNAL DEVOTED TO MAIZE AND ALLIED SPECIES*, 61(2), 1-7.

Despite the fact that the pheromone structure and composition of the European corn borer (*Ostrinia nubilalis*) was identified in the early 1970s, an effective pheromone-based monitoring method of this species has not been established yet in Hungary. The aim of this study was to find an optimal monitoring strategy for this economically important pest using pheromone traps. We compared three trap designs, five ratios and four doses of the earlier identified pheromone components in three different locations in Hungary. In the first year there was no significant difference between the delta and the cone traps as both were able to catch males in sufficient numbers. However, in the second year the cone traps captured significantly more males. In a comparison of the different ratios of the two pheromone components, our results demonstrate that the usage of 97:3 Z:E [97% (Z)11-tetradecenyl acetate and 3% (E)11-tetradecenyl acetate] ratio attracted the highest number of males. Therefore, we suggest that the Z pheromone strain exists in the three monitored regions. In the experiment, where the different doses were compared, there was no significant difference in the number of males caught. In 2015, the flight dynamics of the species showed that males start to fly in the beginning of June and the highest flight peak occurs in mid June. Based on our results we conclude that in Hungary the pheromone traps are able to attract and monitor European corn borer males using the appropriate trap design, dose and ratio under field conditions.

Keszthelyi, S. Second, late summer flight peak of the European corn bo (HtFBNER) in south area of Hungary.

Koutroumpa, F. A., Groot, A. T., Dekker, T., & Heckel, D. G. (2016). Genetic mapping of male pheromone response in the European corn borer identifies candidate genes regulating neurogenesis. *Proceedings of the National Academy of Sciences*, 201610515.

The sexual pheromone communication system of moths is a model system for studies of the evolution of reproductive isolation. Females emit a blend of volatile components that males detect at a distance. Species differences in female pheromone composition and male response directly reinforce reproductive isolation in nature, because even slight variations in the species-specific pheromone blend are usually rejected by the male. The mechanisms by which a new pheromone signal-response system could evolve are enigmatic, because any deviation from the optimally attractive blend should be selected against. Here we investigate the genetic mechanisms enabling a switch in male response. We used a quantitative trait locus-mapping approach to identify the genetic basis of male response in the two pheromone races of the European corn borer, *Ostrinia nubilalis*. Male response to a 99:1 vs. a 3:97 ratio of the E and Z isomers of the female pheromone is governed by a single, sex-linked locus. We found that the chromosomal region most tightly linked to this locus contains genes involved in neurogenesis but, in accordance with an earlier study, does not contain the odorant receptors expressed in the male antenna that detect the pheromone. This finding implies that differences in the development of neuronal pathways conveying information from the antenna, not differences in pheromone detection by the odorant receptors, are primarily responsible for the behavioral response differences among the males

in this system. Comparison with other moth species reveals a previously unexplored mechanism by which male pheromone response can change in evolution.

Kuhar, T. P., & Doughty, H. B. (2016). Evaluation of Insecticides for the Control of Lepidopteran Larvae in Sweet Corn, 2015. *Arthropod Management Tests*, 41(1), tsw032.

LASSANCE, J. M. (2016). The European Corn Borer *Ostrinia nubilalis*. *Pheromone Communication in Moths: Evolution, Behavior, and Application*, 233.

Lynn, D. E., & Harrison, R. L. (2016). Available lepidopteran insect cell lines. *Baculovirus and insect cell expression protocols*, 119-142.

This chapter lists the known cell lines from Lepidoptera, largely based on previous compilations of insect cell lines published by W. Fred Hink. More than 320 lines from 65 species are listed. The official designation is given for each cell line as well as the species, tissue source, and, when known, the susceptibilities to baculoviruses.

Martin, N., Moore, K., Musto, C. J., & Linn Jr, C. E. (2016). Flight tunnel response of male european corn borer moths to cross-specific mixtures of european and Asian corn borer sex pheromones: evidence supporting a critical stage in evolution of a new communication system. *Journal of chemical ecology*, 42(1), 51-54.

Previous flight tunnel studies showed that 3–5 % of male European corn borer (ECB) moths, *Ostrinia nubilalis*, could fly upwind and make contact with sources releasing the sex pheromone of the closely related Asian corn borer (ACB), *Ostrinia furnacalis*, [2:1 (Z)-12-tetradecenyl acetate (Z12-14:OAc) : (E)-12-tetradecenyl acetate (E12-14:OAc)] and that 2–4 % of ACB males could similarly fly upwind to the sex pheromone blends of the ECB Z- [97:3 (Z)-tetradecenyl acetate (Z11-14:OAc) : (E)-tetradecenyl acetate (E11-14:Ac)] and E-strains (1:99 Z/E11-14:OAc) pheromones. The results supported the hypothesis that the evolution of the ACB pheromone system from an ECB-like ancestor included a stage in which males could be attracted to the unusual females emitting Z12- and E12-14:OAc while retaining their responsiveness to the ancestral pheromone blend of Z11- and E11-14:OAc. Here, we showed further that ECB E-strain males exhibited upwind oriented flight and source contacts to sources containing all combinations of ECB and ACB components. Maximal response levels were observed with the E-strain 99:1 E11/Z11-14:OAc blend, and high response levels also were observed with two other blends containing E11-14:OAc as the major component (E11:E12 and E11:Z12). Upwind flight and source contact also occurred at lower levels with the remaining blend combinations in which Z11-, E12-, or Z12-14:OAc was the major component. Our current results support the hypothesis concerning the evolution of ACB from an ECB-like ancestor by showing that males were able to respond to females producing either the 12–14:Ac isomers, 11–14:Ac isomers, or even mixtures of all four components.

Orsucci, M., Audiot, P., Pommier, A., Raynaud, C., Ramora, B., Zanetto, A., ... & Streiff, R. (2016). Host specialization involving attraction, avoidance and performance, in two phytophagous moth species. *Journal of evolutionary biology*, 29(1), 114-125.

Host specialization plays a key role in the extreme diversification of phytophagous insects. Whereas proximate mechanisms of specialization have been studied extensively, their consequences for species divergence remain unclear. Preference for, and performance on hosts are thought to be a major source of divergence in phytophagous insects. We assessed these major components of specialization in two moth species, the European corn borer (ECB) and the Adzuki bean borer (ABB), by testing their oviposition behaviour in different conditions (choice or no-choice set-ups) and their performances, by reciprocal transplant at the larval stage on the usual host and an alternative host plant. We demonstrated that both ABB and ECB have a strong preference for their host plants for oviposition, but that relative larval performances on the usual host and an alternative host differed according to the experiment and the trait

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considered (weight or survival). Finally, we show for the first time that the preference for maize in ECB conceals a strong avoidance of mugwort. The differences in performance, attraction and avoidance between ECB and ABB are discussed in the light of the underlying mechanisms and divergence process.

Oyediran, I., Dively, G., Huang, F., & Burd, T. (2016). Evaluation of European corn borer *Ostrinia nubilalis* (Lepidoptera: Crambidae) larval movement and survival in structured and seed blend refuge plantings. *Crop Protection*, 81, 145-153.

Blending *Bacillus thuringiensis* (Bt) corn and non-Bt corn seeds in the same bag is a convenient and easier compliance solution to satisfy refuge regulations. However, there has been considerable debate and concern about larval movement of the target insects in a seed blend because of its potential effect on the development of resistance. Reported here are studies to determine the larval movement of European corn borers, *Ostrinia nubilalis* (Hübner), in a seed blend compared to a structured refuge and their effects on survival, feeding injury and larval fitness. Also evaluated is the relative performance of a purple-seeded corn hybrid as a surrogate host plant for tracking gene flow. Seed blend and structured refuge arrangements of Agrisure GT/CB/LL Bt corn expressing Cry1Ab and isoline plants were evaluated at two locations in 2013 and 2014 by manually infesting refuge plants with first and second generation corn borer larvae. The majority of leaf and stalk injury was recorded on the refuge plant, which amounted to 66–83% of the total tunnel length. In both refuge arrangements, plant injury and the number of larvae recovered significantly decreased on neighboring plants with increasing distance away from the refuge plant in the same row. The relative decline in injury was much more pronounced in the seed blend, with neighbor Bt plants experiencing very minor tunneling or no injury at all due to the high dose trait. Eighty-nine percent fewer live larvae were also found on neighbor Bt plants in the seed blend compared to those found in the structured refuge plots. Larvae that moved to Bt plants as well as older instars that were manually placed on Bt plants failed to complete development. Comparison of the number of tunnels and larvae recovered per refuge plant indicated that the seed blend may not produce as many susceptible individuals as those produced in a structured refuge arrangement. Although the purple-seeded hybrid showed lower levels of ear and stalk injury, it could serve as an appropriate surrogate refuge plant to track gene flow.

Petzold-Maxwell, J. L., Siegfried, B. D., Hellmich, R. L., Abel, C. A., Coates, B. S., Spencer, T. A., ... & Gassmann, A. J. (2016). Fitness costs associated with Cry1F resistance in the European corn borer. *Journal of Applied Entomology*.

Crops producing insecticidal toxins derived from the bacterium *Bacillus thuringiensis* (Bt) are widely planted to manage insect pests. Bt crops can provide an effective tool for pest management; however, the evolution of Bt resistance can diminish this benefit. The European corn borer, *Ostrinia nubilalis* Hübner, is a significant pest of maize and is widely managed with Bt maize in the Midwest of the United States. When Bt crops are grown in conjunction with non-Bt refuges, fitness costs of Bt resistance can delay the evolution of resistance. Importantly, fitness costs often vary with ecological factors, including host-plant genotype and diapause. In this study, we examined fitness costs associated with Cry1F resistance in *O. nubilalis* when insects were reared on three maize lines. Fitness costs were tested in two experiments. One experiment assessed the fitness costs when Cry1F-resistant and Cry1F-susceptible insects were reared on plants as larvae and experienced diapause. The second experiment tested resistant, susceptible and F1 heterozygotes that were reared on plants but did not experience diapause. Despite some evidence of greater adult longevity for Cry1F-resistant insects, these insects produced fewer fertile eggs than Cry1F-susceptible insects, and this occurred independent of diapause. Reduced fecundity was not detected among heterozygous individuals, which indicated that this fitness cost was recessive. Additionally, maize lines did not affect the magnitude of this fitness cost. The lower fitness of Cry1F-resistant *O. nubilalis* may contribute to the maintenance of Cry1F susceptibility in field populations more than a decade after Cry1F maize was commercialized.

Piwczyński, M., Pabijan, M., Grzywacz, A., Glinkowski, W., Bereś, P. K., & Buszko, J. (2016). High regional genetic diversity and lack of host-specificity in *Ostrinia nubilalis* (Lepidoptera: Crambidae) as revealed by mtDNA variation. *Bulletin of entomological research*, 106(04), 512-521.

The European corn borer (*Ostrinia nubilalis*) infests a wide array of host plants and is considered one of the most serious pests of maize in Europe. Recent studies suggest that individuals feeding on maize in Europe should be referred to *O. nubilalis* (sensu nov.), while those infesting dicots as *Ostrinia scapularis* (sensu nov.). We test if the clear genetic distinctiveness among individuals of *O. nubilalis* living on maize vs. dicots is tracked by mitochondrial DNA (mtDNA). We used fragments of COI and COII genes of 32 individuals traditionally recognized as *O. nubilalis* collected on three host plants, maize, mugwort and hop, growing in different parts of Poland. In addition, we reconstructed the mtDNA phylogeny of *Ostrinia* species based on our data and sequences retrieved from GenBank to assess host and/or biogeographic patterns. We also compared haplotype variation found in Poland (east-central Europe) with other regions (Anatolia, Eastern Europe, Balkans, Far East, North America). Our study showed high mtDNA diversity of *O. nubilalis* in Poland in comparison with other regions and revealed rare haplotypes likely of Asian origin. We did not find distinct mtDNA haplotypes in larvae feeding on maize vs. dicotyledonous plants. Phylogenetic analyses showed an apparent lack of mtDNA divergence among putatively distinct lineages belonging to the *O. nubilalis* group as identical haplotypes are shared by Asian and European individuals. We argue that human-mediated dispersal, hybridization and sporadic host jumps are likely responsible for the lack of a geographic pattern in mtDNA variation.

Popović, B., Tanasković, S., Gvozdenac, S., Kárpáti, Z., & Bognár, C. (2016). POPULATION DYNAMICS OF WCR AND ECB IN MAIZE FIELD IN BEČEJ, VOJVODINA PROVINCE. XI SAVETOVANJE O BIOTEHNOLOGIJ: Zbornik radova, 21(23), 341-346.

WCR and ECB are maize pest present worldwide in Corn Belt. The documented economic level of losses and plant damages of this two pests vary up to 100 %. Experiment was carried out in Vojvodina province, region Bačka, during vegetation 2014-2015, from June until September. During weekly inspection for three months we recorded presence of WCR and ECB in pheromone traps. Both pests show fluctuating flight during experimental years. The highest catch of WCR (71 specimens - 8 August 2015) and ECB (14 specimens - 14 August 2014). WCR flight shows similarity over the two years. But, ECB flight is more extended in 2015.

Priesnitz, K. U., Vaasen, A., & Gathmann, A. (2016). Baseline susceptibility of different European lepidopteran and coleopteran pests to Bt proteins expressed in Bt maize: a systematic review. *Environmental Evidence*, 5(1), 27.

Background: Lepidopteran and coleopteran species are the most important pests in maize. They can be controlled using genetically modified (GM) crops expressing insecticidal *Bacillus thuringiensis* (Bt) proteins. The long-term success of this technology demands a pest resistance management. Important information for the successful management of resistance is the baseline susceptibility of the different target pests to the different Bt proteins. The data on baseline susceptibility should enable risk assessors and managers to assess whether a GM maize produces a Bt protein in a high-dose to specific target organisms and resistance has evolved during the commercial cultivation of this GM maize events. Methods: Our systematic search followed an a priori protocol including the database platforms Web of Science, Scopus, CAB abstracts, Science Direct and JSTOR. We additionally conducted a Google scholar search. We collated all search results and screened all retrieved articles using predetermined inclusion criteria. We identified 30 studies, which fulfilled the criteria of including a relevant Bt protein, a relevant species, an appropriate endpoint, and field-derived pest generations reared in the laboratory no longer than three generations. We then made a quality assessment to discover if the studies considered the dose response curves with confidence intervals, described the protein source, tested the protein concentration and the protein activity via positive controls, use more than ten larvae per concentration, more than two replications, and more than five protein concentrations. Since no quantitative synthesis was possible the synthesis of the results was done in a narrative form. Results: Seventy percent of the studies fulfilled

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five or more criteria and 17% fulfilled four of the seven criteria. Six Bt proteins were tested on one or more of the four species *Ostrinia nubilalis*, *Helicoverpa armigera*, *Sesamia nonagrioides*, and *Diabrotica virgifera virgifera*. We extracted the baseline susceptibility for the given protein-species-combinations and the test method with the Bt protein applied either on the surface of the diet or incorporated. Although, the data displays a high heterogeneity and are thus hard to compare, they give an overview of the baseline susceptibility of lepidopteran/coleopteran pests to Bt proteins. Conclusion: Our systematic review illustrates the heterogeneity of the data and indicates the necessity of standard protocols for testing susceptibility of insect pests, which provide comparable data. The cultivation of Bt crops, as with any other plant protection measure, is likely to result in resistance evolution in the target pests. Industry, policy makers, and research should combine knowledge to protect the benefits of this technology.

RAZINGER, J., MODIC, Š., Annette, H. E. R. Z., & Gregor, U. R. E. K. (2016). Parasitoid inventarisation of European corn borer (*Ostrinia nubilalis* Hübner, 1796) and options for its biological control in Slovenia. *Acta agriculturae Slovenica*, 107(1), 93-102.

European corn borer (*Ostrinia nubilalis*) (ECB) is an important maize pest in central and northern Europe. Presently it is controlled by insecticides or biological agents such as *Trichogramma brassicae* in several European countries, excluding Slovenia, where the pest's pressure is highly variable and no appropriate mechanization is available. Lessening the dependence on chemical pesticides is an integral part of the European Union's agenda for agriculture. Mass release of *Trichogramma* spp. could be seen as a promising alternative for ECB control in countries with a highly fluctuating ECB pressure and no mechanization for insecticide applications. However, no records of naturally occurring hymenopteran parasitoids of ECB exist in Slovenia. To address this important under-researched topic and provide the expert basis for potential introduction of ECB egg parasitoids in Slovene maize production, a systematic inventarisation programme of ECB parasitoids was launched in 2010. Additionally, ECB flight was monitored in 2011 and 2012 at two locations in Slovenia: Jablje and Rakičan. In both locations two ECB generations were observed. ECB was first observed at the end of May in Rakičan. During the five years of the systematic survey we discovered two ECB parasitoid species. ECB egg masses were parasitized by *Trichogramma brassicae*, whereas ECB pupae were parasitized by *Tycherus nigridentis*, with 6 or 7 % parasitization rate, respectively. *T. nigridentis* represents a new taxon report for Slovenia. We conclude that there is a strong need for undertaking systematic surveys of natural enemies of agricultural pests.

Razinger, J., Vasileiadis, V. P., Giraud, M., van Dijk, W., Modic, Š., Sattin, M., & Urek, G. (2016). On-farm evaluation of inundative biological control of *Ostrinia nubilalis* (Lepidoptera: Crambidae) by *Trichogramma brassicae* (Hymenoptera: Trichogrammatidae) in three European maize-producing regions. *Pest management science*, 72(2), 246-254.

BACKGROUND: A 2 year study was conducted to evaluate the efficacy of biological control with optimally timed *Trichogramma brassicae* releases as an integrated pest management tool against the European corn borer (ECB), *Ostrinia nubilalis* (Hübner), in on-farm experiments (i.e. real field conditions) in three European regions with dissimilar geoclimatic conditions and ECB pressure and conventional management (i.e. insecticide treated and untreated). **RESULTS:** Biological control with *Trichogramma* (1) provided ECB protection comparable with conventional management, (2) in all cases maintained mycotoxin levels below the EU threshold for maize raw materials destined for food products, (3) was economically sustainable in southern France and northern Italy, but not in Slovenia where it resulted in a significant decrease in gross margin, mainly owing to the cost of *Trichogramma* product, and (4) enabled avoidance of detrimental environmental effects of lambda-cyhalothrin use in northern Italy. **CONCLUSION :** Optimally timed mass release of *T. brassicae* could be considered a sustainable tool for IPM programmes against ECB in southern France and northern Italy. Better involvement of regional advisory services is needed for the successful dissemination and implementation of biological control. Subsidy schemes could also motivate farmers to adopt this IPM tool and compensate for high costs of *Trichogramma* product.

Salim, M., Gökçe, A., Naqqash, M. N., & Bakhsh, A. (2016). An overview of biological control of economically important lepidopteron pests with parasitoids.

The insect order Lepidoptera is one of the most important insect orders in terms of both species and agriculture point of view. Majority of these are the serious pest of most agricultural crops. Insects-pests are mostly management by using insecticides which are not only ineffective but also resulted in environmental pollution and diseases' outbreak. All these problems solution lies on the implementation of best IPM package. Biological control is one of the best options of Integrated Pest Management. Utilization of bio agent can easily be combined with other management techniques for having best IPM package. Parasitoids in this connection play a very important role in their management. These parasitoids attack the egg, larval or pupal stages of the host insects. In the present review the importance of parasitoids in controlling the different lepidopteron pests was discussed. The two major insect parasitoids orders hymenoptera with four families namely braconidae, ichneumonidae, chalcidae and trichogrammatidae and diptera with one family namely tachinidae in relation to biocontrol of selected lepidopteron pests have been studied. In addition the role of plant volatiles that play an important role in searching and locating their host and effect of temperature on the parasitoid performance has also been reviewed.

Santiago, R., Barros-Rios, J., Alvarez, A., & Malvar, R. A. (2016). Agronomic performance of maize populations divergently selected for diferulate cross-linkage. *The Journal of Agricultural Science*, 154(07), 1270-1279.

The direct response of a divergent selection programme for total cell wall ester-linked diferulate concentration in maize pith stalk tissues and its indirect effect on cell wall degradability and corn borer resistance have been previously evaluated. Since increased total diferulate concentration is expected to improve crop performance in response to corn borers, the objective of the present research was to evaluate the indirect response of the divergent selection for diferulates on agronomic traits under corn borer infestation. For this purpose, five maize populations with contrasting total diferulate concentrations were evaluated four environments for performance under protected and infested conditions. Measured traits were: days to anthesis, days to silking, plant height, stalk lodging, grain moisture at harvest and grain yield. High diferulate populations showed a significant reduction in anthesis (precocity), and were 11 cm taller than the starting population, while low diferulate populations were 9 cm shorter, and showed nearly 1 t/ha lower grain yield than the original and high diferulate populations. The analysis showed that cycles of selection were positively correlated with flowering, plant height and grain yield. The infestations with borers produced >1 t/ha of reduction in grain yield; although the higher diferulate populations showed a better performance under infestation than the low diferulate populations. This positive effect on the grain yield by increasing diferulate content can be considered an extra in order to breed for resistance to corn borers.

Schaub, L., Breitenmoser, S., Derron, J., & Graf, B. (2016). Development and validation of a phenological model for the univoltine European corn borer. *Journal of Applied Entomology*.

Biological control of a univoltine race of European corn borer, *Ostrinia nubilalis* Hübner (Lepidoptera: Crambidae), by *Trichogramma* in Switzerland is currently timed according to repeated, semi-field observations of the post-diapause development of the pest at one site. We developed a phenology model with the aims of replacing this costly labour practice and by considering the Swiss landscape. Observations collected over 29 years were used for model calibration and validation. We parameterized a time-varying distributed delay model based on published laboratory observations of development durations at constant temperatures. The model was driven with hourly temperature recordings beginning on January 1. The calibration of the mean development rates and their variations was based on semi-field data of larval and pupal development. The model, with its calibrated parameters and their variations, allowed the simulation of mean predictions and prediction intervals. We validated the model predictions of emergence with flight data (obtained via light traps) from several sites in western and northern Switzerland. The simulated mean emergence

was 6.9 degree-days earlier than the observed flight at the calibration sites and only 0.5 degree-days earlier than the observed flight at other sites. Our simulation of pupation explained half of the variation in emergence time, whereas semi-field observations of pupation explained three-quarters of this variation. Our model simulations are not subjected to the local potential biases. Simulation errors from a year with an extremely dry spring were explained by the lack of consideration of humidity by the model. Our simulations provide a valid and less labour-intensive alternative to observations for timing biological control in the maize-growing areas of Switzerland and likely other areas of Europe.

Schmidt-Jeffris, R. A., Huseeth, A. S., & Nault, B. A. (2016). Estimating E-Race European Corn Borer (Lepidoptera: Crambidae) Adult Activity in Snap Bean Fields Based on Corn Planting Intensity and Their Activity in Corn in New York Agroecosystems. *Journal of Economic Entomology*, 109(5), 2210-2214.

European corn borer, *Ostrinia nubilalis* (Hübner), is a major pest of processing snap bean because larvae are contaminants in pods. The incidence of *O. nubilalis* -contaminated beans has become uncommon in New York, possibly because widespread adoption of Bt field corn has suppressed populations. Snap bean fields located where Bt corn has been intensively grown in space and time may be at lower risk for *O. nubilalis* than fields located where Bt corn is not common. To manage *O. nubilalis* infestation risk, growers determine insecticide application frequency in snap bean based on pheromone-trapping information in nearby sweet corn fields; adult activity is presumed equivalent in both crops. Our goal was to determine if corn planting intensity and adult activity in sweet corn could be used to estimate *O. nubilalis* populations in snap bean in New York in 2014-2015. Numbers of *O. nubilalis* adults captured in pheromone-baited traps located in snap bean fields where corn was and was not intensively grown were similar, suggesting that *O. nubilalis* does not respond to local levels of Bt corn in the landscape. Numbers of *Ostrinia nubilalis* captured in pheromone-baited traps placed by snap bean fields and proximal sweet corn fields were not related, indicating that snap bean growers should no longer make control decisions based on adult activity in sweet corn. Our results also suggest that the risk of *O. nubilalis* infestations in snap bean is low (~80% of the traps caught zero moths) and insecticide applications targeting this pest should be reduced or eliminated.

Schmidt-Jeffris, R. A., & Nault, B. A. (2016). European Corn Borer Control in Snap Bean, 2015. *Arthropod Management Tests*, 41(1), tsw047.

Skoczek, A., Piesik, D., Wenda-Piesik, A., Buszewski, B., Bocianowski, J., & Wawrzyniak, M. (2016). Volatile organic compounds released by maize following herbivory or insect extract application and communication between plants. *Journal of Applied Entomology*.

To protect themselves from herbivory, plants have evolved an arsenal of physical and chemical defences and release a variety of volatile organic compounds (VOCs). By releasing these VOCs, a signalling plant can both reduce herbivory, sometimes by more than 90%, and also warn neighbouring plants about an attack. The aim of this study was to assess the influence of herbivory and insect extract application on VOC release by damaged/treated and nearby undamaged/untreated maize plants. We confirmed that European corn borer (*Ostrinia nubilalis*) larvae attack or larvae extract application induced maize VOC release. Greater amounts of (Z)-3-hexenal, (E)-2-hexenal, (Z)-3-hexen-1-ol, (E)-2-hexen-1-ol, β -myrcene, (Z)-3-hexen-1-yl acetate, 1-hexyl acetate, (Z)-ocimene, linalool, benzyl acetate, methyl salicylate, indole, methyl anthranilate, geranyl acetate, β -caryophyllene, (E)- β -farnesene and (Z)-3-hexenal, (Z)-3-hexen-1-ol, (Z)-3-hexen-1-yl acetate, (Z)-ocimene, linalool, indole, methyl anthranilate, geranyl acetate, β -caryophyllene and (E)- β -farnesene were released as a result of biotic stress after insect attack or insect extract application. The amounts of each VOC released were qualitatively and quantitatively distinct and dependent on time after biotic stress exposure. However, for all biotic stresses, significantly lower VOC induction was measured when leaves were damaged/treated for three days, as compared to seven days. Our work also demonstrated that undamaged/untreated neighbouring plants

also release significant amounts of VOCs. This suggests that VOC emission by a damaged/treated plant stimulates VOC induction in nearby undamaged/untreated plants. However, the concentrations of all VOCs released by neighbouring undamaged/untreated maize plants were lower than those from damaged/treated plants and were negatively correlated with distance from a damaged/treated plant. Still, significant VOC induction occurred in undamaged/untreated plants even at 3 m distance from a damaged/infected plant. Our work suggests that maize plant protective defence responses (VOC emission) can be induced via application of European corn borer extracts.

TABATA, J., & ISHIKAWA, Y. (2016). Divergence of the Sex Pheromone Systems in "Oriental" *Ostrinia* Species. *Pheromone Communication in Moths: Evolution, Behavior, and Application*, 245.

Tóth, M., Szarukán, I., Nagy, A., Ábri, T., Katona, V., Kőrösi, S., ... & Koczor, S. (2016). An improved female-targeted semiochemical lure for the European corn borer *Ostrinia nubilalis* Hbn. *Acta Phytopathologica et Entomologica Hungarica*, 51(2), 247-254.

The addition of synthetic 4-methoxy-2-phenethyl alcohol to the known attractant phenylacetaldehyde synergized attraction of the European corn borer *Ostrinia nubilalis*, the blend invariably catching 3 to 5 times more than phenylacetaldehyde on its own. Highest catches were recorded by the 1:1 blend. Both females and males were attracted, supposedly in the natural sex ratio of the local population. This improved bisex *O. nubilalis* attractant could be more efficient and more suitable for detection and monitoring purposes than previously known lures, making possible to draw more reliable plant protection decisions.

Trisyono, Y. A. (2016). Response of a European Corn Borer, *Ostrinia nubilalis*, Population to Selection with an Ecdysone Agonist, Tebufenozide. *Jurnal Perlindungan Tanaman Indonesia*, 6(2).

Response of a population of the European corn borer, *Ostrinia nubilalis* (Hubner), to selection with an ecdysone agonist, tebufenozide (RH-5992), was investigated. The selection was carried out by exposing newly hatched larvae of *O. nubilalis* on an artificial diet containing 0.285 ppm tebufenozide for four days. Throughout seven generations of selection, a slight decrease in the larval mortality, an increase in the pupal mortality, and a decrease in the number of offspring produced per female were noticed. After four generations of selection, a shift in susceptibility of the selected *O. nubilalis* larvae to tebufenozide was not observed. The acute and chronic effects of tebufenozide caused the loss of *O. nubilalis* population after seven generations of selection.

Vasileiadis, V. P., Veres, A., Loddo, D., Masin, R., Sattin, M., & Furlan, L. (2016). Careful choice of insecticides in integrated pest management strategies against *Ostrinia nubilalis* (Hübner) in maize conserves *Orius* spp. in the field. *Crop Protection*.

A long-term field experiment was set up in April 2011 at Legnaro, Italy, within the European Project PURE, to evaluate two Integrated Pest Management (IPM) tools against conventional pest management in maize-based cropping systems (MBCS) that involved different crops every year. Three foliar insecticide treatments were applied against *Ostrinia nubilalis* (Hübner) in 2011 and 2014 when maize was present in the rotation. Lambda-cyhalothrin was applied as the conventional management (CON), while chlorantraniliprole and a biological insecticide containing *Bacillus thuringiensis* var. *kurstaki* were tested for IPM1 and IPM2, respectively. The minute pirate bug (*Orius* spp.) was the most abundant among the beneficial organisms and was considered as the indicator species to evaluate the impact of the insecticide treatments tested. Statistical analysis showed no significant difference in *Orius* nymphs (N), adults (A) and total population (N + A) before treatments, whereas after treatments *Orius* was significantly lower in the CON than in IPM in all cases. No differences in *Orius* population were determined between IPM1 and IPM2. The percentage reduction calculated in total *Orius* (N + A) after the three insecticide treatments ranged from 91% for CON, 18% for IPM1 to 4% for IPM2. The latter had a significantly higher number of plants broken below the ear, total number of broken plants and damaged ears by *O. nubilalis* compared to CON and IPM1, but no significant difference was determined between

treatments in percentage ear surface damaged, being below 1% in all cases. Treatment with chlorantraniliprole did not affect Orius population confirming its selectivity towards this species, conserved Orius at the same level as *B. thuringiensis* var. *kurstaki* and had similar efficacy to the CON against *O. nubilalis*.

Vélez, A. M., Alves, A. P., Blankenship, E. E., & Siegfried, B. D. (2016). Effect of Cry1F maize on the behavior of susceptible and resistant *Spodoptera frugiperda* and *Ostrinia nubilalis*. *Entomologia Experimentalis et Applicata*.

Understanding the behavior of pests targeted with *Bacillus thuringiensis* Berliner (Bt) crops is important to define resistance management strategies. Particularly the study of larval movement between plants is important to determine the feasibility of refuge configurations. Exposure to Bt maize, *Zea mays* L. (Poaceae), has been suggested to increase larval movement in lepidopteran species but few studies have examined the potential for resistance to interact with behavioral responses to Bt toxins. Choice and no-choice experiments were conducted with *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) and *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae) to determine whether Cry1F resistance influences neonate movement. Leaf discs of Cry1F maize and the corresponding isoline were used to characterize behavioral responses. In both experiments, the location (on or off of plant tissues) and mortality of susceptible and Cry1F resistant neonates was recorded for 5 days, but the analysis of larvae location was performed until 7 h. Our results indicated no strong difference between resistant and susceptible phenotypes in *S. frugiperda* and *O. nubilalis*, although a small percentage of susceptible neonates in both species abandoned maize tissue expressing Cry1F. However, significant behavioral differences were observed between species. *Ostrinia nubilalis* exhibited increased movement between leaf discs, whereas *S. frugiperda* selected plant tissue within the first 30 min and remained on the chosen plant regardless of the presence of Cry1F. *Spodoptera frugiperda* reduced larval movement may have implications to refuge configuration. This study represents the first step toward understanding the effects of Cry1F resistance on Lepidoptera larval behavior. Information regarding behavioral differences between species could aid in developing better and more flexible resistance management strategies.

Vélez, A. M., Vellichirammal, N. N., Jurat-Fuentes, J. L., & Siegfried, B. D. (2016). Cry1F resistance among lepidopteran pests: a model for improved resistance management?. *Current Opinion in Insect Science*, 15, 116-124.

The Cry1Fa protein from the bacterium *Bacillus thuringiensis* (Bt) is known for its potential to control lepidopteran pests, especially through transgenic expression in maize and cotton. The maize event TC1507 expressing the cry1Fa toxin gene became commercially available in the United States in 2003 for the management of key lepidopteran pests including the European corn borer, *Ostrinia nubilalis*, and the fall armyworm, *Spodoptera frugiperda*. A high-dose/refuge strategy has been widely adopted to delay evolution of resistance to event TC1507 and other transgenic Bt crops. Efficacy of this strategy depends on the crops expressing a high dose of the Bt toxin to targeted pests and adjacent refuges of non-Bt host plants serving as a source of abundant susceptible insects. While this strategy has proved effective in delaying *O. nubilalis* resistance, field-evolved resistance to event TC1507 has been reported in *S. frugiperda* populations in Puerto Rico, Brazil, and the southeastern United States. This paper examines available information on resistance to Cry1Fa in *O. nubilalis* and *S. frugiperda* and discusses how this information identifies opportunities to refine resistance management recommendations for Bt maize.

Willcoxon, M. I., Dennis, J. R., Lau, S. I., Xie, W., You, Y., Leng, S., ... & Yamamoto, T. (2016). A high-throughput, in-vitro assay for *Bacillus thuringiensis* insecticidal proteins. *Journal of biotechnology*, 217, 72-81.

A high-throughput, in-vitro assay for *Bacillus thuringiensis* (Bt) insecticidal proteins designated as Cry was developed and evaluated for screening a large number of Cry protein variants produced by DNA shuffling. This automation-amenable assay exploits an insect cell line expressing a single receptor of Bt Cry proteins. The Cry toxin used to develop this assay is a variant of the Cry1Ab protein called IP1-88, which was produced previously by DNA shuffling. Cell

mortality caused by the activated Bt Cry toxin was determined by chemical cell viability assay in 96/384-well microtiter plates utilizing CellTiter 96® obtained from Promega. A widely-accepted mode-of-action theory of certain Bt Cry proteins suggests that the activated toxin binds to one or more receptors and forms a pore through the insect gut epithelial cell apical membrane. A number of insect proteins such as cadherin-like protein (Cad), aminopeptidase-N (APN), alkaline phosphatase (ALP) and ABC transporter (ABCC) have been identified as the receptors of Bt Cry toxins. In this study, Bt Cry toxin receptors *Ostrinia nubilalis* (European corn borer) cadherin-like protein (On-Cad) and aminopeptidase-N 1 and 3 (On-APN1, On-APN3) and *Spodoptera frugiperda* (fall armyworm) cadherin-like protein (Sf-Cad) were cloned in an insect cell line, Sf21, and a mammalian cell line, Expi293F. It was observed by ligand blotting and immunofluorescence microscopy that trypsin-activated IP1-88 bound to On-Cad and On-APN1, but not Sf-Cad or On-APN3. In contrast, IP1-88 bound only to APN1 in BBMV (Brush Border Membrane Vesicles) prepared from the third and fourth-instar *O. nubilalis* larval midgut. The sensitivity of the recombinant cells to the toxin was then tested. IP1-88 showed no toxicity to non-recombinant Sf21 and Expi293F. Toxicity was observed only when the On-Cad gene was cloned and expressed. Sf-Cad and On-APN1 were not able to make those cells sensitive to the toxin. Since the expression of On-Cad alone was sufficient to make both insect and mammalian cells sensitive to the IP1-88 toxin, it is not likely that a secondary receptor, which may exist specifically in the Sf21 insect cell but not in the Expi293F cell, is involved in the cytotoxicity of IP1-88.

Yasukochi, Y., Ohno, M., Shibata, F., Jouraku, A., Nakano, R., Ishikawa, Y., & Sahara, K. (2016). A FISH-based chromosome map for the European corn borer yields insights into ancient chromosomal fusions in the silkworm. *Heredity*, 116(1), 75-83.

A significant feature of the genomes of Lepidoptera, butterflies and moths, is the high conservation of chromosome organization. Recent remarkable progress in genome sequencing of Lepidoptera has revealed that syntenic gene order is extensively conserved across phylogenetically distant species. The ancestral karyotype of Lepidoptera is thought to be $n=31$; however, that of the most well-studied moth, *Bombyx mori*, is $n=28$, and diverse studies suggest that three chromosomal fusion events occurred in this lineage. To identify the boundaries between predicted ancient fusions involving *B. mori* chromosomes 11, 23 and 24, we constructed fluorescence in situ hybridization (FISH)-based chromosome maps of the European corn borer, *Ostrinia nubilalis* ($n=31$). We first determined a 511 Mb genomic sequence of the Asian corn borer, *O. furnacalis*, a congener of *O. nubilalis*, and isolated bacterial artificial chromosomes and fosmid clones that were expected to localize in candidate regions for the boundaries using these sequences. Combined with FISH and genetic analysis, we narrowed down the candidate regions to 40 kb–1.5 Mb, in strong agreement with a previous estimate based on the genome of a butterfly, *Melitaea cinxia*. The significant difference in the lengths of the candidate regions where no functional genes were observed may reflect the evolutionary time after fusion events.

Zimmermann, G., Huger, A. M., Langenbruch, G. A., & Kleespies, R. G. (2016). Pathogens of the European corn borer, *Ostrinia nubilalis*, with special regard to the microsporidium *Nosema pyrausta*. *Journal of Pest Science*, 89(2), 329-346.

The European corn borer, *Ostrinia nubilalis*, is the most important pest insect of corn (*Zea mays*) in Germany, other European countries and historically in North America. However, in Europe only a few reports on naturally occurring biotic mortality factors are available. In the present review, an overview on pathogens including nematodes attacking *O. nubilalis* is compiled. The primary data were originally derived from long-term diagnostic studies on pathogens of arthropods carried out by the Institute for Biological Control, Darmstadt, Germany. These are updated with findings from the literature and supplemented with data from other pest insects of the same lepidopterous Crambidae family. The most important and most frequently found pathogens are the microsporidium *Nosema pyrausta*, the fungi *Beauveria bassiana* and to some extent also *Fusarium* spp., and the bacteria *Bacillus thuringiensis* and *Serratia marcescens*. Thus far, viruses have not been detected. Data on practical use of *B. thuringiensis*, *B. bassiana* and other

fungi, *N. pyrausta*, and some nematodes for biological control of *O. nubilalis* are presented. Because of the importance of *N. pyrausta* as a population regulator of *O. nubilalis*, causing a chronic disease in larvae and adults, the current knowledge on the occurrence, biology, transmission, effects on the host insect, interactions with beneficial insects and field experiments is presented. These data are complemented with former, unpublished studies on the occurrence and incidence of *N. pyrausta* in some German and French *O. nubilalis* populations (Hessen, Baden-Württemberg, Alsace). The review clearly indicates that pathogens may play an important role as naturally occurring mortality factors of *O. nubilalis* which may also be used as biocontrol agents or within conservation biological control strategies.

Articles parus en 2015

Blandino, M., Scarpino, V., Vanara, F., Sulyok, M., Krska, R., & Reyneri, A. (2015). Role of the European corn borer (*Ostrinia nubilalis*) on contamination of maize with 13 *Fusarium* mycotoxins. *Food Additives & Contaminants: Part A*, 32(4), 533-543.

The European corn borer (ECB) plays an important role in promoting *Fusarium verticillioides* infections and in the consequent fumonisin contamination in maize grain in temperate areas. The objective of this study was to evaluate whether the ECB feeding activity could also affect the occurrence of emerging mycotoxins in maize kernels. During the 2008–10 period, natural infestation of the insect was compared, in field research, with the protection of infestation, which was obtained by using an entomological net. The ears collected in the protected plots were free from ECB attack, while those subject to natural insect attacks showed a damage severity that varied from 10% to 25%. The maize samples were analysed by means of an LC-MS/MS-based multi-mycotoxin method, which led to the detection of various metabolites: fumonisins (FUMs), fusaproliferin (FUS), moniliformin (MON), bikaverin (BIK), beauvericin (BEA), fusaric acid (FA), equisetin (EQU), deoxynivalenol (DON), deoxynivalenol-3-glucoside (DON-3-G), zearalenone (ZEA), culmorin (CULM), aurofusarin (AUR) and butenolide (BUT). The occurrence of mycotoxins produced by *Fusarium* spp. of *Liseola* section was affected significantly by the ECB feeding activity. The presence of ECB injuries increased the FUMs from 995 to 4694 $\mu\text{g kg}^{-1}$, FUS from 17 to 1089 $\mu\text{g kg}^{-1}$, MON from 22 to 673 $\mu\text{g kg}^{-1}$, BIK from 58 to 377 $\mu\text{g kg}^{-1}$, BEA from 6 to 177 $\mu\text{g kg}^{-1}$, and FA from 21 to 379 $\mu\text{g kg}^{-1}$. EQU, produced by *F. equiseti* section *Gibbosum*, was also increased by the ECB activity, by 1–30 $\mu\text{g kg}^{-1}$ on average. Instead, the content of mycotoxins produced by *Fusarium* spp. of *Discolor* and *Roseum* sections was not significantly affected by ECB activity. As for FUMs, the application of a strategy that can reduce ECB damage could also be the most effective solution to minimise the other mycotoxins produced by *Fusarium* spp. of *Liseola* section.

Boettger, R., J. Schaller, S. Lintow and E. G. Dudel (2015). "Aquatic degradation of Cry1Ab protein and decomposition dynamics of transgenic corn leaves under controlled conditions." *Ecotoxicology and Environmental Safety* 113: 454-459.

The increasing cultivation of genetically modified corn plants (*Zea mays*) during the last decades is suggested as a potential risk to the environment. One of these genetically modified variety expressed the insecticidal Cry1Ab protein originating from *Bacillus thuringiensis* (Bt), resulting in resistance against *Ostrinia nubilalis*, the European corn borer. Transgenic litter material is extensively studied regarding the decomposition in soils. However, only a few field studies analyzed the fate of the Cry1Ab protein and the impact of green and senescent leaf litter from corn on the decomposition rate and related ecosystem functions in aquatic environments. Consequently, a microbial litter decomposition experiment was conducted under controlled semi-natural conditions in batch culture using two maize varieties: one variety with Cry1Ab and another one with the appertaining Iso-line as control treatment. The results showed no significant differences between the treatment with Cry1Ab and the Iso-line regarding loss of total mass in dry weight of 43% for Iso-line and 45% for Bt-corn litter, lignin content increased to 137.5% (Iso-line) and 115.7% (Bt-corn), and phenol loss decreased by 53.6% (Iso-line), 62.2% (Bt-corn) during three weeks of the experiment. At the end of the experiment Cry1b protein was still detected with 6% of the initial concentration. A slightly but significant lower cellulose content was found for the Cry1Ab treatment compared to the Iso-line litter at the end of the experiment. The significant higher total protein (25%) and nitrogen (25%) content in Bt corn, most likely due to the additionally expression of the transgenic protein, may increase the microbial cellulose degradation and decrease microbial lignin

degradation. In conclusion a relevant year by year input of protein and therefore nitrogen rich Bt corn litter into aquatic environments may affect the balanced nutrient turnover in aquatic ecosystems.

Bonoan, R. E., Al-Wathiqui, N., & Lewis, S. (2015). Linking larval nutrition to adult reproductive traits in the European corn borer *Ostrinia nubilalis*. *Physiological Entomology*, 40(4), 309-316.

Throughout an organism's lifetime, resources are strategically allocated to many different functions, including reproduction. Reproduction can be costly for both sexes; females produce nutrient-rich eggs, whereas males of many species produce large and complex ejaculates. In capital breeding insects, nutrients are mainly acquired during the larval period, yet allocation decisions impact the reproductive fitness of adults. The present study examines the effect of larval dietary nitrogen on both male and female reproductive traits in the European corn borer moth *Ostrinia nubilalis* Hübner, whose adults do not feed and whose males transfer a large, nitrogen-rich spermatophore. One day post-eclosion, *O. nubilalis* adults reared on one of three different diets (3.0%, 1.6%, or 1.1% nitrogen) are mated and two experiments are undertaken: one to measure nitrogen and carbon content of male ejaculates, and the other to determine female fecundity and fertility. Although male larval diet does not alter the percentage nitrogen content of adult somatic tissue, males reared on the higher nitrogen diet (3.0%) produce spermatophores with increased nitrogen relative to somatic nitrogen. Furthermore, females raised on the 3.0% nitrogen diet receive spermatophores with lower carbon : nitrogen ratios and thus more nitrogen. Overall, females lay more eggs as their larval dietary nitrogen increases, although they lay fewer eggs when their mates are raised on the higher (3.0%) nitrogen diet. This suggests that *O. nubilalis* females may use male-derived nitrogen not to supplement egg production, but rather for somatic maintenance. Overall, the present study furthers our understanding of how larval diet can affect adult fitness in Lepidoptera.

Bzowska-Bakalarz, M., Trendak, A., Marszałek, D., Pniak, M., Bagar, M., & Czarnigowski, J. (2015). Aerial Method of Plant Protection with the Use of an Autogyro for Sustainable Agriculture. *Agriculture and Agricultural Science Procedia*, 7, 54-58.

Despite the limitations in the use of aerial applications resulting from Directive 2009/128/EC of the European Parliament and of the Council and the Plant Protection Agents Act (OJ L item 455. 2013), scientific progress in engineering enables the development of new, environmentally safe technologies to expand the use of agroaviation. This paper proposes an innovative method of biological protection of corn against *Ostrinia nubilalis* with the use of an autogyro and presents the results of these operations. An autogyro adaptation for forest applications is proposed, and the preliminary results of a spray uniformity assessment are presented. Based on a two-year study (542.5 ha), the introduction of the Tricholet preparation against *Ostrinia nubilalis* was found to be highly effective (73.55%), which is a positive indication for the innovative autogyro method for introducing *Trichogramma evanescens*. Similarly, positive results were obtained for a liquid agent application using an autogyro-mounted installation: an even coverage of the area was achieved across the entire spray path width while maintaining the required dosing of the plant protection agent.

Cagaň, L., Plačková, A., & Bokor, P. (2015). The effects of *Nosema pyrausta* infection on European corn borer populations from five European countries. *Acta Protozoologica*, 51(2), 169-177.

Ostrinia nubilalis populations from Slovakia, Romania, Austria, Serbia and Germany were collected in the autumn when the insects were in the larval stage. These insects were then established as laboratory populations. The number of pupae and adults that developed was always higher in the *Nosema pyrausta* non-inoculated (uninfected) populations than in the populations treated by the pathogen *N. pyrausta* (infected). Significant differences were also found among the populations from different countries. Infected females laid significantly fewer eggs compared to uninfected females. The average time for pupal eclosion or adult emergence was not significantly different between the uninfected and infected populations of *O. nubilalis*. However, it was found that the infected females laid their eggs significantly sooner as compared to the uninfected females (37.383 days compared to 40.089 days). Under the same conditions, populations from colder regions developed faster than those from warmer regions. The place of origin of the population did not significantly influence larval weight, larval length or pupal weight. However, larvae infected with *N. pyrausta* spores had significantly lower weight (average 0.0797 g) than uninfected larvae (0.0901 g). With regard to pupal weight, the difference between the infected and uninfected individuals was not significant. It was confirmed that *N. pyrausta* from one European country can infect and influence host larvae originating in other countries. Although

Cette veille bibliographique est réalisée par Nathalie Roullé et Nicolas Chatel-Launay, Pôle d'excellence en lutte intégrée (PELI).

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there have been several statistically significant interactions with regard to the country of origin and *N. pyrausta* infection, it was not believed that *N. pyrausta* from one country would have specific effects on the mortality, developmental rate and larval or pupal weight of *O. nubilalis* populations from different countries.

Camerini, G., Groppali, R., Rama, F., & Maini, S. (2015). Semiochemicals of *Ostrinia nubilalis*: diel response to sex pheromone and phenylacetaldehyde in open field. *Bulletin of Insectology*, 68(1), 45-50.

Ostrinia nubilalis (European corn borer, ECB) is a widely recognized pest of several crops over much of the northern hemisphere. Diel flight rhythms of this moth in response to the attractants phenylacetaldehyde (PAA) and sex pheromones were studied in field conditions. Trapping experiments during three seasons (2008, 2009, 2010) were conducted in an area of the Po valley (northern Italy) where maize cultivation is widespread and *O. nubilalis* E and Z strains live in sympatry. Both ECB males and females were captured by water pan traps baited with PAA and males alone with Z/E pheromone isomers (11-tetradecenyl acetate). Moths caught by traps were counted every three hours, from 18.00 to 06.00 h. Both ECB males and females showed no crepuscular habits. Adults were caught by traps before 21.00 h only at the end of August, when light values were almost zero. Most of females attracted by PAA were trapped early in the night (21.00-24.00 h). Almost all of those females had mated, suggesting that PAA attraction could be related to oviposition. Unlike females, males did not show a diurnal rhythm in response to PAA, i.e. male captures maintained a steady level all night long. Males behaved differently in response to both Z and E pheromone blends; captures were mainly recorded after 24.00 h. This finding is consistent with previous data that demonstrated a gradual increase of pheromone titer and calling behaviour by females during the scotophase, following a decrease of temperature and an increase of relative humidity.

Coates, B. S. (2015). "Horizontal transfer of a non-autonomous Helitron among insect and viral genomes." *Bmc Genomics* 16. Background: The movement of mobile elements among species by horizontal transposon transfer (HTT) influences the evolution of genomes through the modification of structure and function. Helitrons are a relatively new lineage of DNA-based (class II) transposable elements (TEs) that propagate by rolling-circle replication, and are capable of acquiring host DNA. The rapid spread of Helitrons among animal lineages by HTT is facilitated by shuttling in viral particles or by unknown mechanisms mediated by close organism associations (e.g. between hosts and parasites). Results: A non-autonomous Helitron independently annotated as BmHel-2 from *Bombyx mori* and the MITE01 element from *Ostrinia nubilalis* was predicted in the genomes of 24 species in the insect Order Lepidoptera. Integrated Helitrons retained $\geq 65\%$ sequence identity over a 250 bp consensus, and were predicted to retain secondary structures inclusive of a 3'-hairpin and a 5'-subterminal inverted repeat. Highly similar Hel-2 copies were predicted in the genomes of insects and associated viruses, which along with a previous documented case of real-time virus-insect cell line transposition suggests that this Helitron has likely propagated by HTT. Conclusions: These findings provide evidence that insect virus may mediate the HTT of Helitron-like TEs. This movement may facilitate the shuttling of DNA elements among insect genomes. Further sampling is required to determine the putative role of HTT in insect genome evolution.

Coates, B. S., & Siegfried, B. D. (2015). Linkage of an ABC transporter to a single QTL that controls *Ostrinia nubilalis* larval resistance to the *Bacillus thuringiensis* Cry1Fa toxin. *Insect biochemistry and molecular biology*, 63, 86-96.

Field evolved resistance of insect populations to *Bacillus thuringiensis* (Bt) crystalline (Cry) toxins expressed by crop plants has resulted in reduced control of insect feeding damage to field crops, and threatens the sustainability of Bt transgenic technologies. A single quantitative trait locus (QTL) that determines resistance in *Ostrinia nubilalis* larvae capable of surviving on reproductive stage transgenic corn that express the Bt Cry1Fa toxin was previously mapped to linkage group 12 (LG12) in a backcross pedigree. Fine mapping with high-throughput single nucleotide polymorphism (SNP) anchor markers, a candidate ABC transporter (*abcc2*) marker, and de novo mutations predicted from a genotyping-by-sequencing (GBS) data redefined a 268.8 cM LG12. The single QTL on LG12 spanned an approximate 46.1 cM region, in which marker 02302.286 and *abcc2* were ≤ 2.81 cM, and the GBS marker 697 was an estimated 1.89 cM distant from the causal genetic factor. This positional mapping data showed that an *O. nubilalis* genome region encoding an *abcc2* transporter is in proximity to a single QTL involved in the inheritance of Cry1F resistance, and will assist in the future identification the mutation(s) involved with this phenotype.

Cruz, D. and M. Eizaguirre (2015). "Response to conspecific and heterospecific semiochemicals by *Sesamia nonagrioides* (L.) (Lepidoptera: Noctuidae) gravid females." *Bulletin of Entomological Research* 105(3): 347-354.

The Mediterranean corn borer, *Sesamia nonagrioides*, occurs sympatrically in the northeast of Spain with other lepidopteran pests such as *Ostrinia nubilalis* and *Mythimna unipuncta*. In this study, we evaluated the electrophysiological and behavioural response of mated and unmated females and males of *S. nonagrioides* to their own complete pheromone blend, to its own four components separately, and to the pheromone components of the sympatric species *O. nubilalis* and *M. unipuncta*. Results of the electroantennogram recordings revealed that females of *S. nonagrioides* can detect their own pheromone blend and its individual components. Moreover, our results show that unmated females and males of *S. nonagrioides* are more sensitive to the female pheromone, showing higher electrophysiological response than the mated females and males. Electroantennogram recordings showed that males and females can detect the major sexual pheromone component of *O. nubilalis* (Z)-11-tetradecenyl acetate and the minor component of the pheromone of *M. unipuncta* (Z)-9-hexadecenyl acetate. When the sex pheromone stimulus was presented in the dual-choice assays, gravid females of *S. nonagrioides* were attracted to both their own complete pheromone blend and one of their own minor pheromone components, (Z)-11-hexadecenal, but the major sexual pheromone component of *O. nubilalis* acts as a behavioural antagonist to the females.

Fisher, K. E. (2015). Evaluation of natural plant chemical defenses in comparison to *Bacillus thuringiensis* on the survival and feeding preferences of *Ostrinia nubilalis* (Doctoral dissertation, University of Delaware).

Foiada, F., P. Westermeier, B. Kessel, M. Ouzunova, V. Wimmer, W. Mayerhofer, T. Presterl, M. Dilger, R. Kreps, J. Eder and C.-C. Schoen (2015). "Improving resistance to the European corn borer: a comprehensive study in elite maize using QTL mapping and genome-wide prediction." *Theoretical and Applied Genetics* 128(5): 875-891.

The efficiency of marker-assisted selection for native resistance to European corn borer stalk damage can be increased when progressing from a QTL-based towards a genome-wide approach. Marker-assisted selection (MAS) has been shown to be effective in improving resistance to the European corn borer (ECB) in maize. In this study, we investigated the performance of whole-genome-based selection, relative to selection based on individual quantitative trait loci (QTL), for resistance to ECB stalk damage in European elite maize. Three connected biparental populations, comprising 590 doubled haploid (DH) lines, were genotyped with high-density single nucleotide polymorphism markers and phenotyped under artificial and natural infestation in 2011. A subset of 195 DH lines was evaluated in the following year as lines per se and as testcrosses. Resistance was evaluated based on stalk damage ratings, the number of feeding tunnels in the stalk and tunnel length. We performed individual- and joint-population QTL analyses and compared the cross-validated predictive abilities of the QTL models with genomic best linear unbiased prediction (GBLUP). For all traits, the GBLUP model consistently outperformed the QTL model despite the detection of QTL with sizeable effects. For stalk damage rating, GBLUP's predictive ability exceeded at times 0.70. Model training based on DH line per se performance was efficient in predicting stalk breakage in testcrosses. We conclude that the efficiency of MAS for ECB stalk damage resistance can be increased considerably when progressing from a QTL-based towards a genome-wide approach. With the availability of native ECB resistance in elite European maize germplasm, our results open up avenues for the implementation of an integrated genome-based selection approach for the simultaneous improvement of yield, maturity and ECB resistance.

Fujii, T., Y. Yasukochi, Y. Rong, T. Matsuo and Y. Ishikawa (2015). "Multiple Delta 11-desaturase genes selectively used for sex pheromone biosynthesis are conserved in *Ostrinia* moth genomes." *Insect Biochemistry and Molecular Biology* 61: 62-68.

Regulation of the expression of fatty acyl-CoA desaturases, which introduce a double bond into the fatty acid moiety of the substrate, is crucial for the production of species-specific sex pheromones in moths. In *Ostrinia* moths, two distinct Delta 11-desaturases and a Delta 14-desaturase are known to be selectively used in the biosynthesis of sex pheromones. Of the two Delta 11-desaturases, one identified from *Ostrinia nubilalis* and *Ostrinia scapularis*, Z/E Delta 11, forms the Z and E isomers of a double bond at position 11, whereas the other identified from *Ostrinia latipennis*, LATPG1(=E Delta 11), exclusively forms an E double bond at position 11. Since the retroposon(ezi)-fused, non-functional Delta 11-desaturase gene, ezi-Delta 11 alpha, in the genomes of *O. nubilalis* and *O. furnacalis* was previously suggested to be an orthologue of *latpg1*, we here explored Z/E Delta 11 orthologues in the genome of *O. latipennis*. We newly identified two Delta 11-desaturase genes, *latpg2* and *latpg3*, which were orthologous to ezi-Delta 11 beta

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and Z/E Delta 11, respectively. We found that an ezi-like element was integrated in intron 1 of *latpg1*, and confirmed that only *latpg1* was expressed in the pheromone gland of *O. latipennis*. Thus, at least three All-desaturase genes are present in the genome of *O. latipennis*, and *latpg1* is selectively transcribed in the pheromone gland of this moth. The non-functionality of ezi-inserted desaturase genes in *O. nubilalis* and *O. furnacalis* may not be a direct consequence of the insertion of an ezi- or ezi-like element into the gene. (C) 2015 Elsevier Ltd. All rights reserved.

GEORGESCU, E., BURCEA, M., CANA, L., & RASNOVEANU, L. (2015). Technology of the European Corn Borer (*Ostrinia nubilalis* Hbn) Mass Rearing, Successive Generations, in Controlled Conditions, at NARDI FUNDULEA. Bulletin USAMV series Agriculture, 72, 1.

Obtain insects egg batches in laboratory conditions, used for artificial infestation of the maize plants, to establish maize lines and hybrids tolerance to pest attack. Because in nature, the attack of *Ostrinia nubilalis* are not at same level, every year, as result of the climatic conditions, especially at egg batch deposition and larva emergence, artificial infestation of the maize plants is one of the best method to evaluate maize lines and hybrids reaction at this pest. European corn borer is reared at Plant Protection Laboratory, from NARDI Fundulea, Calarasi County, Romania. Field experiments were made at experimental fields of both, Plant Protection and Maize Breeding laboratories. In 2011 it has obtained 136043 egg batches, in 2012 it has obtained 121945 egg batches and in 2013 it has obtained 133550 egg batches. At the end of the year 2013, the insect colony created in 1979 arrived at 442nd consecutive generation, the insect colony created in 2008 arrived at 77th consecutive generation, the insect colony created in 2010 arrived at 51st consecutive generation and insect colony created in 2011 arrived at 38th consecutive generation. Even if insects are reared more then 440 generations in laboratory conditions, they don't lose capacity of attacking maize plants. Rearing of the European corn borer (*Ostrinia nubilalis* Hbn) in laboratory conditions, in continuous flux, on same artificial diet, is one of the best methods for mass production of the egg-batches necessary for the field researches concerning maize hybrids and lines tolerance at the attack produced by this pest.

GEORGESCU, E., CANĂ, L., & RASNOVEANU, L. (2015). BEHAVIOR OF SOME MAIZE HYBRIDS TO THE EUROPEAN CORN BORER (*Ostrinia nubilalis* HBN) ATTACK, AT NARDI FUNDULEA, 2013-2014. Agronomy Series of Scientific Research/Lucrari Stiintifice Seria Agronomie, 58(1).

In this paper there were presented some results concerning testing of 18 maize hybrids to evaluate reaction at European corn borer attack (*Ostrinia nubilalis* Hbn.), in climatic conditions of the years 2013 and 2014, at NARDI Fundulea. Maize plants were artificial infested with ECB egg batches, produced in laboratory conditions, by rearing insects, successive generations, on continuous flux, using same artificial diet. Also, it has evaluated maize plants in conditions of ECB natural attack. Total number of egg batches obtained in laboratory was 133550 in 2013 and 159116 in 2014. Climatic conditions from summer period, registered at NARDI Fundulea, were more favorable for pest attack in 2014 comparative with 2013. Average natural attack frequency of the *O. nubilalis* at maize hybrids from the experiment was of 43.3 % in climatic conditions of the year 2013 and 79.4 % in climatic conditions of the year 2014. In case of artificial infestation of maize plants with ECB egg batches, average attack frequency was 91.7 % in 2013 and 95.5 % in 2014. Attack intensity was higher in 2014 comparative with 2013, both, at plants not infested and plants artificial infested. In both years, the differences between hybrids reaction to the attack of European corn borer were higher in case of artificial infestation, comparative with natural attack. Higher attack values, in both years, it has registered at Milcov, Paltin and F 59-09 hybrids while lower attack it has registered in case of F 475 M hybrid. Some maize hybrids have different reaction to ECB attack in 2013 comparative with 2014.

Hamilton, B. (2015). Coordination And Disruption Of Traits Contributing To Reproductive Isolation In *Ostrinia Nubilalis*, The European Corn Borer.

Central to the process of speciation is understanding mate choice and its consequence, the evolution of reproductive isolation. The coordination of signal and response is essential to the evolution of divergent mating systems, but insights into the genetic processes that allow such coevolution to take place are limited. The two pheromone strains of the European corn borer (ECB) moth (*Ostrinia nubilalis*) allow for the study of a signal/response system, female production of pheromone, and male behavioral response. This study utilizes males collected from traps in New York State baited with either of the two pheromone blends and analyzes their genotypes at *pgFAR*, the gene responsible for divergent female pheromone production. ECB strains also differ in post-diapause development (PDD) time, which can contribute

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to temporal isolation in natural populations. Therefore, we also assay genotypes in a genomic region around Tpi associated with control of post-diapause development. Significant non-random associations are found between this region, pgFAR, and the type of trap in which a male was found. This study also assays field-collected females from New York, North Carolina, and Delaware for pheromone production, post-diapause development, and Tpi gene genealogies. Whereas populations in New York and North Carolina display the expected association between all three characters, the association between Tpi and pheromone production is disrupted in Delaware.

Huseth, A. S., Groves, R. L., Chapman, S. A., & Nault, B. A. (2015). Evaluation of diamide insecticides co-applied with other agrochemicals at various times to manage *Ostrinia nubilalis* in processing snap bean. *Pest management science*, 71(12), 1649-1656.

BACKGROUND: Multiple applications of pyrethroid insecticides are used to manage European corn borer, *Ostrinia nubilalis* Hübner, in snap bean, but new diamide insecticides may reduce application frequency. In a 2 year small-plot study, *O. nubilalis* control was evaluated by applying cyantraniliprole (diamide) and bifenthrin (pyrethroid) insecticides at one of three phenological stages (bud, bloom and pod formation) of snap bean development. Co-application of these insecticides with either herbicides or fungicides was also examined as a way to reduce the total number of sprays during a season. **RESULTS:** Cyantraniliprole applications timed either during bloom or during pod formation controlled *O. nubilalis* better than similar timings of bifenthrin. Co-applications of insecticides with fungicides controlled *O. nubilalis* as well as insecticide applications alone. Insecticides applied either alone or with herbicides during bud stage did not control this pest. **CONCLUSION:** Diamides are an alternative to pyrethroids for the management of *O. nubilalis* in snap bean. Adoption of diamides by snap bean growers could improve the efficiency of production by reducing the number of sprays required each season.

Jakka, S., Ferré, J., & Jurat-Fuentes, J. L. (2015). Cry toxin binding site models and their use in strategies to delay resistance evolution. Bt resistance: characterization and strategies for GM crops producing *Bacillus thuringiensis* toxins. Wallingford: CABI, 138-49.

Leggieri, M. C., Bertuzzi, T., Pietri, A., & Battilani, P. (2015). Mycotoxin occurrence in maize produced in Northern Italy over the years 2009–2011: focus on the role of crop related factors. *Phytopathologia Mediterranea*, 54(2), 212.

The occurrence of mycotoxins associated with *Fusarium* spp. and *Aspergillus flavus* in Northern Italy, and the role of cropping systems, were investigated on 140 field samples collected over the years 2009–2011. Samples were analysed for fumonisins B1 and B2 (FBs), aflatoxins B1, B2, G1 and G2 (AFs), deoxynivalenol (DON) and zearalenone (ZEN) using validated analytical methods. Information on: maize hybrid, preceding crop, tillage applied, mineral nutrition, pest and disease control, severity of European Corn Borer (ECB) attack, sowing and harvesting dates, kernel moisture at harvesting and longitude of the sampled province, were also collected. During this period there were distinct differences in FBs and AFs concentrations between years and geographic origins, and very low contamination with DON and ZEN was always found. The incidence of AFs exceeded 75% across all samples, and was almost 100% for FBs. The meteorological trends were quite different in the 3 years surveyed. 2009 was the coldest in June and the warmest in August, 2010 the most humid, and in 2011 cold weather occurred during flowering and dry conditions during ripening. The run of a logistic equation with the backward stepwise approach selected three parameters, (seeding week, ECB severity and longitude of sampling province) to predict AFB1 contamination and four parameters (year, sowing week, ECB severity and longitude of sampling province) to predict FB contamination. The internal validation gave good results, with 76% correct predictions. The probability of harvesting maize with more than 5 µg kg⁻¹ of AFB1 varied between 86 and 5%, and the probability of harvesting maize with more than 4,000 µg kg⁻¹ of FBs varied between 81 and 2%, respectively, for conducive and non-conducive environments. Therefore, considerable variability was found even if a limited area and only 3 years were considered.

Levic, J., Gosic-Dondo, S., Ivanovic, D., Stankovic, S., Krnjaja, V., Bocarov-Stancic, A., & Stepanic, A. (2015). An outbreak of *Aspergillus* species in response to environmental conditions in Serbia.

The frequency and incidence of *A. flavus* and *A. niger* on barley, maize, soybean, sunflower and wheat grain, the abundance of European corn borer (*Ostrinia nubilalis*) moths and their interaction depending on weather conditions in the 2008-2012 period were studied. Under the agroecological conditions of Serbia, the species *A. niger* is more

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frequent than *A. flavus*, and concerning the crop species, its frequency is highest in kernels of sunflower, than soybean, maize, barley and wheat. *A. flavus* was extremely dominant on all plant species in 2012 regarding its frequency: 100% on soybean, 95.3% on maize, 65.2% on barley, 57.1% on sunflower and 45.8% on wheat. Furthermore, the incidence of *A. flavus* was higher in 2012 than in previous years. The uncommonly high frequency and incidence of *A. flavus* infestation of maize grain in 2012 were caused by extremely stressful agrometeorological conditions, high temperatures and drought over the period from flowering to waxy maturity of maize. The precipitation factor (Pf = precipitation sum / average monthly temperature) showed that 2012 was extremely arid in June (Pf = 0.57), July (Pf = 1.45), August (Pf = 0.15) and September (Pf = 1.42). European corn borer (ECB) was a second factor causing intensive occurrence of *A. flavus* on maize grain in 2012. The maximum flight of ECB moths was recorded as early as in July (5,149) and, as a result of this, high damage and numerous injuries were detected at harvest. Those injuries were covered by visible olive-green powdery colonies typical of *A. flavus*. In the chronology of *A. flavus* occurrence, these are the first data on its very high frequency and incidence under the agroecological conditions of Serbia. As intensive infections with *A. flavus* were rare in the past 50 years, the level of aflatoxins in maize grain was low.

Levy, R. C. (2015). Rhythm & cues: circadian clock genes and temporal reproductive isolation in the European corn borer moth (*Ostrinia nubilalis*) (Doctoral dissertation, TUFTS UNIVERSITY).

Temporal reproductive isolation is currently a well-documented but poorly-understood mechanism for divergence between incipient species. The circadian clock regulates biological rhythms on 24-hour cycles and is potentially involved in detection of seasonal variation in photoperiod, and genes in this pathway are prime candidates for genetic control of both seasonal and circadian shifts in mating time. The European corn borer, *Ostrinia nubilalis*, is a model for how temporal isolation contributes to speciation, as the species' E and Z pheromone strains are temporally isolated from each other on seasonal and 24-hour time scales. In this thesis, I examine how genetic variation within the *O. nubilalis* clock is linked to life cycle timing in the Z strain and shifts in generation number across a latitudinal cline, and how key circadian genes are differentially expressed between the strains during scotophase, which may be triggering divergence in the timing of pheromone release and subsequent mating.

Levy, R. C., G. M. Kozak, C. B. Wadsworth, B. S. Coates and E. B. Dopman (2015). "Explaining the sawtooth: latitudinal periodicity in a circadian gene correlates with shifts in generation number." *Journal of Evolutionary Biology* 28(1): 40-53.

Many temperate insects take advantage of longer growing seasons at lower latitudes by increasing their generation number or voltinism. In some insects, development time abruptly decreases when additional generations are fit into the season. Consequently, latitudinal sawtooth' clines associated with shifts in voltinism are seen for phenotypes correlated with development time, like body size. However, latitudinal variation in voltinism has not been linked to genetic variation at specific loci. Here, we show a pattern in allele frequency among voltinism ecotypes of the European corn borer moth (*Ostrinia nubilalis*) that is reminiscent of a sawtooth cline. We characterized 145 autosomal and sex-linked SNPs and found that period, a circadian gene that is genetically linked to a major QTL determining variation in post-diapause development time, shows cyclical variation between voltinism ecotypes. Allele frequencies at an unlinked circadian clock gene cryptochrome1 were correlated with period. These results suggest that selection on development time to fit' complete life cycles into a latitudinally varying growing season produces oscillations in alleles associated with voltinism, primarily through changes at loci underlying the duration of transitions between diapause and other life history phases. Correlations among clock loci suggest possible coupling between the circadian clock and the circannual rhythms for synchronizing seasonal life history. We anticipate that latitudinal oscillations in allele frequency will represent signatures of adaptation to seasonal environments in other insects and may be critical to understanding the ecological and evolutionary consequences of variable environments, including response to global climate change.

Lundgren, J. G., McDonald, T., Rand, T. A., & Fausti, S. W. (2015). Spatial and numerical relationships of arthropod communities associated with key pests of maize. *Journal of Applied Entomology*, 139(6), 446-456.

Pest management largely focuses on managing individual pest species with little concern for the diverse communities that co-occur with key pests and potentially shape their population dynamics. During anthesis, we described the foliar arthropod communities on 53 maize farms throughout the region of eastern South Dakota. The resulting communities were examined for trends in local associations in the abundances of taxa with key pests in the system (rootworms [*Diabrotica* spp.], European corn borers [*Ostrinia nubilalis*], aphids and Western bean cutworm [*Striacosta albicosta*])

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using regression analyses. Regional spatial clustering in the abundances of key pests with members of the community was explored using Moran's I test statistic. The distributions of rootworms and European corn borer were mapped. A total of 37 185 arthropods representing at least 91 taxa were collected in South Dakota maize; there was an average of 5.06 predators and 8.29 herbivores found per plant. Key pests were never found at economically threatening levels (with one exception for *Diabrotica*). Numerous species were consistently numerically associated with each of the key pests across the farms during anthesis. Occasionally, these pests shared species with which they were locally associated with; for example, coccinellid egg abundances were predictive of the abundances of all key pest species except rootworm adults. Spatial analysis across the region suggested that species co-occurred with key pests based on local characteristics surrounding the fields, rather than as a result of regional characteristics. Exceptions were documented; namely aphids and Western bean cutworms that spatially clustered with a handful of other members of the community. The results of the study point out that the abundances of key pests of maize were interconnected through indirect associations in the abundances of other members of the community. These associations may be useful for manipulating maize agroecosystems to minimize the effects of maize pests.

Magda, S., & Hussein, M. M. (2015). Usage of the nano phosphorous fertilizers in enhancing the corn crop and its effect on corn borers infestations after fungi treatments. *International Journal of ChemTech Research*, 8(9), 167-173.

The effect of the fertilizer phosphorous and the bio-insecticide fungi, were studied under laboratory and field conditions. Results, showed that the LC50 of the target insect pests after treatment with nano phosphorous mixed with the entomopathogenic fungi under laboratory conditions. The obtained data show that LC50 of *O. nubilalis* recorded 101 and 116 conidia/ ml after treated with *B. Bassiana* (B.b) + Nano-Phosphorous fertilization and *M. anisopliae* (M.a)+ Nano-Phosphorous fertilization respectively. When *S. cretica* were treated with corresponding treatments the LC50 reached 106 and 119X 104conidia/ml. The applications of the nano bioinsecticides *M. anisopliae* and *B. Bassiana* after the corn plants fertilize by the nano phosphorous fertilizer which detected that in the control plots the infestation of *Ostrinia nubilalis* were 78 ± 2.3 and 86 ± 2.1 individuals during season 2013 and 2014, respectively after 100 days of applications. The infestations of *Sesamia cretica* reached to 88 ± 5.1 and 93 ± 2.9 individuals after 100 days of applications. *Chilo agamemnon* individual recorded after 100 days during 2013 and 2014, 99 ± 3.9 and 99 ± 2.3 individuals, respectively. When the corresponding insect pests treated with M.a only during season 2014, the individual mean number obtained, 28 ± 2.8 , 26 ± 2.1 and 29 ± 9.3 individuals for the three pests, respectively. The infestation were highly significant decreased among the B.b+ Nano-Phosphorous fertilization. The inflation means number for the three pest 8 ± 2.9 , 9 ± 2.9 and 12 ± 9.3 individuals during 2014. During season 2013, the field applications in maize field, show that the nano phosphorus have a positive effect for increasing the corn weight which reached to 5563 ± 32.92 kg/ feddan after nano phosphorous fertilizations plots. In the plots treated with B.b+ Nano-Phosphorous fertilization the weight of the corn recorded 6667 ± 89.76 kg/ feddan Kg/ feddan as compared to 2310 ± 79.02 kg/ feddan in the control . During season 2014 the B.b+ Nano-Phosphorous fertilization recorded the highest weight amount reached to 7866 ± 89.76 kg/ feddan as compared to 2002 ± 34.12 kg/ feddan in the control plots.

Martin, J. (2015). The magnitude of the island of genetic differentiation surrounding a strong, prezygotic reproductive isolating barrier (Doctoral dissertation, TUFTS UNIVERSITY).

Numerous studies have observed regions of elevated genetic differentiation (islands) when comparing the genomes of incipient species. The mechanisms that lead to the formation of these islands nor their basic characteristics (length, frequency, distribution) are well understood. One hypothesis is that islands of elevated genetic differentiation form around loci that encode reproductive isolating barriers, but there is currently little empirical evidence to support this thinking. In this thesis, I test this idea using an emerging model of speciation, the pheromone strains of *Ostrinia nubilalis*. I quantify the size of the island that forms around pgFAR, the gene responsible for differential pheromone production in the two strains. I observed the island surrounding pgFAR to be several hundred kilobases long, several orders of magnitude smaller than some of the islands observed in previous work. This discrepancy in island sizes suggests that there may be multiple different mechanisms responsible for island creation.

Molnár, B. P., Tóth, Z., Fejes-Tóth, A., Dekker, T., & Kárpáti, Z. (2015). Electrophysiologically-Active Maize Volatiles Attract Gravid Female European Corn Borer, *Ostrinia nubilalis*. *Journal of chemical ecology*, 41(11), 997-1005.

The European corn borer (ECB) is an important pest of maize in the northern hemisphere, but no reliable techniques exist for monitoring females during their reproductive period. In this study, we aimed to identify host-plant volatiles used by gravid Z-strain females in search for oviposition sites. Headspace of maize plants, to which gravid females orientated in a wind tunnel, was collected, and physiologically-active components were identified by using gas chromatography (GC) coupled with electroantennographic detection followed by GC-mass spectrometry. The antennae of female moths consistently responded to two maize volatiles, nonanal and decanal. Although these compounds are individually not characteristic for maize, a synthetic mix in a ratio found in maize headspace, 1:2.4 at $1 \mu\text{g } \mu\text{l}^{-1}$ induced source contact and landing responses similar to maize plants in the wind tunnel. However, fewer females took flight in response to the mix, and those that took flight did so with an increased latency. To our knowledge, this is the first blend of host-plant volatiles that has been found to be physiologically active and to be able to induce attraction of gravid ECB females under laboratory conditions. Future tests will evaluate the attractiveness of the blend to the E-strain of ECB, the attractiveness of the blend in the field, and its potential in monitoring ECB populations.

Murrell, E. G., Hanson, C. R., & Cullen, E. M. (2015). European corn borer oviposition response to soil fertilization practices and arbuscular mycorrhizal colonization of corn. *Ecosphere*, 6(6), 1-12.

Soil fertility and resulting crop plant nutrition contribute to optimal crop yields in both conventional and organic farming systems. Additionally, soil management practices can affect the colonization and efficacy of arbuscular mycorrhizae (AM), which in turn may improve crop resilience to drought and soil nutrient deficiencies. Soil mineral fertilization and AM colonization have been shown to affect herbivorous insect oviposition response and performance. However, the below-ground interaction of fertilization practices and AM colonization on plant nutrition and insect oviposition response has been largely unexplored. To test this, we obtained soils from agricultural fields managed under 3 different soil fertilization practices for 5 continuous years: Synthetic fertilizers only with a 2-year corn-soybean rotation (conventional farming, or CONV), dairy manure with a 4-year alfalfa/oat-alfalfa-corn-soybean rotation (standard organic farming, or STDO), and dairy manure + 4-year alfalfa/oat-alfalfa-corn-soybean rotation with biannual gypsum applications (organic basic cation saturation ratio farming, or BCSR). Soils from these treatments have been previously shown to vary significantly in their Ca:Mg:K ratios and also in S content. We reared field corn plants in these soils in a greenhouse, then used them to conduct oviposition choice assays with the corn insect pest *Ostrinia nubilalis* (European corn borer, or ECB). Colonization of AM on plant roots did not significantly differ among treatments. Plant tissue minerals (primarily S, Fe, and Cu) varied significantly among treatments but were not affected by AM colonization. However, the number of ECB eggs laid per plant per trial varied significantly by soil fertilization treatment, plant height, and AM colonization, with significant interaction effects. Female oviposition response was positively correlated with AM colonization and height in low mineral soil fertilization treatments (STDO and CONV), but moths showed a negative response to AM colonization in BCSR plants as plant height increased. Our results indicate that both fertilization practices and mycorrhizal associations can interact to modify oviposition in pest insects, which may have significant implications for the utilization of fertilization practices for pest insect suppression.

Nanoth Vellichirammal, N., H. Wang, S.-I. Eyun, E. N. Moriyama, B. S. Coates, N. J. Miller and B. D. Siegfried (2015). "Transcriptional analysis of susceptible and resistant European corn borer strains and their response to Cry1F protoxin." *Bmc Genomics* 16: 558-558.

BACKGROUND: Despite a number of recent reports of insect resistance to transgenic crops expressing insecticidal toxins from *Bacillus thuringiensis* (Bt), little is known about the mechanism of resistance to these toxins. The purpose of this study is to identify genes associated with the mechanism of Cry1F toxin resistance in European corn borer (*Ostrinia nubilalis* Hubner). For this, we compared the global transcriptomic response of laboratory selected resistant and susceptible *O. nubilalis* strain to Cry1F toxin. We further identified constitutive transcriptional differences between the two strains. **RESULTS:** An *O. nubilalis* midgut transcriptome of 36,125 transcripts was assembled de novo from 106 million Illumina HiSeq and Roche 454 reads and used as a reference for estimation of differential gene expression analysis. Evaluation of gene expression profiles of midgut tissues from the Cry1F susceptible and resistant strains after toxin exposure identified a suite of genes that responded to the toxin in the susceptible strain ($n = 1,654$), but almost 20-fold fewer in the resistant strain ($n = 84$). A total of 5,455 midgut transcripts showed significant constitutive expression differences between Cry1F susceptible and resistant strains. Transcripts coding for previously identified Cry toxin receptors, cadherin and alkaline phosphatase and proteases were also differentially expressed in the midgut of

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the susceptible and resistant strains. CONCLUSIONS: Our current study provides a valuable resource for further molecular characterization of Bt resistance and insect response to Cry1F toxin in *O. nubilalis* and other pest species.

Popović, Ž. D., & Grubor-Lajšić, G. Diapause induces remodeling of the fatty acid composition of 2 membrane and storage lipids in overwintering larvae of 3 *Ostrinia nubilalis*, Hubn. (Lepidoptera: Crambidae).

Seasonal changes in the FA composition of triacylglycerols and phospholipids prepared from the whole body of non-diapausing and diapausing fifth instar larvae of *Ostrinia nubilalis*, Hubn. (Lepidoptera: Crambidae) were determined to evaluate the role of these lipids in diapause. Substantial changes in the FA composition of triacyl-glycerols and phospholipids were triggered by diapause development. This led to a significant increase in the overall FA unsaturation (UFAs/SFAs ratio), attributable to an increase in the relative proportion of MUFAs and the concomitant decrease in PUFAs and SFAs. In triacylglycerols, the significant changes in the FAs composition are the result of an increase in the relative proportions of MUFAs, palmitoleic acid (16:1n-7) and oleic acid (18:1n-9), and a concomitant reduction in the composition of SFAs and PUFAs, mainly palmitic acid (16:0) and linoleic acid (18:2n-6), respectively. Changes in the composition of phospholipids were more subtle with FAs contributing to the overall increase of FA unsaturation. Differential scanning calorimetry (DSC) analysis revealed that the melt transition temperatures of total lipids prepared from whole larvae, primarily attributable to the triacylglycerol component, were significantly lower during the time course of diapause compared with non-diapause. These observations were correlated to the FA composition of triacylglycerols, most likely enabling them to remain functional during colder winter conditions. We conclude that *O. nubilalis* undergoes remodeling of FA profiles of both energy storage triacylglycerols and membrane phospholipids as an element of its overwintering physiology which may improve the ability to cold harden during diapause.

Popović, Ž. D., Subotić, A., Nikolić, T. V., Radojčić, R., Blagojević, D. P., Grubor-Lajšić, G., & Košťál, V. (2015). Expression of stress-related genes in diapause of European corn borer (*Ostrinia nubilalis* Hbn.). *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, 186, 1-7.

Diapause is a state of arrested development during which insects cope with many external and internal stressful factors. European corn borer, *Ostrinia nubilalis*, overwinters as a fifth instar freeze-tolerant diapausing larva. In order to explore diapause-linked stress tolerance processes, the expression of selected genes coding for stress-related proteins—glutathione S-transferase (Gst), thioredoxin (Trx), glutaredoxin (Grx), ferritin (Fer), metallothionein (Mtn), and heat shock proteins Hsp90, Hsc70, Hsp20.4, and Hsp20.1—was assessed in the fat body of diapause-destined, warm (22 °C) and cold (5 °C) acclimated diapausing larvae using the quantitative real-time PCR. Gene expression was normalised to mRNA transcripts for Actin and Rps03, and relative expression was calculated using non-diapausing larvae as a control group. During the initiation phase of diapause, the abundance of mRNA transcripts of Grx, Hsp90, Hsc70, and Hsp20.1 was significantly upregulated, Trx, Fer, Mtn, and Hsp20.1 were unchanged, while only Gst was clearly downregulated in comparison to non-diapause control. Later, in the early phase of diapause, the expression of most genes (except Trx and Hsp20.1) was upregulated in warm-acclimated larvae, while only Trx and Hsp90 were upregulated in cold-acclimated larvae. Furthermore, the relative expression of all genes (except Trx) increased gradually throughout the diapause in cold-acclimated larvae. This result indicates that the half-life of mRNAs is prolonged during diapause at low temperature, which may lead to a gradual accumulation of mRNA transcripts. Our results show that both diapause programming and temperatures affect the expression of stress-related genes in *Ostrinia nubilalis*.

Przybyłowicz, Ł., Pniak, M., & Tofilski, A. (2015). Semiautomated identification of European corn borer (Lepidoptera: Crambidae). *Journal of Economic Entomology*, 108, 300-306.

The European corn borer *Ostrinia nubilalis* (Hübner, 1796) is a serious and widely studied pest of corn. The most common method of its control is by means of insecticides. However, biological control is becoming more and more popular. The hymenopteran parasitoid *Trichogramma* sp. is the most promising and effective one among the biological agents and is now widely used in North America and Europe. Its application should occur at the time when the European corn borer is at the beginning of the eggs laying period. However, the discrimination between the European corn borer and some other species occurring in agricultural landscapes at the same time can be difficult, especially for farmers which are neither familiar with the morphological nor molecular methods of identification. The scope of this study is to test the ability of the automatic computer equipment to determine the European corn borer and to separate it from the most common Lepidoptera pests found in corn plantations. The experiment showed that the 97.0% of the

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247 specimens belonging to four common pest lepidopterans were correctly classified by the use of a personal computer, desktop scanner, and the special software. The obtained results showed that this technique based on wing measurements can be an effective tool for monitoring of the European corn borer. In the future, this method can be used by farmers to identify this pest and apply control measures at optimal time.

Purać, J., Kojić, D., Popović, Ž., Vukašinović, E., Tiziani, S., Gunther, U., & Grubor-Lajšić, G. (2015). Metabolomic analysis of diapausing and non-diapausing larvae of European corn borer *Ostrinia nubilalis* (Hbn.) (Lepidoptera: Crambidae). *Acta Chimica Slovenica*, 62(4), 761-767.

Nuclear magnetic resonance (NMR) spectroscopy is powerful metabolomic technique which allows overview of numerous compounds simultaneously. In this study, ¹H-NMR-based metabolomic approach was used to investigate entering into diapause and cold hardiness of diapausing larvae of European corn borer (*Ostrinia nubilalis*). Obvious relationship between diapause and cold hardiness of this species is poorly understood, especially on metabolomic level. Therefore, we have compared the metabolomic patterns in polar extract of hemolymph of non-diapausing and diapausing larvae of *O. nubilalis*. Results have shown that diapauses, as dormant state, has different metabolomic pattern compared to active non-diapausing phase. Furthermore, differences were indicated among diapausing larvae that were at 5 °C and chilled to -3 °C and -16 °C for two weeks. This separation includes 13 metabolites: seven amino acids, glycerol, acetate, citrate, succinate, lactate and putrescine. ¹H-NMR spectroscopy gave new insight into metabolomics of cold resistance and diapause of *O. nubilalis* indicating distinct metabolomes of actively developing and diapausing larvae.

Sabbour, M. M., & Singer, S. M. (2015). Efficacy of *Nano Isaria fumosorosea* and *Metarhizium flavoviride* against Corn Pests under Laboratory and Field Conditions in Egypt. *International Journal of Science and Research (IJSR)*. ISSN (Online), 2319-7064.

The effect of nano fungus *Metarhizium flavoviride* show that the obtained LC50 recorded 88x10⁴, 76x10⁴ and 106x10⁴ spores/ml for *Ostrinia nubilalis*, *Sesamia cretica* and *Chilo agamemnon* respectively. Results showed that the LC50 of the nano fungus *Isaria fumosorosea* of the corresponding insect pests recorded, 56 x10⁴, 68x10⁴, 68x10⁴ and 95x10⁴ spores/ml, respectively the infestation of the target insect pests were significantly decreased during both successive seasons, during season 2014 the infestations of *O. nubilalis* were significantly decreased after 90 days to 18±0.2 and 22±1.0 in plots treated with Nano-M. *flavoviride* and Nano-I. *fumosorosea* respectively as compared to 89±9.1 individuals in the control. *S. cretica* significantly decreased to 19±0.3 and 26±2.1 individuals when treated with and Nano-I. *fumosorosea* respectively as compared to 97±2.9 individuals in the control during season 2014. The same results obtained when *C. agamemnon* treated with both nano fungi. The application of the bioinsecticides which affected on decreasing the infestation, the number of infestations of *O. nubilalis* and *Sesamia cretica* significantly decreased to 20±2.9 and 22±1.1., respectively, after treatment with *M. flavoviride* after 20 day as compared to 69±9.3 and 70±9.1 individual in the control for the corresponding pests, during seasons 2014. In all treatments the number of corn pests were significantly decreased. *Chilo agamemnon* infestation decreased to 20±3.3 and 25±3.1 individuals after 90 days during season, 2014 and 2013 as compared to 98±9.3 and 99±9.3 individuals in the control plots in both two seasons. The weight of corn in the field during season 2013, 4089±82.80 and 4999±66.73 after treatments with Nano-M. *flavoviride* and Nano-I. *fumosorosea* respectively as compared to 2611±33.80 in the control. The percentage of yield loss 47% in the control and 0.1% in the plots treated with Nano-I. *fumosorosea*. During season 2014 the results show that the weight of corn were significantly decreased to in the control as compared to and in plots treated with Nano-I. *fumosorosea* and Nano-M. *flavoviride*, respectively. The percentage of yield loss are 0.02% and 52% in plots treated with Nano-I. *fumosorosea* and in the control.

Sarajlić, A., Raspudić, E., Majić, I., Lončarić, Z., Brmež, M., & Josipović, M. (2015). Relationship between European corn borer feeding activity and nitrogen leaf content under different agricultural practices. *POLJOPRIVREDA*, 21(1), 41-45.

One of the most destructive maize pest in Croatia is European corn borer (*Ostrinia nubilalis* Hübner) (ECB). The aim of this study was to determine the influence of irrigation, nitrogen fertilization, different maize genotypes and nitrogen leaf content on ECB feeding activity. The experiment was set up in Osijek, Croatia under field conditions during 2012-2013 vegetation season. Experiment treatments were as follows: three irrigation levels (A1 - control, A2 from 60% to 80% field water capacity - FWC and A3 from 80% to 100% FWC), three nitrogen fertilizer levels (B1 - 0, B2 - 100 and B3 - 200 kg N/ha) and four different genotypes (C1 - OSSK 596; C2 - OSSK 617; C3 - OSSK 602 and C4 - OSSK 552). Ear

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weight, number of larvae in stem and shank, tunnel length and nitrogen leaf content were evaluated. Genotype C1 was the most susceptible for following the tested variables of ECB feeding: tunnel length (TL), larvae in stalk (LS) and total number of larvae (TNL) at $P < 0.05$ probability level. By raising the level of irrigation, European corn borer feeding activity was reduced while by raising the level of nitrogen fertilization feeding activity was increased. These results suggest that good production practices can significantly affect the susceptibility of maize to European corn borer.

Scarpino, V., A. Reyneri, F. Vanara, C. Scopel, R. Causin and M. Blandino (2015). "Relationship between European Corn Borer injury, *Fusarium proliferatum* and *F. subglutinans* infection and moniliformin contamination in maize." *Field Crops Research* 183: 69-78.

The European Corn Borer (ECB), *Ostrinia nubilalis* (Hubner), plays an important role in promoting *Fusarium* infection and fumonisin production in maize kernels. Moniliformin (MON) is a mycotoxin that is usually found in association with fumonisins (FB), and as a consequence ECB is also expected to play a role in MON contamination. The aim of the current study was to investigate the influence of ECB activity on MON contamination and on the fungi responsible for its contamination. A comparison has been made between maize infected naturally by insect larvae and protected maize, from 2008 to 2010 in North-West Italy; the latter was obtained by positioning an entomological net at the end of maize flowering. The *Fusarium proliferatum* infection of the maize grain was higher in each growing season than that caused by *Fusarium subglutinans*, although both species were significantly increased due to the ECB damage to the maize ears. The ECB activity significantly increased the MON content 26-fold in 2008 from 43 to 1137 $\mu\text{g kg}^{-1}$, 25-fold in 2009 from <LOQ to 77 $\mu\text{g kg}^{-1}$ and 94-fold in 2010 from 6 to 564 $\mu\text{g kg}^{-1}$. The relationship between the MON content and the *Fusarium* species producers of MON was closer for *F. proliferatum* ($r = 0.96$, $P < 0.001$) than for *F. subglutinans* ($r = 0.83$, $P < 0.001$). An in vitro assay was carried on in order to assess the toxigenic capacity of different *F. proliferatum* and *F. subglutinans* strains isolated from a field experiment and artificially inoculated on a maize substrate. On average, the *F. proliferatum* isolated strains showed a significantly higher ($P < 0.001$) toxigenic capacity than the *F. subglutinans* strains. In conclusion, the combination of the high toxigenic capacity of *F. proliferatum*, and its more frequent occurrence and greater intensity in the field make it possible to state that the production of MON in maize temperate areas, such as North Italy, is mainly due to *F. proliferatum* infections and is closely linked to the injury caused by ECB larvae. (C) 2015 Elsevier B.V. All rights reserved.

Smith, J. L., Baute, T. S., & Mason, C. E. (2015). Pheromone races of *Ostrinia nubilalis* Hübner (Lepidoptera: Crambidae) infesting grain corn in Manitoba, Ontario, and Québec provinces of Canada. *The Journal of the Entomological Society of Ontario*, 146.

Ostrinia nubilalis (Hübner) (Lepidoptera: Crambidae), European corn borer, is an economic pest of *Zea mays* (Linnaeus) (Poaceae) and other vegetable crops that is distributed throughout the agricultural production regions of Ontario, Québec, and Manitoba in Canada. Two phenotypic races of *O. nubilalis* have been identified that differ in the proportion of isomers of 11-tetradecenyl acetate (11-14:OAc) in their sex pheromone. The Z-race (Z-11-14:OAc) is the predominant race in the United States of America, known to inhabit *Zea mays* as its primary host, whereas the E-race (E-11-14:OAc) infests a wider host range, including many vegetable crops, and is only found within the Eastern coastal states of the United States of America. Collections of *O. nubilalis* were made from grain corn in agricultural regions of Ontario, Québec, and Manitoba in 1997, 2008, 2009, and 2010, and females were analyzed for pheromone race using gas chromatography (GC). Only Z-race *O. nubilalis* were found in Ontario (from Essex to Leeds and Grenville Counties) and in Southern Manitoba. E-race individuals were detected in collections from Ottawa, Ontario and St. Anicet, Québec, with an increasing proportion of E-race phenotypes in samples from west to east. This is the first report of pheromone race determination using GC among Canadian *O. nubilalis* populations and the first documentation of E-race *O. nubilalis* in Canada using GC.

Swale, D. R., P. R. Carlier, J. A. Hartsel, M. Ma and J. R. Bloomquist (2015). "Mosquitocidal carbamates with low toxicity to agricultural pests: an advantageous property for insecticide resistance management." *Pest Management Science* 71(8): 1158-1164.

BACKGROUND Insecticide resistance in the malaria mosquito *Anopheles gambiae* is well documented, and widespread agricultural use of pyrethroids may exacerbate development of resistance when pyrethroids are used in vector control. We have developed carbamate anticholinesterases that possess a high degree of *An. gambiae*:human selectivity for enzyme inhibition. The purpose of this study was to assess the spectrum of activity of these carbamates against other

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mosquitoes and agricultural pests. RESULTSExperimental carbamates were potent inhibitors of mosquito acetylcholinesterases, with IC50 values in the nanomolar range. Similar potencies were observed for *Musca domestica* and *Drosophila melanogaster* enzymes. Although meta-substituted carbamates were potent inhibitors, two ortho-substituted carbamates displayed poor enzyme inhibition (IC50 10(-6)M) in honey bee (*Apis mellifera*), Asian citrus psyllid (*Diaphorina citri*) and lepidopteran agricultural pests (*Plutella xylostella* and *Ostrinia nubilalis*). Enzyme inhibition results were confirmed by toxicity studies in caterpillars, where the new carbamates were 2-3-fold less toxic than propoxur and up to tenfold less active than bendiocarb, indicating little utility of these compounds for crop protection. CONCLUSIONThe experimental carbamates were broadly active against mosquito species but not agricultural pests, which should mitigate selection for mosquito insecticide resistance by reducing agricultural uses of these compounds.

Tabashnik, B. E., Carrière, Y., Soberón, M., Gao, A., & Bravo, A. (2015). Successes and failures of transgenic Bt crops: global patterns of field-evolved resistance. Bt resistance: characterization and strategies for GM crops producing *Bacillus thuringiensis* toxins, 1-4.

Tiziani, S., Günther, U. L., & Grubor-Laj, G. Metabolomic Analysis of Diapausing and Non-diapausing Larvae of the European Corn Borer *Ostrinia nubilalis* (Hbn.)(Lepidoptera: Crambidae).

In this study, an H-NMR -based metabolomic approach was used to investigate the biochemical mechanisms of diapause and cold hardiness in diapausing larvae of the European corn borer *Ostrinia nubilalis*. Metabolomic patterns in polar hemolymph extracts from non-diapausing and diapausing larvae of *O. Nubilalis* were compared. Analysis indicated 13 metabolites: 7 amino acids, glycerol, acetate, citrate, succinate, lactate and putrescine. Results show that diapausing larvae display different metabolomic patterns compared to active non-diapausing larvae, with predominant metabolites identified as glycerol, proline and alanine. In specific diapausing larvae initially kept at 5 °C then gradually chilled to -3 °C and -16 °C, alanine, glycerol and acetate were predominant metabolites. H-NMR spectroscopy provides new insight into the metabolomic patterns associated with cold resistance and diapause in *O. Nubilalis* larvae, suggesting distinct metabolomes function in actively developing and diapausing larvae.

Tokarev, Y. S., Malysh, J. M., Kononchuk, A. G., Seliverstova, E. V., Frolov, A. N., & Issi, I. V. (2015). Redefinition of *Nosema pyrausta* (*Perezia pyraustae* Paillot 1927) basing upon ultrastructural and molecular phylogenetic studies. *Parasitology research*, 114(2), 759-761.

Populations of European corn borer (*Ostrinia nubilalis* Hübner) from Krasnodar Territory (Southwestern Russia) become regularly infected with *Nosema*-like microsporidia. To identify the parasite, it was subjected to electron microscopy and small subunit ribosomal RNA (SSU rRNA) gene sequencing. The spore ultrastructure of the parasite was highly similar to *Nosema bombycis* from China and *Nosema pyrausta* from the USA. The nucleotide sequence of SSU rRNA gene was identical to a microsporidium isolated from *O. nubilalis* in southern France (GenBank accession no. HM566196) and closely related to *Nosema bombycis* (no. AY209011, 99.7 % sequence similarity) from *Bombyx mori* of Chinese origin and *N. pyrausta* (no. AY958071) from *O. nubilalis* of North American origin. As the molecular haplotype of SSU rRNA is fixed for the parasite infecting *O. nubilalis* across Europe and *N. pyrausta* was initially described in France as *Perezia pyraustae* (Paillot CR Acad Sci Paris 185: 673-675, 1927), we conclude that the parasite examined under the present study correspond to the type isolate of *N. pyrausta*. The microsporidium from *O. nubilalis* in North America (no. AY958071) corresponds therefore to a closely related, yet distinct haplotype.

Vellichiramal, N. N., Wang, H., Eyun, S. I., Moriyama, E. N., Coates, B. S., Miller, N. J., & Siegfried, B. D. (2015). Transcriptional analysis of susceptible and resistant European corn borer strains and their response to Cry1F protoxin. *BMC genomics*, 16(1), 558.

Background: Despite a number of recent reports of insect resistance to transgenic crops expressing insecticidal toxins from *Bacillus thuringiensis* (Bt), little is known about the mechanism of resistance to these toxins. The purpose of this study is to identify genes associated with the mechanism of Cry1F toxin resistance in European corn borer (*Ostrinia nubilalis* Hübner). For this, we compared the global transcriptomic response of laboratory selected resistant and susceptible *O. nubilalis* strain to Cry1F toxin. We further identified constitutive transcriptional differences between the two strains. Results: An *O. nubilalis* midgut transcriptome of 36,125 transcripts was assembled de novo from 106 million Illumina HiSeq and Roche 454 reads and used as a reference for estimation of differential gene expression analysis.

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Evaluation of gene expression profiles of midgut tissues from the Cry1F susceptible and resistant strains after toxin exposure identified a suite of genes that responded to the toxin in the susceptible strain ($n = 1,654$), but almost 20-fold fewer in the resistant strain ($n = 84$). A total of 5,455 midgut transcripts showed significant constitutive expression differences between Cry1F susceptible and resistant strains. Transcripts coding for previously identified Cry toxin receptors, cadherin and alkaline phosphatase and proteases were also differentially expressed in the midgut of the susceptible and resistant strains. Conclusions: Our current study provides a valuable resource for further molecular characterization of Bt resistance and insect response to Cry1F toxin in *O. nubilalis* and other pest species.

Vukašinović, E. L., Pond, D. W., Worland, M. R., Kojić, D., Purać, J., Popović, Ž. D., & Grubor-Lajšić, G. (2015). Diapause induces remodeling of the fatty acid composition of membrane and storage lipids in overwintering larvae of *Ostrinia nubilalis*, Hubn. (Lepidoptera: Crambidae). *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, 184, 36-43.

Seasonal changes in the FA composition of triacylglycerols and phospholipids prepared from the whole bodies of non-diapausing and diapausing fifth instar larvae of *Ostrinia nubilalis*, Hubn. (Lepidoptera: Crambidae) were determined to evaluate the role of these lipids in diapause. Substantial changes in the FA composition of triacylglycerols and phospholipids were triggered by diapause development. This led to a significant increase in the overall FA unsaturation (UFAs/SFAs ratio), attributable to an increase in the relative proportion of MUFAs and the concomitant decrease in PUFAs and SFAs. In triacylglycerols, the significant changes in the FAs composition are the result of an increase in the relative proportions of MUFAs, palmitoleic acid (16:1n-7) and oleic acid (18:1n-9), and a concomitant reduction in the composition of SFAs and PUFAs, mainly palmitic acid (16:0) and linoleic acid (18:2n-6), respectively. Changes in the composition of phospholipids were more subtle with FAs contributing to the overall increase of FA unsaturation. Differential scanning calorimetry (DSC) analysis revealed that the melt transition temperatures of total lipids prepared from whole larvae, primarily attributable to the triacylglycerol component, were significantly lower during the time course of diapause compared with non-diapause. These observations were correlated to the FA composition of triacylglycerols, most likely enabling them to remain functional during colder winter conditions. We conclude that *O. nubilalis* undergoes remodeling of FA profiles of both energy storage triacylglycerols and membrane phospholipids as an element of its overwintering physiology which may improve the ability to cold harden during diapause.

Wadsworth, C. B., & Dopman, E. B. (2015). Transcriptome profiling reveals mechanisms for the evolution of insect seasonality. *Journal of Experimental Biology*, 218(22), 3611-3622.

Rapid evolutionary change in seasonal timing can facilitate ecological speciation and resilience to climate warming. However, the molecular mechanisms behind shifts in animal seasonality are still unclear. Evolved differences in seasonality occur in the European corn borer moth (*Ostrinia nubilalis*), in which early summer emergence in E-strain adults and later summer emergence in Z-strain adults is explained by a shift in the length of the termination phase of larval diapause. Here, we sample from the developmental time course of diapause in both strains and use transcriptome sequencing to profile regulatory and amino acid changes associated with timing divergence. Within a previously defined quantitative trait locus (QTL), we nominate 48 candidate genes, including several in the insulin signaling and circadian rhythm pathways. Genome-wide transcriptional activity is negligible during the extended Z-strain termination, whereas shorter E-strain termination is characterized by a rapid burst of regulatory changes involved in resumption of the cell cycle, hormone production and stress response. Although gene expression during diapause termination in *Ostrinia* is similar to that found previously in flies, nominated genes for shifts in timing are species specific. Hence, across distant relatives the evolution of insect seasonality appears to involve unique genetic switches that direct organisms into distinct phases of the diapause pathway through wholesale restructuring of conserved gene regulatory networks.

Wadsworth, C. B., Li, X., & Dopman, E. B. (2015). A recombination suppressor contributes to ecological speciation in *OSTRINIA* moths. *Heredity*, 114(6), 593-600.

Despite unparalleled access to species' genomes in our post-genomic age, we often lack adequate biological explanations for a major hallmark of the speciation process—genetic divergence. In the presence of gene flow, chromosomal rearrangements such as inversions are thought to promote divergence and facilitate speciation by suppressing recombination. Using a combination of genetic crosses, phenotyping of a trait underlying ecological

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isolation, and population genetic analysis of wild populations, we set out to determine whether evidence supports a role for recombination suppressors during speciation between the Z and E strains of European corn borer moth (*Ostrinia nubilalis*). Our results are consistent with the presence of an inversion that has contributed to accumulation of ecologically adaptive alleles and genetic differentiation across roughly 20% of the *Ostrinia* sex chromosome (~4 Mb). Patterns in *Ostrinia* suggest that chromosomal divergence may involve two separate phases—one driving its transient origin through local adaptation and one determining its stable persistence through differential introgression. As the evolutionary rate of rearrangements in lepidopteran genomes appears to be one of the fastest among eukaryotes, structural mutations may have had a disproportionate role during adaptive divergence and speciation in *Ostrinia* and in other moths and butterflies.

Walker, H. L., & Mason, C. E. A method for nondestructive sampling of European corn borer, *Ostrinia nubilalis* (Hübner), for determination of pheromone race.

The European corn borer (ECB), *Ostrinia nubilalis* (Hübner), is considered a major economic pest of corn in the United States and Canada. Introduced from Europe in the early 1900's, it has a wide documented host plant range. There are currently two recognized pheromone races of ECB (the E and Z races), which produce different ratios of the E- and Z-isomers of 11-tetradecenyl acetate in their pheromone blend. Hybrids do occur in areas of sympatry (Coates et al. 2013). The pheromone races also exhibit variation in important life-history traits, such as emergence behavior and host-plant selection (Mason et al. 1996), which may have important effects on their overall fitness. Previously, methods to type ECB pheromone race required destructive sampling techniques by either removing the pheromone gland from adult females or by removing the thoracic region of adult moths. The goal here is to develop a non-destructive method of pheromone typing to establish pure pheromone race families for future fitness studies.

Zhang, Y., G. Yu, L. Han and T. Guo (2015). "Identification of Four Moth Larvae Based on Near-Infrared Spectroscopy Technology." *Spectroscopy Letters* 48(1): 1-6.

Identification of larvae is of great importance in the field of biosafety. Near-infrared spectroscopy (NIRS) was applied in the identification of larvae, and 200 larvae samples of *Heliocoverpa armigera* Hubner (cotton bollworm), *Spodoptera exigua* Hübner (beet armyworm), *Prodenia litura* Fabricius, and *Ostrinia nubilalis* Hubner (corn borer) were selected, from which the spectra of the 4000-7000 cm⁻¹ waveband were obtained for analysis. The results showed that the identification accuracy of the prediction larvae sets predicted by the model of PLS-DA (partial least squares-discriminant analysis) was 100%; the correlation coefficient between the NIR-predicted category variable value and the true value was above 0.90; and the identification accuracy of the prediction larvae sets predicted by the Mahalanobis distance method and correlation coefficient method was above 90%. NIRS provides a promising approach for early category identification of pests in agriculture and forestry.

Zhang, Y. F., G. Y. Yu, L. Han and T. T. Guo (2015). "Identification of Four Moth Larvae Based on Near-Infrared Spectroscopy Technology." *Spectroscopy Letters* 48(1): 1-6.

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Zhao, C., Jurat-Fuentes, J. L., Abdelgaffar, H. M., Pan, H., Song, F., & Zhang, J. (2015). Identification of a new cry1I-type gene as a candidate for gene Pyramiding in corn to control *Ostrinia* species larvae. *Applied and environmental microbiology*, 81(11), 3699-3705.

Pyramiding of diverse cry toxin genes from *Bacillus thuringiensis* with different modes of action is a desirable strategy to delay the evolution of resistance in the European corn borer (*Ostrinia nubilalis*). Considering the dependency of

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susceptibility to Cry toxins on toxin binding to receptors in the midgut of target pests, a diverse mode of action is commonly defined as recognition of unique binding sites in the target insect. In this study, we present a novel cry1Ie toxin gene (cry1Ie2) as a candidate for pyramiding with Cry1Ab or Cry1Fa in corn to control *Ostrinia* species larvae. The new toxin gene encodes an 81-kDa protein that is processed to a protease-resistant core form of approximately 55 kDa by trypsin digestion. The purified protoxin displayed high toxicity to *Ostrinia furnacalis* and *O. nubilalis* larvae but low to no activity against *Spodoptera* or heliothine species or the coleopteran *Tenebrio molitor*. Results of binding assays with ¹²⁵I-labeled Cry1Ab toxin and brush border membrane vesicles from *O. nubilalis* larvae demonstrated that Cry1Ie2 does not recognize the Cry1Ab binding sites in that insect. Reciprocal competition binding assays with biotin-labeled Cry1Ie2 confirmed the lack of shared sites with Cry1Ab or Cry1Fa in *O. nubilalis* brush border membrane vesicles. These data support Cry1Ie2 as a good candidate for pyramiding with Cry1Ab or Cry1Fa in corn to increase the control of *O. nubilalis* and reduce the risk of resistance evolution.

Articles parus en 2014

Al-Wathiqi, N., S. M. Lewis and E. B. Dopman (2014). "Using RNA sequencing to characterize female reproductive genes between Z and E Strains of European Corn Borer moth (*Ostrinia nubilalis*)." *Bmc Genomics* 15.

Background: Reproductive proteins often evolve rapidly and are thought to be subject to strong sexual selection, and thus may play a key role in reproductive isolation and species divergence. However, our knowledge of reproductive proteins has been largely limited to males and model organisms with sequenced genomes. With advances in sequencing technology, Lepidoptera are emerging models for studies of sexual selection and speciation. By profiling the transcriptomes of the bursa copulatrix and bursal gland from females of two incipient species of moth, we characterize reproductive genes expressed in the primary reproductive tissues of female Lepidoptera and identify candidate genes contributing to a one-way gametic incompatibility between Z and E strains of the European corn borer (*Ostrinia nubilalis*). Results: Using RNA sequencing we identified transcripts from similar to 37,000 and similar to 36,000 loci that were expressed in the bursa copulatrix or the bursal gland respectively. Of bursa copulatrix genes, 8% were significantly differentially expressed compared to the female thorax, and those that were up-regulated or specific to the bursa copulatrix showed functional biases toward muscle activity and/or organization. In the bursal gland, 9% of genes were differentially expressed compared to the thorax, with many showing reproduction or gamete production functions. Of up-regulated bursal gland genes, 46% contained a transmembrane region and 16% possessed secretion signal peptides. Divergently expressed genes in the bursa copulatrix were exclusively biased toward protease-like functions and 51 proteases or protease inhibitors were divergently expressed overall. Conclusions: This is the first comprehensive characterization of female reproductive genes in any lepidopteran system. The transcriptome of the bursa copulatrix supports its role as a muscular sac that is the primary site for disruption of the male ejaculate. We find that the bursal gland acts as a reproductive secretory body that might also interact with male ejaculate. In addition, differential expression of proteases between strains supports a potential role for these tissues in contributing to reproductive isolation. Our study provides new insight into how male ejaculate is processed by female Lepidoptera, and paves the way for future work on interactions between post-mating sexual selection and speciation.

Binning, R. R., J. Coats, X. X. Kong and R. L. Hellmich (2014). "Susceptibility and Aversion of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) to Cry1F Bt Maize and Considerations for Insect Resistance Management." *Journal of Economic Entomology* 107(1): 368-374.

Bacillus thuringiensis (Bt) maize was developed primarily for North American pests such as European corn borer (*Ostrinia nubilalis* (Hubner)). However, most Bt maize products are also cultivated outside of North America, where the primary pests may be different and may have lower susceptibility to Bt toxins. Fall armyworm (*Spodoptera frugiperda* JE Smith) is an important pest and primary target of Bt maize in Central and South America. *S. frugiperda* susceptibility to Cry1F (expressed in event TC1507) is an example of a pest-by-toxin interaction that does not meet the high-dose definition. In this study, the behavioral and toxic response of *S. frugiperda* to Cry1F maize was investigated by measuring the percentage of time naive third instars spent feeding during a 3-min exposure. *S. frugiperda* also were

exposed as third instars to Cry1F maize for 14 d to measure weight gain and survival. *S. frugiperda* demonstrated an initial, postingestive aversive response to Cry1F maize, and few larvae survived the 14 d exposure. The role of susceptibility and avoidance are discussed in the context of global IRM refuge strategy development for Bt products.

Bohnenblust, E. W., J. A. Breining, J. A. Shaffer, S. J. Fleischer, G. W. Roth and J. F. Tooker (2014). "Current European corn borer, *Ostrinia nubilalis*, injury levels in the northeastern United States and the value of Bt field corn." *Pest Management Science* 70(11): 1711-1719.

BACKGROUND: Recent evidence indicates that some populations of European corn borer (ECB), *Ostrinia nubilalis* (Hubner), have declined to historic lows owing to widespread adoption of Bt corn hybrids. To understand current ECB populations in Pennsylvania field corn, the authors assessed larval damage in Bt and non-Bt corn hybrids at 29 sites over 3 years. The influence of Bt adoption rates, land cover types and moth activity on levels of ECB damage was also considered. **RESULTS:** Bt hybrids reduced ECB damage when compared with non-Bt, but these differences inconsistently translated to higher yields and, because of higher seed costs, rarely improved profits. No relationships were detected between land use or Bt adoption and ECB damage rates, but positive relationships were found between plant damage and captures of Z-race ECB moths in pheromone traps in the PestWatch network. **CONCLUSIONS:** ECB damage levels were generally low and appear to be declining across Pennsylvania. In many locations, farmers may gain greater profits by planting competitive non-Bt hybrids; however, Bt hybrids remain valuable control options, particularly in the parts of Pennsylvania where ECB populations persist. Moth captures from PestWatch appear to provide insight into where Bt hybrids are most valuable. (C) 2013 Society of Chemical Industry

Bourguet, D., S. Ponsard, R. Streiff, S. Meusnier, P. Audiot, J. Li and Z. Y. Wang (2014). "'Becoming a species by becoming a pest' or how two maize pests of the genus *Ostrinia* possibly evolved through parallel ecological speciation events." *Molecular Ecology* 23(2): 325-342.

New agricultural pest species attacking introduced crops may evolve from pre-existing local herbivores by ecological speciation, thereby becoming a species by becoming a pest. We compare the evolutionary pathways by which two maize pests (the Asian and the European corn borers, ACB and ECB) in the genus *Ostrinia* (Lepidoptera, Crambidae) probably diverged from an ancestral species close to the current Adzuki bean borer (ABB). We typed larval *Ostrinia* populations collected on maize and dicotyledons across China and eastern Siberia, at microsatellite and mitochondrial loci. We found only two clusters: one on maize (as expected) and a single one on dicotyledons despite differences in male mid-tibia morphology, suggesting that all individuals from dicotyledons belonged to the ABB. We found evidence for migrants and hybrids on both host plant types. Hybrids suggest that field reproductive isolation is incomplete between ACB and ABB. Interestingly, a few individuals with an ABB-like microsatellite profile collected on dicotyledons had ACB mtDNA rather than ABB-like mtDNA, whereas the reverse was never found on maize. This suggests asymmetrical gene flow directed from the ACB towards the ABB. Hybrids and backcrosses in all directions were obtained in no-choice tests. In laboratory conditions, they survived as well as parental strain individuals. In Xinjiang, we found ACB and ECB in sympatry, but no hybrids. Altogether, our results suggest that reproductive isolation between ACB and ABB is incomplete and mostly prezygotic. This points to ecological speciation as a possible evolutionary scenario, as previously found for ECB and ABB in Europe.

Bowers, E., R. Hellmich and G. Munkvold (2014). "Comparison of Fumonisin Contamination Using HPLC and ELISA Methods in Bt and Near-Isogenic Maize Hybrids Infested with European Corn Borer or Western Bean Cutworm." *Journal of Agricultural and Food Chemistry* 62(27): 6463-6472.

Field trials were conducted from 2007 to 2010 to compare grain fumonisin levels among non-Bt maize hybrids and Bt hybrids with transgenic protection against manual infestations of European corn borer (ECB) and Western bean cutworm (WBC). HPLC and ELISA were used to measure fumonisin levels. Results of the methods were highly correlated, but ELISA estimates were higher. Bt hybrids experienced less insect injury, Fusarium ear rot, and fumonisin contamination compared to non-Bt hybrids. WBC infestation increased fumonisin content compared to natural infestation in non-Bt and hybrids expressing Cry1Ab protein in five of eight possible comparisons; in Cry1F hybrids, WBC did not impact fumonisins. These results indicate that WBC is capable of increasing fumonisin levels in maize. Under WBC infestation, Cry1F mitigated this risk more consistently than Cry1Ab or non-Bt hybrids. Transgenically

expressed Bt proteins active against multiple lepidopteran pests can provide broad, consistent reductions in the risk of fumonisin contamination.

Campan, E. D. M., S. Havard, A. Sagouis, C. Pelissier, F. J. Muller, C. Villemant, Y. Savriama, D. Guery, J. Hu and S. Ponsard (2014). "Acceptability and suitability of the European *Ostrinia nubilalis* Hubner for *Macrocentrus cingulum* Brischke from Asia and Europe." *Biological Control* 74: 13-20.

We examined whether *Macrocentrus cingulum* (Hymenoptera: Braconidae) of Asian origin could serve as a biological control agent of the maize pest *Ostrinia nubilalis* (Lepidoptera: Crambidae) in Europe. *M. cingulum* is already present in Europe, where it does not parasitize *O. nubilalis* but *Ostrinia scapularis*, a related species feeding on wild dicotyledons. In contrast, *M. cingulum* have been imported from Europe and Asia into North America (where *O. nubilalis* had been accidentally introduced from Europe), and does parasitize *O. nubilalis* there. We conducted laboratory infestations to assess host acceptability (parasitoid's propensity to oviposit) and suitability (parasitoid's ability to develop) of European *O. nubilalis* for *M. cingulum* of European and Asian origin, and of *Ostrinia furnacalis* (their original host) for Asian *M. cingulum*. Asian *M. cingulum* parasitized European *O. nubilalis* as readily as *O. furnacalis*, and developed equally well in terms of: % female cocoons, time to first emergence from the cocoon, total number of adult offspring, % female offspring and adult longevity. Adult female parasitoids were significantly larger when emerging from *O. nubilalis*, mixed-sex and male cocoons were significantly more and less frequent, respectively. The acceptability of *O. nubilalis* was significantly lower for European than for Asian *M. cingulum*, and its suitability was zero. Asian *M. cingulum* appears a potential candidate for introduction as a biological control agent of a major maize pest, European *O. nubilalis*, provided environmental impact studies, economic analyses, and foreseeable interactions with other biological control agents such as the egg parasitoid *Trichogramma brassicae* (Hymenoptera: Trichogrammatidae) are satisfying. (C) 2014 Elsevier Inc. All rights reserved.

Crava, C. M., Y. Bel, J. Ferre and B. Escriche (2014). "Susceptibility to Cry proteins of a Spanish *Ostrinia nubilalis* glasshouse population repeatedly sprayed with *Bacillus thuringiensis* formulations." *Journal of Applied Entomology* 138(1-2): 78-86.

Ostrinia nubilalis Hubner (Lepidoptera: Crambidae), a major pest of corn in temperate climates, can feed on other crops due to its polyphagous behaviour. In particular, this species became a serious problem in some sweet pepper commercial glasshouses in south-eastern Spain repeatedly sprayed with *Bacillus thuringiensis* (Bt) products to control *Spodoptera exigua* Hubner (Lepidoptera: Noctuidae). The susceptibility of an *O. nubilalis* colony established from individuals collected in these Bt-sprayed glasshouses was compared with a reference laboratory colony. Differences in susceptibility between the two colonies to Cry1Aa, Cry1Ab, Cry1Ac and Cry2Aa proteins were found. However, our results indicate that the *O. nubilalis* control failure in the glasshouse was not due to selection for resistance. Intraspecific variation probably accounts for differences between the glasshouse-derived population and the laboratory strain. This conclusion is based on several lines of evidence: the glasshouse-derived population retained its susceptibility to a Bt standard product and to most of its individual components (both in the form of protoxins and in the form of activated toxins), and it did not respond to laboratory selection with high doses of Cry1Ab.

de Escudero, I. R., N. Banyuls, Y. Bel, M. Maeztu, B. Escriche, D. Munoz, P. Caballero and J. Ferre (2014). "A screening of five *Bacillus thuringiensis* Vip3A proteins for their activity against lepidopteran pests." *Journal of Invertebrate Pathology* 117: 51-55.

Five *Bacillus thuringiensis* Vip3A proteins (Vip3Aa, Vip3Ab, Vip3Ad, Vip3Ae and Vip3Af) and their corresponding trypsin-activated toxins were tested for their toxicity against eight lepidopteran pests: *Agrotis ipsilon*, *Helicoverpa armigera*, *Mamestra brassicae*, *Spodoptera exigua*, *Spodoptera frugiperda*, *Spodoptera littoralis*, *Ostrinia nubilalis* and *Lobesia botrana*. Toxicity was first tested at a high dose at 7 and 10 days. No major differences were found when comparing protoxins vs. trypsin-activated toxins. The proteins that were active against most of the insect species were Vip3Aa, Vip3Ae and Vip3Af, followed by Vip3Ab. Vip3Ad was non-toxic to any of the species tested. Considering the results by insect species, *A. ipsilon*, *S. frugiperda* and *S. littoralis* were susceptible to Vip3Aa, Vip3Ab, Vip3Ae and Vip3Af; *S. exigua* was susceptible to Vip3Aa and Vip3Ae, and moderately susceptible to Vip3Ab; *M. brassicae* and *L. botrana* were susceptible to Vip3Aa, Vip3Ae and Vip3Af; *H. armigera* was moderately susceptible to Vip3Aa, Vip3Ae and Vip3Af, and *O. nubilalis* was tolerant to all Vip3 proteins tested, although it showed some susceptibility to Vip3Af. The results obtained will help to design new combinations of insecticidal protein genes in transgenic crops or in recombinant bacteria for the control of insect pests. (C) 2014 Elsevier Inc. All rights reserved.

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Havard, S., C. Pelissier, S. Ponsard and E. D. M. Campan (2014). "Suitability of three *Ostrinia* species as hosts for *Macrocentrus cingulum*: A comparison of their encapsulation abilities." *Insect Science* 21(1): 93-102.

Two cornborer species, *Ostrinia furnacalis* (Lepidoptera: Crambidae) and *O. nubilalis*, are major corn pests in Asia and Europe, respectively. In both continents, the larval endoparasitoid *Macrocentrus cingulum* (Hymenoptera: Braconidae) develops on another, closely related stemborer, *O. scapularis*, which feeds on mugwort and other dicotyledons. *M. cingulum* also emerges from *O. furnacalis* in Asia and *O. nubilalis* in North America, but not from *O. nubilalis* in Europe. We assessed the ability of three populations of each of the three *Ostrinia* species to encapsulate foreign bodies of a size similar to that of a *M. cingulum* egg. We conclude that variations in encapsulation ability alone cannot account for the differences observed in the field between parasite emergence rates in these different host species and geographic areas.

Hernandez-Martinez, P., C. Sara Hernandez-Rodriguez, J. Van Rie, B. Escriche and J. Ferre (2014). "Different binding sites for *Bacillus thuringiensis* Cry1Ba and Cry9Ca proteins in the European corn borer, *Ostrinia nubilalis* (Hubner)." *Journal of Invertebrate Pathology* 120: 1-3.

Binding studies using I-125-Cry9Ca and biotinylated-Cry1Ba proteins showed the occurrence of independent binding sites for these proteins in *Ostrinia nubilalis*. Our results, along with previously available binding data, indicate that combinations of Cry1A or Cry1Fa proteins with Cry1Ba and/or Cry9Ca could be a good strategy for the resistance management of *O. nubilalis*. (C) 2014 Elsevier Inc. All rights reserved.

Leppik, E. and B. Frerot (2014). "Maize field odorscape during the oviposition flight of the European corn borer." *Chemoecology* 24(6): 221-228.

Most crop pests find a suitable host through chemical cues released from plants, but little is known about the odorscape encountered by host-seeking gravid females under natural, outdoor conditions. In this field study, the volatile organic compound (VOC) composition of maize (*Zea mays*, L.), a host for the European corn borer (ECB) (*Ostrinia nubilalis* Hub.) was characterized during the oviposition flight and compared with a forest odorscape. VOCs from maize fields and the forest atmosphere were collected by solid phase microextraction and characterized by gas chromatography-mass spectrometry. The electroantennographic (EAG) response of female ECB antennae to candidate VOCs was tested. Analyses revealed clear differences between the maize field and the forest odorscapes, mainly composed of ubiquitous VOCs but in specific ratios. The maize field odorscape is more complex than the forest odorscape for maize found 18 VOCs but only eight in the forest. Both biotopes shared seven VOCs-green leaf volatiles (GLV), monoterpenes (MT) and homoterpenes. In addition, we found in the forest a distinctive sesquiterpene (SQT) identified as isodene. The highest EAG responses were elicited by two GLVs and a MT shared by the two biotopes. SQT elicited weak EAG responses, except beta-farnesene, only found in the maize field odorscape. Our results suggest that the two biotopes produce specific chemical signatures that insects may use as host cues. To the best of our knowledge this paper is the first report on the maize odorscapes under field conditions. The putative role of the VOCs in host plant detection and selection is discussed.

Li, F. Y., Q. J. Mo, W. G. Duan, G. S. Lin, B. Cen, N. Y. Chen and Z. Q. Yang (2014). "Synthesis and insecticidal activities of N-(5-dehydroabietyl-1,3,4-thiadiazol-2-yl)-benzenesulfonamides." *Medicinal Chemistry Research* 23(10): 4420-4426.

In an attempt to search for natural product-based insecticidal agents, a series of novel dehydroabietic acid derivatives bearing 1,3,4-thiadiazole moiety were designed and synthesized. Their structures were characterized by IR, MS, H-1-NMR, C-13-NMR, and elemental analysis. The insecticidal activities against cotton bollworm (*Helicoverpa armigera*), corn borer (*Ostrinia nubilalis* Hubner), and diamondback moth (*Plutella xylostella* (L.)) were evaluated. The bioassay test showed that some of the target compounds exhibited excellent insecticidal activities at the concentration of 200 µg/ml; compound 3a had the best mortality rate of 90.0 and 80.0 % against *H. armigera* and *O. nubilalis* Hubner, respectively.

Maag, D., C. Dalvit, D. Thevenet, A. Kohler, F. C. Wouters, D. G. Vassao, J. Gershenzon, J. L. Wolfender, T. C. J. Turlings, M. Erb and G. Glauser (2014). "3-beta-D-Glucopyranosyl-6-methoxy-2-benzoxazolinone (MBOA-N-Glc) is an insect detoxification product of maize 1,4-benzoxazin-3-ones." *Phytochemistry* 102: 97-105.

Cette veille bibliographique est réalisée par Nathalie Roullé et Nicolas Chatel-Launay, Pôle d'excellence en lutte intégrée (PELI).

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In order to defend themselves against arthropod herbivores, maize plants produce 1,4-benzoxazin-3-ones (BXs), which are stored as weakly active glucosides in the vacuole. Upon tissue disruption, BXs come into contact with beta-glucosidases, resulting in the release of active aglycones and their breakdown products. While some aglycones can be reglucosylated by specialist herbivores, little is known about how they detoxify BX breakdown products. Here we report on the structure of an N-glucoside, 3-beta-D-glucopyranosyl-6-methoxy-2-benzoxazolinone (MBOA-N-Glc), purified from *Spodoptera frugiperda* faeces. In vitro assays showed that MBOA-N-Glc is formed enzymatically in the insect gut using the BX breakdown product 6-methoxy-2-benzoxazolinone (MBOA) as precursor. While *Spodoptera littoralis* and *S. frugiperda* caterpillars readily glucosylated MBOA, larvae of the European corn borer *Ostrinia nubilalis* were hardly able to process the molecule. Accordingly, *Spodoptera* caterpillar growth was unaffected by the presence of MBOA, while *O. nubilalis* growth was reduced. We conclude that glucosylation of MBOA is an important detoxification mechanism that helps insects tolerate maize BXs. (C) 2014 Elsevier Ltd. All rights reserved.

Maiorano, A. and M. Donatelli (2014). "Validation of an insect pest phenological model for the European corn borer (*Ostrinia nubilalis* Hbn) in the Po Valley in Italy." *Italian Journal of Agrometeorology-Rivista Italiana Di Agrometeorologia* 19(2): 43-50.

The European corn borer (ECB) *Ostrinia nubilalis* Hb. is one of the most important insect pests of maize. The chemical treatment by means of self-powered spraying machines is the main strategy adopted in Northern Italy to control the pest. The success of the treatment mostly depends on the timing of its application. Phenological models can be successfully used for identifying the right application period for the treatments. The main objectives of this work were the validation of an existing ECB phenological model and evaluating its possible future use as a management tool in Northern Italy. Model accuracy was tested against data collected from traps placed in 26 collaborating maize farm fields in Northern Italy from 2010 to 2012. The ECB adult flight activity was monitored and the model was tested for its accuracy in simulating the occurrence of the first generation adult flight peak. The model resulted accurate in the explored conditions, unbiased (negligible tendency to overestimation), and it was able to explain 76% of variation. The model was able to predict the occurrence of the adult peak with an error of +/- 4.3 days (Root Mean Square Error). The observed level of error can be considered acceptable for effective chemical treatments.

Meissle{Ahmed, A., 2013 #16;Bell, 2012 #20;Binning, 2014 #9;Bohnenblust, 2013 #14;Bourguet, 2014 #12;Burkness, 2011 #24;Chapman, 2009 #36;de Escudero, 2014 #8;Fujii, 2011 #29;Gardner, 2012 #21;Gardner, 2013 #19;Gomez, 2013 #15;Havard, 2014 #11;Huang, 2011 #28;Huffaker, 2011 #26;Kocmankova, 2011 #30;Li, 2014 #3;Maag, 2014 #4;Meissle, 2010 #33;Meissle, 2011 #25;Novacek, 2014 #13;Ordas, 2013 #18;O'Rourke, 2011 #22;O'Rourke, 2011 #27;Palma, 2014 #5;Priestley, 2009 #37;Rule, 2014 #10;Selwet, 2011 #31;Song, 2014 #2;Suverkropp, 2009 #35;Suverkropp, 2010 #32;Svobodova, 2014 #6;Svobodova, 2014 #7;Tabashnik, 2011 #23;Wraight, 2010 #34;Zhang, 2015 #1}Yao, J. X., L. L. Buschman, N. Y. Lu, C. Khajuria and K. Y. Zhu (2014). "Changes in Gene Expression in the Larval Gut of *Ostrinia nubilalis* in Response to *Bacillus thuringiensis* Cry1Ab Protoxin Ingestion." *Toxins* 6(4): 1274-1294.

We developed a microarray based on 2895 unique transcripts assembled from 15,000 cDNA sequences from the European corn borer (*Ostrinia nubilalis*) larval gut. This microarray was used to monitor gene expression in early third-instar larvae of *Bacillus thuringiensis* (Bt)-susceptible *O. nubilalis* after 6 h feeding on diet, with or without the Bt Cry1Ab protoxin. We identified 174 transcripts, for which the expression was changed more than two-fold in the gut of the larvae fed Cry1Ab protoxin ($p < 0.05$), representing 80 down-regulated and 94 up-regulated transcripts. Among 174 differentially expressed transcripts, 13 transcripts putatively encode proteins that are potentially involved in Bt toxicity, and these transcripts include eight serine proteases, three aminopeptidases, one alkaline phosphatase, and one cadherin. The expressions of trypsin-like protease and three aminopeptidase transcripts were variable, but two potential Bt-binding proteins, alkaline phosphatase and cadherin were consistently up-regulated in larvae fed Cry1Ab protoxin. The significantly up and down-regulated transcripts may be involved in Cry1Ab toxicity by activation, degradation, toxin binding, and other related cellular responses. This study is a preliminary survey of Cry1Ab protoxin-induced transcriptional responses in *O. nubilalis* gut and our results are expected to help with further studies on Bt toxin-insect interactions at the molecular level.

Murrell, E. G. and E. M. Cullen (2014). "Conventional and Organic Soil Fertility Management Practices Affect Corn Plant Nutrition and *Ostrinia nubilalis* (Lepidoptera: Crambidae) Larval Performance." *Environmental Entomology* 43(5): 1264-1274.

Cette veille bibliographique est réalisée par Nathalie Roullé et Nicolas Chatel-Launay, Pôle d'excellence en lutte intégrée (PELI).

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Few studies compare how different soil fertilization practices affect plant mineral content and insect performance in organic systems. This study examined: 1) The European corn borer, *Ostrinia nubilalis* (Hubner), larval response on corn (*Zea mays* L.) grown in field soils with different soil management histories; and 2) resilience of these plants to *O. nubilalis* herbivory. Treatments included: 1) standard organic-organically managed soil fertilized with dairy manure and 2 yr of alfalfa (*Medicago sativa* L.) in the rotation; 2) basic cation saturation ratio-organically managed soil fertilized with dairy manure and alfalfa nitrogen credits, plus addition of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) according to the soil balance hypothesis; and 3) conventional-conventionally managed soil fertilized with synthetic fertilizers. Corn plants were reared to maturity in a greenhouse, and then infested with 0-40 *O. nubilalis* larvae for 17 d. *O. nubilalis* exhibited negative competitive response to increasing larval densities. Mean development time was significantly faster for larvae consuming basic cation saturation ratio plants than those on standard organic plants, with intermediate development time on conventional plants. Neither total yield (number of kernels) nor proportion kernels damaged differed among soil fertility treatments. Soil nutrients differed significantly in S and in Ca:Mg and Ca:K ratios, but principal components analysis of plant tissue samples taken before *O. nubilalis* infestation showed that S, Fe, and Cu contributed most to differences in plant nutrient profiles among soil fertility treatments. Results demonstrate that different fertilization regimens can significantly affect insect performance within the context of organic systems, but the effects in this study were relatively minor compared with effects of intraspecific competition.

Novacek, M. J., S. C. Mason, T. D. Galusha and M. Yaseen (2014). "Bt transgenes minimally influence maize grain yield and lodging across plant populations." *Maydica* 59(1-4): 91-96.

Adoption of maize (*Zea mays* L) hybrids containing Bt (*Bacillus thuringiensis*) transgenes and increased plant population is widespread but little scientific research exists on their interactions with production environments in the Western Maize Belt of the United States. Two pairs of near-isogenic Bt and non-Bt maize hybrids were grown under rainfed and irrigated conditions from 2008 to 2010 at target populations from 49,300 to 111,100 plants ha⁻¹ near Mead, NE. The objective was to determine the influence of the presence/absence of Bt transgenes for European corn borer [*Ostrinia nubilalis* (Hubner) - ECB1 and corn rootworm *Piabrotica* spp. - CRWI on maize yield and lodging across a range of target populations. Bt maize hybrids produced 0.6 Mg ha⁻¹ more grain, 0.2 more ears m⁻², and 1.3 g heavier 100-kernel weight than non-Bt hybrids in absence of visible ECB and CRW rootworm pressure. Yield of Bt and non-Bt hybrids responded similarly to increasing target population, with Deka lb DKC 58-16 and 58-19 increasing from 11.0 to 13.1 Mg ha⁻¹ and Dekalb DKC 61-69 and 61-72 from 11.8 to 12.7 Mg ha⁻¹ as the target population increased from 49,300 to 111,100 plants ha⁻¹. Lodging increased linearly with increasing target population, with a greater increase in rainfed than irrigated environments. Lodging of Bt and non-Bt maize hybrids was inconsistent. Grain yield, seed and insecticide cost, likelihood of ECB and CRW infestation, and environmental concerns related to soil insecticide use should be the drivers when determining if Bt maize hybrid use is justified. If CRW resistance occurs, planting non-Bt maize hybrids along with application of soil insecticide is a viable alternative.

Palma, L., D. Munoz, C. Berry, J. Murillo and P. Caballero (2014). "Draft Genome Sequences of Two *Bacillus thuringiensis* Strains and Characterization of a Putative 41.9-kDa Insecticidal Toxin." *Toxins* 6(5): 1490-1504.

In this work, we report the genome sequencing of two *Bacillus thuringiensis* strains using Illumina next-generation sequencing technology (NGS). Strain Hu4-2, toxic to many lepidopteran pest species and to some mosquitoes, encoded genes for two insecticidal crystal (Cry) proteins, cry1Ia and cry9Ea, and a vegetative insecticidal protein (Vip) gene, vip3Ca2. Strain Leapi01 contained genes coding for seven Cry proteins (cry1Aa, cry1Ca, cry1Da, cry2Ab, cry9Ea and two cry1Ia gene variants) and a vip3 gene (vip3Aa10). A putative novel insecticidal protein gene 1143 bp long was found in both strains, whose sequences exhibited 100% nucleotide identity. The predicted protein showed 57 and 100% pairwise identity to protein sequence 72 from a patented Bt strain (US8318900) and to a putative 41.9-kDa insecticidal toxin from *Bacillus cereus*, respectively. The 41.9-kDa protein, containing a C-terminal 6x HisTag fusion, was expressed in *Escherichia coli* and tested for the first time against four lepidopteran species (*Mamestra brassicae*, *Ostrinia nubilalis*, *Spodoptera frugiperda* and *S. littoralis*) and the green-peach aphid *Myzus persicae* at doses as high as 4.8 µg/cm² and 1.5 mg/mL, respectively. At these protein concentrations, the recombinant 41.9-kDa protein caused no mortality or symptoms of impaired growth against any of the insects tested, suggesting that these species are outside the protein's target range or that the protein may not, in fact, be toxic. While the use of the polymerase chain reaction has allowed a

significant increase in the number of Bt insecticidal genes characterized to date, novel NGS technologies promise a much faster, cheaper and efficient screening of Bt pesticidal proteins.

Petzold-Maxwell, J. L., B. D. Siegfried, R. L. Hellmich, C. A. Abel, B. S. Coates, T. A. Spencer and A. J. Gassmann (2014). "Effect of Maize Lines on Larval Fitness Costs of Cry1F Resistance in the European Corn Borer (Lepidoptera: Crambidae)." *Journal of Economic Entomology* 107(2): 764-772.

Crops producing insecticidal toxins from the bacterium *Bacillus thuringiensis* (Bt) are widely planted and enable management of key insect pests while reducing the use of conventional insecticides. However, the evolution of Bt resistance could diminish these benefits. Fitness costs of Bt resistance occur in the absence of Bt toxin when individuals with resistance alleles show a reduction in fitness relative to susceptible individuals, and they can delay the evolution of resistance. Ecological factors including host-plant variety can affect the magnitude of fitness costs, and consequently, the degree to which fitness costs delay resistance. In this study, we measured fitness costs of resistance to Bt toxin Cry1F in the European corn borer *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae) using Cry1F-resistant and Cry1F-susceptible strains sharing a similar genetic background. Fitness costs were tested on three lines of maize, *Zea mays* L., by measuring larval survival and development in two greenhouse experiments with plants in either the vegetative or reproductive stage. Both experiments showed that maize line significantly affected larval survival and developmental rate. However, larval survival, mass, and developmental rate did not differ between the Cry1F-resistant and susceptible strains, indicating a lack of fitness costs of resistance to Cry1F for the larval fitness components measured in this experiment. Future experiments should test for fitness costs of Cry1F resistance affecting survival to adulthood and adult life-history parameters.

Rausch, M. A., J. A. Kroemer, A. J. Gassmann and R. L. Hellmich (2014). "On-Plant Selection and Genetic Analysis of European Corn Borer (Lepidoptera: Crambidae) Behavioral Traits: Plant Abandonment Versus Plant Establishment." *Environmental Entomology* 43(5): 1254-1263.

Although some studies have investigated how insect behavior could influence resistance evolution to transgenic plants, none have determined if behavioral traits respond to selection pressure and how they may be inherited. We investigated plant establishment and abandonment traits for the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), by conducting a laboratory selection experiment and quantifying patterns of gene expression. Egg masses with emerging larvae were placed on maize plants and silking individuals were collected every 15 min during a 4-h period to generate a plant abandonment (PA) colony. Plants were dissected 24-72 h later, and larvae were collected for a plant establishment colony. Selection of the PA colony showed an increased propensity to abandon the host plant by the third generation. The propensity for larvae to establish on the plants, however, did not show a significant response until the sixth generation. Quantitative real-time-polymerase chain reaction (qRT-PCR) was used to determine expression profiles for behavior associated genes (foraging and *OnsImo*). Egg samples from the two selected colonies and nonselected laboratory colony were collected at 0, 24, 48, 72, and 96 h after egg deposition, and first instars were sampled after exposure to maize tissue. Compared with the plant establishment and nonselected laboratory colonies at the 0-h time period, foraging and *OnsImo* showed higher expression in the PA colony. This is the first study that has specifically selected for these traits over several generations and analyzed behavior-associated genes to elucidate genetic changes.

Rule, D. M., S. P. Nolting, P. L. Prasifka, N. P. Storer, B. W. Hopkins, E. F. Scherder, M. W. Siebert and W. H. Hendrix (2014). "Efficacy of Pyramided Bt Proteins Cry1F, Cry1A.105, and Cry2Ab2 Expressed in SmartStax Corn Hybrids Against Lepidopteran Insect Pests in the Northern United States." *Journal of Economic Entomology* 107(1): 403-409.

Commercial field corn (*Zea mays* L.) hybrids transformed to express some or all of the lepidopteran insect-resistant traits present in SmartStax corn hybrids were evaluated for insecticidal efficacy against a wide range of lepidopteran corn pests common to the northern United States, during 2008 to 2011 at locations in 15 states. SmartStax hybrids contain a pyramid of two *Bacillus thuringiensis* (Bt) derived events for lepidopteran control: event TC1507 expressing Cry1F protein and MON 89034 expressing Cry1A.105+Cry2Ab2. These studies focused on characterization of the relative efficacy of each event when expressed alone or in combination, and compared with non-Bt hybrid. Corn hybrids containing pyramided insecticidal proteins Cry1F+Cry1A.105+Cry2Ab2 (SmartStax) consistently showed reduced plant feeding damage by a wide range of lepidopteran larvae compared with single event and non-Bt hybrids. Corn hybrids

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expressing TC1507 or MON 89034 as single or pyramided events were consistently efficacious against *Ostrinia nubilalis* (Hubner). SmartStax hybrids had less injury from *Agrotis ipsilon* (Hufnagel) and *Striacosta albicosta* (Smith) than corn hybrids containing only event MON 89034 but were not more efficacious than single event TC1507 hybrids. Corn hybrids with event MON 89034 provided better control of *Helicoverpa zea* (Boddie), than event TC1507 alone. *Spodoptera frugiperda* (J.E. Smith) efficacy was higher for hybrids with pyramid events and single events compared with the non-Bt hybrids. The spectra of activity of events TC1507 and MON 89034 differed. The combination of TC1507 + MON 89034 provided redundant control of some pests where the spectra overlapped and thereby are expected to confer a resistance management benefit.

Siegfried, B. D., M. Rangasamy, H. C. Wang, T. Spencer, C. V. Haridas, B. Tenhumberg, D. V. Sumerford and N. P. Storer (2014). "Estimating the frequency of Cry1F resistance in field populations of the European corn borer (Lepidoptera: Crambidae)." *Pest Management Science* 70(5): 725-733.

BACKGROUND Transgenic corn hybrids that express toxins from *Bacillus thuringiensis* (Bt) have suppressed European corn borer populations and reduced the pest status of this insect throughout much of the US corn belt. A major assumption of the high-dose/refuge strategy proposed for insect resistance management and Bt corn is that the frequency of resistance alleles is low so that resistant pests surviving exposure to Bt corn will be rare. RESULTS The frequency of resistance to the Cry1F Bt toxin was estimated using two different screening tools and compared with annual susceptibility monitoring based on diagnostic bioassays and LC50 and EC50 determinations. An F-1 screening approach where field-collected individuals were mated to a resistant laboratory strain and progeny were assayed to determine genotype revealed that resistance alleles could be recovered even during the first year of commercially available Cry1F corn (2003). Estimates of frequency from 2003-2005 and 2006-2008 indicated that, although allele frequency was higher than theoretical assumptions (0.0286 and 0.0253 respectively), there was no indication that the frequency was increasing. Similar estimates in 2008 and 2009 using an F-2 screening approach confirmed the presence of non-rare resistance alleles (frequency approximate to 0.0093 and 0.0142 for 2008 and 2009, respectively). The results of both screening methods were in general agreement with the observed mortality in diagnostic bioassays and LC50 and EC50 determinations. CONCLUSIONS These results are consistent with previous modeling results, suggesting that the high-dose/refuge strategy that is in place for Bt corn may be effective in delaying resistance evolution even when a relatively high frequency of resistance alleles exists. (c) 2013 Society of Chemical Industry

Song, H. J., Y. X. Liu, Y. X. Liu, Y. Q. Huang, Y. Q. Li and Q. M. Wang (2014). "Design, synthesis, anti-TMV, fungicidal, and insecticidal activity evaluation of 1,2,3,4-tetrahydro-beta-carboline-3-carboxylic acid derivatives based on virus inhibitors of plant sources." *Bioorganic & Medicinal Chemistry Letters* 24(22): 5228-5233.

By drawing the creation ideas of botanical pesticides, a series of tetrahydro-beta-carboline-3-carboxylic acid derivatives were designed and synthesized, and first evaluated for their anti-TMV, fungicidal and insecticidal activities. Most of these derivatives exhibited good antiviral activity against TMV both in vitro and in vivo. Especially, the activities of compounds 8 and 15 in vivo were higher than that of ribavirin. The compound 8 exhibited more than 70% fungicidal activities against *Cercospora arachidicola* Hori, *Alternaria solani*, *Bipolaris maydis*, and *Rhizoctonia solani* at 50 mg/kg, compounds 16 and 20 exhibited more than 60% insecticidal activities against *Mythimna separate* and *Ostrinia nubilalis*. (C) 2014 Elsevier Ltd. All rights reserved.

Streiff, R., B. Courtois, S. Meusnier and D. Bourguet (2014). "Genetic mapping of two components of reproductive isolation between two sibling species of moths, *Ostrinia nubilalis* and *O. scapularis*." *Heredity* 112(4): 370-381.

We report the quantitative trait loci (QTL) mapping of reproductive isolation traits between *Ostrinia nubilalis* (the European corn borer) and its sibling species *O. scapularis* (the Adzuki bean borer), focusing on two traits: mating isolation (mi) and pheromone production (Pher). Four genetic maps were generated from two backcross families, with two maps (one chromosomal map and one linkage map) per backcross. We located 165-323 AFLP markers on these four maps, resulting in the identification of 27-31 linkage groups, depending on the map considered. No-choice mating experiments with the offspring of each backcross led to the detection of at least two QTLs for mi in different linkage groups. QTLs underlying Pher were located in a third linkage group. The Z heterochromosome was identified by a specific marker (Tpi) and did not carry any of these QTLs. Finally, we considered the global divergence between the two sibling species, distortions of segregation throughout the genome, and the location and effect of mi and Pher QTLs in

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light of the known candidate genes for reproductive isolation within the genus *Ostrinia* and, more broadly, in phytophagous insects.

Svobodova, E., M. Trnka, M. Dubrovsky, D. Semeradova, J. Eitzinger, P. Stepanek and Z. Zalud (2014). "Determination of areas with the most significant shift in persistence of pests in Europe under climate change." *Pest Management Science* 70(5): 708-715. **BACKGROUND** This study aimed to estimate the impact of climate change on the ranges of crop pest species in Europe. The organisms included in the study were species from the family Tortricidae (*Cydia pomonella*, *Lobesia botrana*) and the family Pyralidae (*Ostrinia nubilalis*), Chrysomelidae beetles (*Leptinotarsa decemlineata*, *Oulema melanopus*) and species from the family Aphididae (*Ropalosiphum padi*, *Sitobion avenae*). Climate conditions in the year 2055 were simulated using a subset of five representative global circulation models. Model simulations using these climate change scenarios showed significant shifts in the climatic niches of the species in this study. **RESULTS** For Central Europe, the models predicted a shift in the ranges of pest species to higher altitudes and increases in the number of generations (NG) of the pests. In contrast, in the southern regions of Europe, the NG is likely to decrease owing to insufficient humidity. The ranges of species are likely to shift to the north. **CONCLUSION** Based on the ensemble-scenario mean for 2055, a climate-driven northward shift of between 3 degrees N (*O. nubilalis*) and 11 degrees N (*L. botrana*) is expected. The areas that are most sensitive to experiencing a significant increase in climate suitability for future pest persistence were identified. These areas include Central Europe, the higher altitudes of the Alps and Carpathians and areas above 55 degrees N. (c) 2013 Society of Chemical Industry

Svobodova, E., M. Trnka, Z. Zalud, D. Semeradova, M. Dubrovsky, J. Eitzinger, P. Stepanek and R. Brazdil (2014). "Climate variability and potential distribution of selected pest species in south Moravia and north-east Austria in the past 200 years - lessons for the future." *Journal of Agricultural Science* 152(2): 225-237.

The present study investigated the historical occurrence of the European corn borer (*Ostrinia nubilalis*), the European grape vine moth (*Lobesia botrana*) and the Codling moth (*Cydia pomonella*) in southern Moravia and northern Austria from 1803-2008 by using climate and pest models. The pest model used, CLIMEX, indicates areas that are climatically favourable for the pest's development and long-term survival, considering the climatic parameters, especially daily air temperature, as determining factors for pest development. For model input parameters, two sets of meteorological data were prepared: (i) a generated meteorological series for 1803-2008 and (ii) a measured reference meteorological series for 1976-2008. In addition to estimating the historical climatic suitability for the persistence of a given pest, a second aim of the present study was to specify the core of the climatic niche during the continued presence of the pest and evaluate the applicability of the meteorological data generated for climate, based on pest mapping. This evaluation resulted in a partial overestimation of pest occurrence for *L. botrana* when using the generated meteorological data set. This species, native to warmer areas, has proved to be a sensitive indicator of increased temperatures.

Waligora, H., A. Weber, W. Skrzypczak and E. Chwastek (2014). "THE EFFECT OF WEATHER CONDITIONS ON CORN SMUT INFECTION AND EUROPEAN CORN BORER INFESTATION IN SEVERAL CULTIVARS OF SWEET CORN." *Romanian Agricultural Research* 31: 357-366.

The aim of this study was to assess the effect of temperature and precipitation on the occurrence of corn smut and European corn borer on several cultivars of sweet corn. The field experiment was conducted in the years 2010-2012 at the Gorzyn Experimental and Teaching Station, branch in Swadzim, belonging to the Poznan University of Life Sciences. Eight cultivars of sweet corn were analysed in this study. Prior to harvest the number of plants infested with corn smut was determined, while after ear harvest the number of plants damaged by the European corn borer was established. The analysis of variance ($\alpha=0.05$) and calculations of the correlation coefficient and regression were performed using the Statistica 10 programme. Analyses showed a significant effect of temperature ($p<0.001$) and precipitation ($p<0.05$) on the incidence of corn smut and damage by the European corn borer. In both cases temperature played a considerable role ($r=0.6411$, $r=0.4362$). Weather conditions influenced the occurrence of corn smut to a greater extent than they influenced the damage by the European corn borer. The study showed a significant effect ($p<0.05$) of insect feeding on *Ustilago maydis* Corda. infestation. Synthesis of the three years of experiments indicated significant differences between sweet corn cultivars in the number of plants damaged by European corn borers and infested by corn smut.

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White, J. A., E. C. Burkness and W. D. Hutchison (2014). "Biased sex ratios, mating frequency and *Nosema* prevalence in European corn borer, at low population densities." *Journal of Applied Entomology* 138(3): 195-201.

Xu, Z., B. Liu, H. Dong and M. Wang (2014). "Synthesis, Insecticidal Activity of New Benzoylthioureas and Benzoylureas." *Chinese Journal of Organic Chemistry* 34(12): 2517-2522.

Fifteen novel benzoylthioureas and benzoylureas containing hydantoin ring were synthesized by the reaction of 5-(4-aminophenyl)- and 5-(4-aminobenzyl)-hydantoin or 5-(4-aminobenzyl)-thiohydantoin with substituted benzoyl or pyridineacetyl isocyanates and isothiocyanates, respectively. Their structures were characterized by the IR, ¹H-NMR and HR-ESI-MS spectral data. Their bioactivities were evaluated with the insects *Mythimna separata*, *Helicoverpa armigera*, *Ostrinia nubilalis*, *Plutella xylostella*, *Aphis laburni* and *Culex pipiens pallens*. The results showed that 5-(4-aminophenyl)hydantoin-2,4,6-trichlorobenzoylthiourea (4) exhibit 85%, 90% and 100% mortality against *H. armigera*, *O. nubilalis* and *P. xylostella* at the concentration of 600 mg/L, 100% mortality against larva of *C. pipiens* at the concentration of 5 and 10 mg/L, respectively.

Yao, J. X., L. L. Buschman, N. Y. Lu, C. Khajuria and K. Y. Zhu (2014). "Changes in Gene Expression in the Larval Gut of *Ostrinia nubilalis* in Response to *Bacillus thuringiensis* Cry1Ab Protoxin Ingestion." *Toxins* 6(4): 1274-1294.

We developed a microarray based on 2895 unique transcripts assembled from 15,000 cDNA sequences from the European corn borer (*Ostrinia nubilalis*) larval gut. This microarray was used to monitor gene expression in early third-instar larvae of *Bacillus thuringiensis* (Bt)-susceptible *O. nubilalis* after 6 h feeding on diet, with or without the Bt Cry1Ab protoxin. We identified 174 transcripts, for which the expression was changed more than two-fold in the gut of the larvae fed Cry1Ab protoxin ($p < 0.05$), representing 80 down-regulated and 94 up-regulated transcripts. Among 174 differentially expressed transcripts, 13 transcripts putatively encode proteins that are potentially involved in Bt toxicity, and these transcripts include eight serine proteases, three aminopeptidases, one alkaline phosphatase, and one cadherin. The expressions of trypsin-like protease and three aminopeptidase transcripts were variable, but two potential Bt-binding proteins, alkaline phosphatase and cadherin were consistently up-regulated in larvae fed Cry1Ab protoxin. The significantly up and down-regulated transcripts may be involved in Cry1Ab toxicity by activation, degradation, toxin binding, and other related cellular responses. This study is a preliminary survey of Cry1Ab protoxin-induced transcriptional responses in *O. nubilalis* gut and our results are expected to help with further studies on Bt toxin-insect interactions at the molecular level.

Articles parus avant 2014

Ahmed, T., T. T. Zhang, Z. Y. Wang, K. L. He and S. X. Bai (2013). "Morphology and ultrastructure of antennal sensilla of *Macrocentrus cingulum* Brischke (Hymenoptera: Braconidae) and their probable functions." *Micron* 50: 35-43.

Macrocentrus cingulum Brischke (Hymenoptera: Braconidae) is a polyembryonic endoparasitoid of the Asian corn borer, *Ostrinia furnacalis* and the European corn borer, *Ostrinia nubilalis*. To better understand the host location mechanism, we examined the external morphology and ultrastructure of the antennal sensilla of this parasitoid by using scanning and transmission electron microscopy. Antennae of male and female of the *M. cingulum* are filiform in shape, 5.90-6.64 mm in length and consist of scape, pedicel, and flagellum with 39 and 40 flagellomeres, respectively. Cuticular pore and nine types of morphologically distinct sensilla were identified in both sexes, including two types of sensilla chaetica (nonporous), *s. trichodea* (nonporous), *s. basiconica I* (nonporous blunt tip), *s. basiconica II* (porous wall) and *s. basiconica III* (nonporous wall) with branched blunt tip, *s. coeloconica* with finger-like projections, protruded *s. campaniform* with central tip pore, and plate-like *s. placodea* (porous). We compared number, morphology, and distribution of sensilla between sexes. *S. campaniform* and non-porous *s. basiconica I* may play a role in gustatory functions whereas type II, and *s. placodea* may play a function in detecting odor stimuli due to their porous wall. The sensilla chaetica and *s. trichodea* may be involved in mechanosensation. *S. coeloconica* probably plays a role as thermo-hygro receptor, whilst cuticular pores may detect odor stimuli. No differences in antenna shape and basic structure in the males and females, but male antennae length and width were significantly greater than those of females.

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Furthermore, males had more placodea than females. The sensilla types, morphology, and structure of both sexes were compared to those found in other parasitic hymenoptera, especially braconid wasps. (c) 2013 Elsevier Ltd. All rights reserved.

Alexandre, H., S. Ponsard, D. Bourguet, R. Vitalis, P. Audiot, S. Cros-Arteil and R. Streiff (2013). "When History Repeats Itself: Exploring the Genetic Architecture of Host-Plant Adaptation in Two Closely Related Lepidopteran Species." *Plos One* 8(7).

The genus *Ostrinia* includes two allopatric maize pests across Eurasia, namely the European corn borer (ECB, *O. nubilalis*) and the Asian corn borer (ACB, *O. furnacalis*). A third species, the Adzuki bean borer (ABB, *O. scapularis*), occurs in sympatry with both the ECB and the ACB. The ABB mostly feeds on native dicots, which probably correspond to the ancestral host plant type for the genus *Ostrinia*. This situation offers the opportunity to characterize the two presumably independent adaptations or preadaptations to maize that occurred in the ECB and ACB. In the present study, we aimed at deciphering the genetic architecture of these two adaptations to maize, a monocot host plant recently introduced into Eurasia. To this end, we performed a genome scan analysis based on 684 AFLP markers in 12 populations of ECB, ACB and ABB. We detected 2 outlier AFLP loci when comparing French populations of the ECB and ABB, and 9 outliers when comparing Chinese populations of the ACB and ABB. These outliers were different in both countries, and we found no evidence of linkage disequilibrium between any two of them. These results suggest that adaptation or preadaptation to maize relies on a different genetic architecture in the ECB and ACB. However, this conclusion must be considered in light of the constraints inherent to genome scan approaches and of the intricate evolution of adaptation and reproductive isolation in the *Ostrinia* spp. complex.

Bohnenblust, E., J. Breining, G. Roth and J. Tooker (2013). "Corn pith weevil, *Geraeus penicillus* (Coleoptera: Curculionidae), in transgenic, insect-resistant and conventional field corn hybrids." *Journal of Applied Entomology* 137(9): 668-672.

The corn pith weevil *Geraeus penicillus* (Herbst) is occasionally found boring in corn stalks throughout the eastern and Midwestern United States. Injury caused by *G. penicillus* is not typically economical, but may be confused with that of the European corn borer *Ostrinia nubilalis* (Hubner), an important economic pest throughout the United States. During efforts to assess European corn borer infestations, we discovered *G. penicillus* in field corn in south-eastern Pennsylvania, including hybrids genetically modified (i.e. Bt hybrids) to control European corn borer among other herbivore species. Our analysis across sites indicated that tunnels of *G. penicillus* were significantly more abundant in transgenic Bt hybrids than non-Bt hybrids, but comparisons of Bt hybrids and their near isolines revealed mostly similar numbers of *G. penicillus* tunnels, suggesting other hybrid features might be affecting the distribution of *G. penicillus*. Tunnels of *G. penicillus* were equally distributed among the three transgenic trait packages represented in our study. In plants where we found *G. penicillus*, tunnels were more abundant in stalks free of European corn borer damage. Our report appears to be the first to note *G. penicillus* feeding in Bt corn hybrids. These findings are notable because they document insect damage in Bt hybrids that may be mistaken for European corn borer damage and may provide evidence of an insect herbivore proliferating following a mild winter or possibly even moving into competitor-free space.

Coates, B. S., H. Johnson, K. S. Kim, R. L. Hellmich, C. A. Abel, C. Mason and T. W. Sappington (2013). "Frequency of hybridization between *Ostrinia nubilalis* E- and Z-pheromone races in regions of sympatry within the United States." *Ecology and Evolution* 3(8): 2459-2470.

Female European corn borer, *Ostrinia nubilalis*, produce and males respond to sex pheromone blends with either E- or Z-Delta 11-tetradecenyl acetate as the major component. E- and Z-race populations are sympatric in the Eastern United States, Southeastern Canada, and the Mediterranean region of Europe. The E- and Z-pheromone races of *O. nubilalis* are models for incipient species formation, but hybridization frequencies within natural populations remain obscure due to lack of a high-throughput phenotyping method. Lassance et al. previously identified a pheromone gland-expressed fatty-acyl reductase gene (*pgfar*) that controls the ratio of Delta 11-tetradecenyl acetate stereoisomers. We identified three single nucleotide polymorphism (SNP) markers within *pgfar* that are differentially fixed between E- and Z-race females, and that are $\geq 98.2\%$ correlated with female pheromone ratios measured by gas chromatography. Genotypic data from locations in the United States demonstrated that *pgfar*-z alleles were fixed within historically allopatric Z-pheromone race populations in the Midwest, and that hybrid frequency ranged from 0.00 to 0.42 within 11 sympatric sites where the two races co-occur in the Eastern United States (mean hybridization frequency or

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heterozygosity (H-O) = 0.226 +/- 0.279). Estimates of hybridization between the E- and Z-races are important for understanding the dynamics involved in maintaining race integrity, and are consistent with previous estimates of low levels of genetic divergence between E- and Z-races and the presence of weak prezygotic mating barriers.

Coates, B. S., D. V. Sumerford, B. D. Siegfried, R. L. Hellmich and C. A. Abel (2013). "Unlinked genetic loci control the reduced transcription of aminopeptidase N 1 and 3 in the European corn borer and determine tolerance to *Bacillus thuringiensis* Cry1Ab toxin." *Insect Biochemistry and Molecular Biology* 43(12): 1152-1160.

Transgenic expression of *Bacillus thuringiensis* (Bt) crystalline (Cry) toxins by crop plants result in reduced insect feeding damage, but sustainability is threatened by the development of resistance traits in target insect populations. We investigated Bt toxin resistance trait in a laboratory colony of the European corn borer, *Ostrinia nubilalis*, selected for increased survival when exposed to Cry1Ab and correlated survival on Cry1Ab toxin with a constitutive 146.2 +/- 17.3-fold reduction in midgut aminopeptidase N1 (apn1) transcript levels. A 7.1 +/- 1.9-fold reduction apn3 transcript level was also correlated with Cry1Ab resistance. Quantitative trait locus (QTL) mapping identified a single major genome region controlling Cry1Ab resistance on linkage group 24 (LG24), and a minor QTL on LG27. Both QTL were independent of apn1 and apn3 loci on LG02. Positional mapping identified genetic markers that may assist in the identification of causal gene(s) within QTL intervals. This study indicates that genetic factor(s) may act in trans to reduce both apn1 and apn3 expression in Cry1Ab resistant *O. nubilalis* larvae, and suggest that gene regulatory pathways can influence Bt resistance traits. These findings show that gene interactions (epistasis) may influence Bt resistance in target insect populations. Published by Elsevier Ltd.

Crava, C. M., Y. Bel, A. K. Jakubowska, J. Ferre and B. Escriche (2013). "Midgut aminopeptidase N isoforms from *Ostrinia nubilalis*: Activity characterization and differential binding to Cry1Ab and Cry1Fa proteins from *Bacillus thuringiensis*." *Insect Biochemistry and Molecular Biology* 43(10): 924-935.

Aminopeptidase N (APN) isoforms from Lepidoptera are known for their involvement in the mode of action of insecticidal Cry proteins from *Bacillus thuringiensis*. These enzymes belong to a protein family with at least eight different members that are expressed simultaneously in the midgut of lepidopteran larvae. Here, we focus on the characterization of the APNs from *Ostrinia nubilalis* (OnAPNs) to identify potential Cry receptors. We expressed OnAPNs in insect cells using a baculovirus system and analyzed their enzymatic activity by probing substrate specificity and inhibitor susceptibility. The interaction with Cry1Ab and Cry1Fa proteins (both found in transgenic insect-resistant maize) was evaluated by ligand blot assays and immunocytochemistry. Ligand blots of brush border membrane proteins showed that both Cry proteins bound mainly to a 150 kDa-band, in which OnAPNs were greatly represented. Binding analysis of Cry proteins to the cell-expressed OnAPNs showed that OnAPN1 interacted with both Cry1Ab and Cry1Fa, whereas OnAPN3a and OnAPN8 only bound to Cry1Fa. Two isoforms, OnAPN2 and OnAPN3b, did not interact with any of these two proteins. This work provides the first evidence of a differential role of OnAPN isoforms in the mode of action of Cry proteins in *O. nubilalis*. (c) 2013 Elsevier Ltd. All rights reserved.

Crava, C. M., G. P. Farinos, Y. Bel, P. Castanera and B. Escriche (2013). "Quantitative genetic analysis of Cry1Ab tolerance in *Ostrinia nubilalis* Spanish populations." *Journal of Invertebrate Pathology* 113(3): 220-227.

Tolerance to *Bacillus thuringiensis* Cry1Ab toxin in Spanish *Ostrinia nubilalis* populations was analyzed by quantitative genetic techniques, using isolines established from field-derived insects. F-1 offspring was tested for susceptibility to trypsin activated Cry1Ab using a concentration that caused a mean larval mortality of 87% (+/- 17% SD). The progeny of the most tolerant isolines (that had shown mortalities lower than 60%) was crossed to obtain the F-2 generation that was exposed to the same Cry1Ab concentration. A clear reduction in mortality (62 +/- 17% SD) was observed. The upper limit for heritability was estimated to range between 0.82 and 0.90, suggesting that a high part of phenotypic variation in tolerance to Cry1Ab was attributable to genetic differences. An estimate of the minimum number of segregating factors indicated that the loci involved in tolerance to Cry1Ab were at least two. The role of the cadherin gene, which is a *B. thuringiensis* resistance gene in Lepidoptera, was assessed in the most tolerant isolines by using an EPIC-PCR marker specifically developed for this study. Association between cadherin and tolerance was obtained in one tolerant isolate; however it could be not confirmed by segregation analysis in the F-2 progeny because F-2 offspring was not viable. Our results indicate that the tolerance trait is common in Spanish field populations. Quantitative genetic

techniques may be helpful for estimating the influence of genetic factors to Cry1Ab tolerance in *O. nubilalis*. (C) 2013 Elsevier Inc. All rights reserved.

Dafoe, N. J., J. D. Thomas, P. D. Shirk, M. E. Legaspi, M. M. Vaughan, A. Huffaker, P. E. Teal and E. A. Schmelz (2013). "European Corn Borer (*Ostrinia nubilalis*) Induced Responses Enhance Susceptibility in Maize." *Plos One* 8(9).

Herbivore-induced plant responses have been widely described following attack on leaves; however, less attention has been paid to analogous local processes that occur in stems. Early studies of maize (*Zea mays*) responses to stem boring by European corn borer (ECB, *Ostrinia nubilalis*) larvae revealed the presence of inducible acidic diterpenoid phytoalexins, termed kauralexins, and increases in the benzoxazinoid 2-hydroxy-4,7-dimethoxy-1,4-benzoxazin-3-one-glucose (HDMBOA-Glc) after 24 h of herbivory. Despite these rapidly activated defenses, larval growth was not altered in short-term feeding assays. Unexpectedly, ECB growth significantly improved in assays using stem tissue preconditioned by 48 h of larval tunneling. Correspondingly, measures of total soluble protein increased over 2.6-fold in these challenged tissues and were accompanied by elevated levels of sucrose and free linoleic acid. While microarray analyses revealed up-regulation of over 1100 transcripts, fewer individual protein increases were demonstrable. Consistent with induced endoreduplication, both wounding and ECB stem attack resulted in similar significant expansion of the nucleus, nucleolus and levels of extractable DNA from challenged tissues. While many of these responses are triggered by wounding alone, biochemical changes further enhanced in response to ECB may be due to larval secreted effectors. Unlike other Lepidoptera examined, ECB excrete exceedingly high levels of the auxin indole-3-acetic acid (IAA) in their frass which is likely to contact and contaminate the surrounding feeding tunnel. Stem exposure to a metabolically stable auxin, such as 2,4-dichlorophenoxyacetic acid (2,4-D), promoted significant protein accumulation above wounding alone. As a future testable hypothesis, we propose that ECB-associated IAA may function as a candidate herbivore effector promoting the increased nutritional content of maize stems.

Gardner, J., T. H. Yong, S. A. Pitcher and M. P. Hoffmann (2013). "Overwintering of *Trichogramma ostrinae* (Hymenoptera: Trichogrammatidae) within target and non-target host eggs." *Biocontrol Science and Technology* 23(4): 367-380.

Trichogramma ostrinae was imported into the USA from China and it continues to be evaluated as a biological control agent against the European corn borer and other lepidopteran pest species. A natural enemy's ability to overwinter is a facet of its biology with important ramifications for biological control and non-target effects. Thus, studies were conducted to examine the ability of the introduced egg parasitoid to survive over winters in central New York State. Eggs of *Ostrinia nubilalis*, *Ephestia kuehniella*, *Trichoplusia ni*, *Helicoverpa zea* and *Utetheisa ornatrix* were subjected to parasitism by adult *T. ostrinae* and then placed out of doors and exposed to winter conditions. For trials initiated in 2003 and 2004, the adult parental wasps were exposed to a diapause-inducing photoperiod and temperature regime in the laboratory; in 2010, parental wasps were conditioned out of doors and prior to the onset of winter conditions. Emergence of their progeny was monitored over time by taking aliquots of parasitised eggs, and holding them under warm conditions until emergence was complete. The level of wasp emergence generally displayed a decline followed by gradual increase until spring. Levels of overwintering ranged from 1% for *O. nubilalis* to 76% for *E. kuehniella*, and logistic regression indicated that the odds of overwintering was dependent on the year, host species, time out of doors and varied over exposure time depending on host. The potential to overwinter in New York was further confirmed by positive identification of *T. ostrinae* from naturally occurring *O. nubilalis* eggs collected from field sites where augmentative releases had been made in previous years.

Gomez, R., M. Liebman, D. N. Sundberg and C. A. Chase (2013). "Comparison of crop management strategies involving crop genotype and weed management practices in conventional and more diverse cropping systems." *Renewable Agriculture and Food Systems* 28(3): 220-233.

Cropping systems that include forage legumes and small grains in addition to corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] can achieve similar or higher crop productivity and economic return than simpler corn-soybean rotations. We hypothesized that this rotation effect occurs regardless of the crop genotype planted and the herbicide and cultivation regime selected for weed management. To test this hypothesis, we conducted a 3-year experiment that compared three cropping systems: a conventional 2-year corn-soybean rotation, a 3-year corn-soybean-oat (*Avena sativa* L.) / red clover (*Trifolium pretense* L.) rotation, and a 4-year corn-soybean-oat/alfalfa-alfalfa (*Medicago sativa* L.) rotation. Within each cropping system, two contrasting sets of management strategies were used: (i) genetically

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engineered corn with resistance to insect pests (*Ostrinia nubilalis* Hubner and *Diabrotica* spp.) plus the broadcast application of pre-emergence herbicides, followed in the rotation by a genetically engineered soybean variety with resistance to the herbicide glyphosate plus the post-emergence broadcast application of glyphosate; and (ii) non-genetically engineered corn plus the banded application of post-emergence herbicides, followed in the rotation by a non-genetically engineered soybean and banded application of several post-emergence herbicides. The two management strategies were identified as 'GE' and 'non-GE.' Corn yield was higher in the 3-year (12.51 Mg ha⁻¹) and 4-year (12.79 Mg ha⁻¹) rotations than in the conventional 2-year (12.16 Mg ha⁻¹) rotation, and was also 2% higher with the GE strategy than with the non-GE strategy. Soybean yield was similar among rotation systems in 2008, but higher in the 3- and 4-year systems than the 2-year rotation in 2009 and 2010. Soybean yield was similar between management strategies in 2008, but higher in the GE strategy in 2009, and similar between strategies in the 3- and 4-year rotations in 2010. Increases in rotation length were accompanied by 88-91% reductions in synthetic N fertilizer application, and the use of the non-GE rather than the GE strategy was accompanied by a 93% reduction in herbicide active ingredients applied. Averaged over the period of 2008-2010, net returns to land and labor were highest for the 3-year rotation managed with either the GE (\$928 ha⁻¹ yr⁻¹) or non-GE (\$936 ha⁻¹ yr⁻¹) strategies, least in the 2-year rotation managed with the non-GE strategy (\$738 ha⁻¹ yr⁻¹), and intermediate in the other rotation x management combinations. Our results indicate that more diverse crop rotation systems can be as profitable as conventional corn-soybean systems and can provide farmers with greater flexibility in crop management options.

Hernandez-Rodriguez, C. S., P. Hernandez-Martinez, J. Van Rie, B. Escribe and J. Ferre (2013). "Shared Midgut Binding Sites for Cry1A. 105, Cry1Aa, Cry1Ab, Cry1Ac and Cry1Fa Proteins from *Bacillus thuringiensis* in Two Important Corn Pests, *Ostrinia nubilalis* and *Spodoptera frugiperda*." *Plos One* 8(7).

First generation of insect-protected transgenic corn (Bt-corn) was based on the expression of Cry1Ab or Cry1Fa proteins. Currently, the trend is the combination of two or more genes expressing proteins that bind to different targets. In addition to broadening the spectrum of action, this strategy helps to delay the evolution of resistance in exposed insect populations. One of such examples is the combination of Cry1A. 105 with Cry1Fa and Cry2Ab to control *O. nubilalis* and *S. frugiperda*. Cry1A. 105 is a chimeric protein with domains I and II and the C-terminal half of the protein from Cry1Ac, and domain III almost identical to Cry1Fa. The aim of the present study was to determine whether the chimeric Cry1A. 105 has shared binding sites either with Cry1A proteins, with Cry1Fa, or with both, in *O. nubilalis* and in *S. frugiperda*. Brush-border membrane vesicles (BBMV) from last instar larval midguts were used in competition binding assays with I-125-labeled Cry1A. 105, Cry1Ab, and Cry1Fa, and unlabeled Cry1A. 105, Cry1Aa, Cry1Ab, Cry1Ac, Cry1Fa, Cry2Ab and Cry2Ae. The results showed that Cry1A. 105, Cry1Ab, Cry1Ac and Cry1Fa competed with high affinity for the same binding sites in both insect species. However, Cry2Ab and Cry2Ae did not compete for the binding sites of Cry1 proteins. Therefore, according to our results, the development of cross-resistance among Cry1Ab/Ac, Cry1A. 105, and Cry1Fa proteins is possible in these two insect species if the alteration of shared binding sites occurs. Conversely, cross-resistance between these proteins and Cry2A proteins is very unlikely in such case.

Kocourek, F., P. Saska and M. Rezac (2013). "Diversity of Carabid Beetles (Coleoptera: Carabidae) under Three Different Control Strategies against European Corn Borer in Maize." *Plant Protection Science* 49(3): 146-153.

We compared three control strategies against European corn borer (*Ostrinia nubilalis* Hubner) in maize with respect to carabid beetles, beneficial epigeal arthropods. The impact of the focal treatment (insect resistant Bt maize MON 810) was compared with conventionally farmed and Trichogramma-treated plots at two sites (Prague-Ruzyne and Ivanovice na Hane) in the Czech Republic, replicated in three cropping seasons (2002-2004). The sampled assemblages were species-poor. The species were unevenly distributed in terms of their catch size - the communities were dominated by 7 (Ruzyne) or 3 (Ivanovice) species. No differences were found in species richness or species composition between treatments, seasons or sites, suggesting no effect of planting transgenic insect resistant Bt maize MON 810 on the assemblages of carabid beetles in the study fields.

Lira, J., J. Beringer, S. Burton, S. Griffin, J. Sheets, S. Y. Tan, A. Woosley, S. Worden and K. E. Narva (2013). "Insecticidal Activity of *Bacillus thuringiensis* Cry1Bh1 against *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) and Other Lepidopteran Pests." *Applied and Environmental Microbiology* 79(24): 7590-7597.

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Bacillus thuringiensis is an important source of insect resistance traits in commercial crops. In an effort to prolong *B. thuringiensis* trait durability, insect resistance management programs often include combinations of insecticidal proteins that are not cross resistant or have demonstrable differences in their site of action as a means to mitigate the development of resistant insect populations. In this report, we describe the activity spectrum of a novel *B. thuringiensis* Cry protein, Cry1Bh1, against several lepidopteran pests, including laboratory-selected *B. thuringiensis*-resistant strains of *Ostrinia nubilalis* and *Heliothis virescens* and progeny of field-evolved *B. thuringiensis*-resistant strains of *Plutella xylostella* and *Spodoptera frugiperda*. Cry1Bh1 is active against susceptible and *B. thuringiensis*-resistant colonies of *O. nubilalis*, *P. xylostella*, and *H. virescens* in laboratory diet-based assays, implying a lack of cross-resistance in these insects. However, Cry1Bh1 is not active against susceptible or Cry1F-resistant *S. frugiperda*. Further, Cry1Bh1 does not compete with Cry1Fa or Cry1Ab for *O. nubilalis* midgut brush border membrane binding sites. Cry1Bh1-expressing corn, while not completely resistant to insect damage, provided significantly better leaf protection against Cry1Fa-resistant *O. nubilalis* than did Cry1Fa-expressing hybrid corn. The lack of cross-resistance with Cry1Ab and Cry1Fa along with independent membrane binding sites in *O. nubilalis* makes Cry1Bh1 a candidate to further optimize for in-plant resistance to this pest.

Louis, J., M. Peiffer, S. Ray, D. S. Luthe and G. W. Felton (2013). "Host-specific salivary elicitor(s) of European corn borer induce defenses in tomato and maize." *New Phytologist* 199(1): 66-73.

Plants turn on induced defenses upon insect herbivory. In the current study, we evaluated the role of European corn borer (ECB) elicitors (molecules secreted by herbivores) that either induce/suppress defenses in *Solanum lycopersicum* (tomato) and *Zea mays* (maize), two very important crop plants that are grown for food and/or fuel throughout the world. We used a combination of molecular, biochemical, confocal and scanning electron microscopy, caterpillar spinneret ablation/cauterization, and conventional insect bioassay methods to determine the role of ECB elicitors in modulating defenses in both tomato and maize crop plants. Our results clearly demonstrate that the components present in the ECB saliva induce defense-related proteinase inhibitors in both tomato (PIN2) and maize (MPI). Presence of glucose oxidase in the ECB saliva induced defenses in tomato, but not in maize. However, ECB saliva induced genes present in the jasmonic acid biosynthesis pathway in both tomato and maize. Although ECB saliva can induce defenses in both tomato and maize, our results suggest that host-specific salivary components are responsible for inducing host plant defenses. Proteomic analysis of ECB salivary elicitors and plant receptors/signaling mechanisms involved in recognizing different ECB elicitors remains to be determined.

Mencarelli, M., C. Accinelli and A. Vicari (2013). "Implications of European corn borer, *Ostrinia nubilalis*, infestation in an *Aspergillus flavus*-biocontrolled corn agroecosystem." *Pest Management Science* 69(9): 1085-1091.

Background A novel biocontrol strategy consisting of field application of bioplastic-based granules inoculated with a non-toxicogenic *Aspergillus flavus* L. strain has recently been shown to be effective for reducing aflatoxin contamination in corn. ECB), *Ostrinia nubilalis* H., in the dispersal and infestation of *A. flavus* in corn and its impact on crop yield. Results In spite of the high percentage of corn ears showing larval feeding damage, ECB-bored kernels accounted for only 3 and 4% in 2009 and 2010 respectively. Most of the damaged kernels were localised in the ear tip or immediately below. More precisely, the average incidence of ECB-bored kernels in the upper end of the ear was 32%. However, less than 5% of kernels from the central body of the ear, which includes the majority of kernels, were injured by ECB. Conclusions Although ECB larvae showed a high tolerance to aflatoxin B1 and thus had the potential to serve as vectors of the mould, fungal infection of kernels was poorly associated with insect damage. ECB infestation resulted in grain yield losses not exceeding 2.5%. (c) 2012 Society of Chemical Industry

Merrill, S. C., S. M. Walter, F. B. Peairs and E. M. Schlep (2013). "The Distribution of European Corn Borer (Lepidoptera: Crambidae) Moths in Pivot-Irrigated Corn." *Journal of Economic Entomology* 106(5): 2084-2092.

The European corn borer, *Ostrinia nubilalis* (Hubner), is a damaging pest of numerous crops including corn, potato, and cotton. An understanding of the interaction between *O. nubilalis* and its spatial environment may aid in developing pest management strategy. Over a 2-yr period, approximate to 8,000 pheromone trap catches of *O. nubilalis* were recorded on pivot-irrigated corn in northeastern Colorado. The highest weekly moth capture per pivot-irrigated field occurred on the week of 15 July 1997 at 1,803 moths captured. The lowest peak moth capture per pivot-irrigated field was recorded on the week of 4 June 1998 at 220 moths captured. Average trap catch per field ranged from

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approximate to 1.6 moths captured per trap per week in 1997 to approximate to 0.3 moths captured per trap per week in 1998. Using pheromone trap moth capture data, we developed a quantified understanding of the spatial distribution of adult male moths. Our findings suggest strong correlations between moth density and adjacent corn crops, prevailing wind direction, and an edge effect. In addition, directional component effects suggest that more moths were attracted to the southwestern portion of the crop, which has the greatest insolation potential. In addition to the tested predictor variables, we found a strong spatial autocorrelation signal indicating positive aggregations of these moths and that males from both inside and outside of the field are being attracted to within-field pheromone traps, which has implications for refuge strategy management.

Nusawardani, T., J. A. Kroemer, M. Y. Choi and R. A. Jurenka (2013). "Identification and characterization of the pyrokinin/pheromone biosynthesis activating neuropeptide family of G protein-coupled receptors from *Ostrinia nubilalis*." *Insect Molecular Biology* 22(3): 331-340.

Insects have two closely related G protein-coupled receptors belonging to the pyrokinin/pheromone biosynthesis activating neuropeptide (pyrokinin/PBAN) family, one with the ligand PBAN or pyrokinin-2 and another with diapause hormone or pyrokinin-1 as a ligand. A related receptor is activated by products of the *capa* gene, periviscerokinins. Here we characterized the PBAN receptor and the diapause hormone receptor from the European corn borer, *Ostrinia nubilalis*. We also identified a partial sequence for the periviscerokinins receptor. Quantitative PCR of mRNA for all three receptors indicated differential expression in various life stages and tissues. All three splice variants of the PBAN receptor were identified with all variants found in pheromone gland tissue. Immunohistochemistry of V5 tags of expressed receptors indicated that all three variants and the diapause hormone receptor were expressed at similar levels in *Spodoptera frugiperda* 9 (Sf9) cells. However, the A- and B-variants were not active in our functional assay, which confirms studies from other moths. Functional expression of the C-variant indicated that it has a 44nM half effective concentration for activation by PBAN. The diapause hormone receptor was activated by diapause hormone with a 150nM half effective concentration.

Obopile, M. and R. B. Hammond (2013). "The influence of planting date, transgenic Bt maize and hybrid relative maturity on European corn borer *Ostrinia nubilalis* (Lepidoptera: Crambidae) ovipositional patterns." *Entomological Research* 43(5): 299-305. A three year study was carried out at Hoytville and at Wooster, Ohio, USA from 2006 to 2008 to investigate the influence of planting date, transgenic maize and hybrid maturity on *Ostrinia nubilalis* (Hubner) population dynamics and oviposition patterns. Maize plants were planted in late April or early May, mid-May and early June during each year. The moth flight pattern showed bivoltine generations during the three years. The first moth flight peaked in June, with the populations declining during July. The second moth flight peaked in August and declined towards the end of September or early October. Egg mass density did not differ significantly between transgenic and non-transgenic maize of different maturities. Significant differences were observed, however, among planting dates, sampling dates, and sampling date x planting date interactions. Generally higher numbers of egg masses from second generation moths were deposited on late planted maize than middle and early plantings.

Ordas, B., A. Alvarez, P. Revilla, A. Butron and R. A. Malvar (2013). "Relationship Between Time to Flowering and Stalk and Ear Damage by Second Generation Corn Borers." *Journal of Economic Entomology* 106(3): 1234-1239.

In the Mediterranean area, the main corn borer species are *Sesamia nonagrioides* Lefebvre (Mediterranean corn borer) and *Ostrinia nubilalis* Hubner (European corn borer). In the overall context of integrated pest control, it is possible to reduce the effect of a pest without having a negative effect on the environment by varying the sowing date. Benefits are possible if the most susceptible stages of the crop no longer coincide with the peak of the pest. We used different cycles of selection (0, 6, 8, 10, and 12) of two populations (Purdue A and Purdue B) of maize selected for early flowering to get a more precise estimation of the relationship between maturity of plant tissues and corn borer damage. We found a relationship between the damage produced by corn borers and the number of days from flowering to infestation. We conclude that, after flowering, a later stage of plant development at the moment of the infestation by corn borers reduces the damage caused by the larvae. Based on our results, we recommend to plant as early as possible so the tissues would be as mature as possible at the moment of insect attack.

Piesik, D., D. Rochat, K. J. Delaney and F. Marion-Poll (2013). "Orientation of European corn borer first instar larvae to synthetic green leaf volatiles." *Journal of Applied Entomology* 137(3): 234-240.

European corn borer (ECB) neonate larvae are capable of orienting towards maize odours and of avoiding spinach odours. We previously reported that maize odours' attraction was dependent on the stimulus regime. This led us to propose that maize odours could have a repellent or attractive effect depending on their concentration. In this work, we tested this hypothesis by evaluating attraction or avoidance of neonate ECB larvae to four concentrations of each of six single green leaf volatiles (GLVs); these are commonly found in maize and other plants. We found a dose-dependent effect for all of these GLVs with the exception of 1-hexyl acetate, which did not elicit any orientation behaviour over the range of concentrations tested. These five GLVs were repellent at high concentrations, while two of them were attractive at a lower concentration. These observations indicate for the first time that plant odours induce different behaviours in ECB neonate larvae depending not only on their chemical identity but also their concentration.

Tan, S. Y., B. F. Cayabyab, E. P. Alcantara, F. N. Huang, K. L. He, K. W. Nickerson and B. D. Siegfried (2013). "Comparative binding of Cry1Ab and Cry1F *Bacillus thuringiensis* toxins to brush border membrane proteins from *Ostrinia nubilalis*, *Ostrinia furnacalis* and *Diatraea saccharalis* (Lepidoptera: Crambidae) midgut tissue." *Journal of Invertebrate Pathology* 114(3): 234-240.

The European (*Ostrinia nubilalis* Hubner) and Asian corn borers (*Ostrinia furnacalis* Guenee) are closely related and display similar sensitivity to Cry1 toxins. In this study, we compared the binding patterns of Cry1Ab and Cry1F toxins between both *Ostrinia* spp., as well as the expression of putative cadherin- and aminopeptidase-N (APN)-like protein receptors. Additionally, cDNA sequences of these putative toxin receptors from both *Ostrinia* species were compared. Ligand blots for both species indicated a similar binding pattern for Cry1Ab with the strongest immunoreactive band at 260 kDa in both species. In addition, similar expression of the putative cadherin- and APN-like protein receptors were observed at 260 and 135 kDa, respectively. A high degree of similarity (98% amino acid sequence identity) of cDNA sequences for both putative receptor sequences was observed. The Cry1F ligand blot revealed that *O. furnacalis* and *O. nubilalis* BBMV exhibited slightly different binding patterns, with strong binding to putative proteins at 150 and 140 kDa, respectively. Both proteins appeared to also bind Cry1Ab, although the signal intensity was much reduced with Cry1Ab. *O. furnacalis* showed an additional but weaker band at 210 kDa relative to the 150 kDa band. *Diatraea saccharalis* (Fabricius), which was used as an outgroup species, exhibited different binding patterns than either *Ostrinia* species, with both Cry1Ab and Cry1F toxins binding to a 210 kDa protein. These results support the previous experiments indicating that *O. nubilalis* and *O. furnacalis* share similar patterns of susceptibility to Cry toxins. (C) 2013 Elsevier Inc. All rights reserved.

Vellau, H., E. Leppik, B. Frerot and T. Tammaru (2013). "Detecting a difference in reaction norms for size and time at maturation: pheromone strains of the European corn borer (*Ostrinia nubilalis*: Lepidoptera, Crambidae)." *Evolutionary Ecology Research* 15(5): 589-599.

Background: Sibling herbivore species or host strains specialized to different food plants frequently evolve specific adaptations to their hosts, including host-specific differences in developmental traits (body mass and development time). Such differences may (1) be a consequence of an evolutionary change in relative quality of different hosts, or (2) reflect host-specific changes in the reaction norms for size and time at maturation per se. Aim: Detect a difference in reaction norms for size and time at maturation among the host strains of an herbivorous insect. Organism: European corn borer *Ostrinia nubilalis*, a polyphagous pest moth with two distinct host plant strains E and Z feeding on hop/mugwort and on maize, respectively. Methods: A laboratory growth trial in which the larvae from these two strains were reared on an artificial diet that was either neutral or included the native host plant of the respective strain. The growth of the larvae was monitored on a daily basis. Results: Larvae from strain Z developed over a longer period and attained higher pupal masses than larvae from strain E, the strains thereby showing systematic differences in reaction norms for time and size at maturation. Conclusion: Examining the sign of the correlation between size and time at maturation at the level of among-strain comparison is recommended as a tool for detecting host-specific changes in the reaction norms for size and time at maturation.

Vukasinovic, E. L., D. W. Pond, M. R. Worland, D. Kojic, J. Purac, D. P. Blagojevic and G. Grubor-Lajsic (2013). "Diapause induces changes in the composition and biophysical properties of lipids in larvae of the European corn borer, *Ostrinia nubilalis* (Lepidoptera: Crambidae)." *Comparative Biochemistry and Physiology B-Biochemistry & Molecular Biology* 165(4): 219-225.

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This study compares the composition and biophysical properties of lipids in non-diapausing and diapausing fifth instar larvae of *Ostrinia nubilalis* Hubn. (Lepidoptera: Crambidae). The majority of fat body lipids in both of these physiological states were comprised of similar to 90% triacylglycerols (TAGs), whereas the haemolymph contained a more even distribution of all lipid classes. The fatty acid composition and biophysical properties of the fat body lipids differed markedly between non-diapausing and diapausing larvae. Diapause was associated with a dramatic increase in the proportions of palmitoleic acid (16:1n-7) and oleic acid (18:1n-9), with concurrent reductions in palmitic acid (16:0) and linoleic acid (18:2n-6). The increase in the level of unsaturation of the fat body lipids, which caused a marked shift in their phase transitions to lower temperatures, was triggered by diapause rather than low temperatures. Adjustments of fatty acid compositions are likely to be an important component of winter diapause mechanisms, possibly maintaining the fluidity of cell membranes and the functionality of the organism during lower winter temperatures. (c) 2013 Elsevier Inc. All rights reserved.

Bell, J. R., E. C. Burkness, A. E. Milne, D. W. Onstad, M. Abrahamson, K. L. Hamilton and W. D. Hutchison (2012). "Putting the brakes on a cycle: bottom-up effects damp cycle amplitude." *Ecology Letters* 15(4): 310-318.

Pest population density oscillations have a profound effect on agroecosystem functioning, particularly when pests cycle with epidemic persistence. Here, we ask whether landscape-level manipulations can be used to restrict the cycle amplitude of the European corn borer moth [*Ostrinia nubilalis* (Hubner)], an economically important maize pest. We analysed time series from Minnesota (1963-2009) and Wisconsin (1964-2009) to quantify the extent of regime change in the US Corn Belt where rates of transgenic Bt maize adoption varied. The introduction of Bt maize explained cycle damping when the adoption of the crop was high (Minnesota); oscillations were damped but continued to persist when Bt maize was used less intensely (Wisconsin). We conclude that host plant quality is key to understanding both epidemic persistence and the success of intervention strategies. In particular, the dichotomy in maize management between states is thought to limit the spatial autocorrelation of *O. nubilalis*.

Bickerton, M. W. and G. C. Hamilton (2012). "Effects of Intercropping With Flowering Plants on Predation of *Ostrinia nubilalis* (Lepidoptera: Crambidae) Eggs by Generalist Predators in Bell Peppers." *Environmental Entomology* 41(3): 612-620.

Bell pepper plots intercropped with flowering plants were measured for improving biological control provided by natural enemies of the European corn borer [*Ostrinia nubilalis* (Hubner)]. The intercropped plants Dill, *Anethum graveolens* L.; coriander, *Coriandrum sativum* L.; and buckwheat, *Fagopyrum esculentum* Moench; were established on the edge of two pepper plots and compared with nonintercropped control plots. Predation by the three species *Orius insidiosus* Say; *Coleomegilla maculata* DeGeer; and *Chrysoperla*, sp. Stephens, was monitored by installing *O. nubilalis* egg masses on sentinel plants in 2008, 2009, and 2010. To assess negative impacts of alternative prey on *O. nubilalis* egg predation, green peach aphid, *Myzus persicae* (Sulzer) populations were monitored via whole-plant counts in 2009 and 2010. *Myzus persicae* densities on pepper plants peaked in June or July and then declined rapidly. Predation on *O. nubilalis* eggs increased rapidly after aphid populations declined. Aphid populations were reduced in two out of three field-seasons in intercropped plots. Seasonal predation by *O. insidiosus* was significantly higher in the intercropped system four out of five field-seasons and one field season by *C. maculata*. Results indicate that biocontrol of *O. nubilalis* can be improved by intercropping with flowering plants, although this capacity may depend on the abundance of alternative prey.

Cagan, L., A. Plackova and P. Bokor (2012). "The Effects of *Nosema pyrausta* Infection on European Corn Borer Populations from Five European Countries." *Acta Protozoologica* 51(2): 169-177.

Ostrinia nubilalis populations from Slovakia, Romania, Austria, Serbia and Germany were collected in the autumn when the insects were in the larval stage. These insects were then established as laboratory populations. The number of pupae and adults that developed was always higher in the *Nosema pyrausta* non-inoculated (uninfected) populations than in the populations treated by the pathogen *N. pyrausta* (infected). Significant differences were also found among the populations from different countries. Infected females laid significantly fewer eggs compared to uninfected females. The average time for pupal eclosion or adult emergence was not significantly different between the uninfected and infected populations of *O. nubilalis*. However, it was found that the infected females laid their eggs significantly sooner as compared to the uninfected females (37.383 days compared to 40.089 days). Under the same conditions, populations from colder regions developed faster than those from warmer regions. The place of origin of the

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population did not significantly influence larval weight, larval length or pupal weight. However, larvae infected with *N. pyrausta* spores had significantly lower weight (average 0.0797 g) than uninfected larvae (0.0901 g). With regard to pupal weight, the difference between the infected and uninfected individuals was not significant. It was confirmed that *N. pyrausta* from one European country can infect and influence host larvae originating in other countries. Although there have been several statistically significant interactions with regard to the country of origin and *N. pyrausta* infection, it was not believed that *N. pyrausta* from one country would have specific effects on the mortality, developmental rate and larval or pupal weight of *O. nubilalis* populations from different countries.

Dinnesen, S., T. Nedelev, M. Gossmann, C. Buttner, H. E. Hummel and C. Ulrichs (2012). *Fusarium* spp. and Mycotoxins in maize fields of western Romania considering infestation with *Diabrotica v. virgifera* and *Ostrinia nubilalis*. *Mitteilungen Der Deutschen Gesellschaft Fur Allgemeine Und Angewandte Entomologie*, Bd 18. S. Handel. 18: 443-445.

Fusarium spp. and Mycotoxins in maize fields of western Romania considering infestation with *Diabrotica v. virgifera* and *Ostrinia nubilalis* The results indicate a surprising ineffectiveness of the wheat-maize crop rotation to regulate the population density of adult western corn rootworms whereas maize following barley showed a significantly lower abundance of adult *Diabrotica v. virgifera*. This also corresponds with a lower percentage of ears damaged by insect feeding and less symptoms of ear rot. The predominant *Fusarium* species were *F. subglutinans*, *F. proliferatum* and *F. verticillioides*. In individual cases *F. lateritium* var. *lateritium*, *F. semitectum* var. *majus* and *F. sporotrichioides* were found. At the locality Sistarovat only *F. subglutinans* was detected in a small number of samples. The detection of fumonisin B-1 by HPLC-UV showed no significant concentrations. Overall the results showed the prevailing influence of local climatic conditions on the spectrum of *Fusarium* spp. and the appearance of ear rot. But in areas with favorable conditions also high population densities of pest insects can strengthen the incidence of ear rot symptoms.

Droney, D. C., C. J. Musto, K. Mancuso, W. L. Roelofs and C. E. Linn (2012). "The Response to Selection for Broad Male Response to Female Sex Pheromone and its Implications for Divergence in Close-Range Mating Behavior in the European Corn Borer Moth, *Ostrinia nubilalis*." *Journal of Chemical Ecology* 38(12): 1504-1512.

Coordinated sexual communication systems, seen in many species of moths, are hypothesized to be under strong stabilizing natural selection. Stabilized communication systems should be resistant to change, but there are examples of species/populations that show great diversification. A possible solution is that it is directional sexual selection on variation in male response that drives evolution. We tested a component of this model by asking whether 'rare' males (ca. 5 % of all males in a population) of the European corn borer moth (ECB), *Ostrinia nubilalis*, that respond to the sex pheromones of both ECB and a different *Ostrinia* species (*O. furnacalis*, the Asian corn borer, ACB), might play an important role in diversification. We specifically tested, via artificial selection, whether this broad male response has an evolvable genetic component. We increased the frequency of broad male response from 5 to 70 % in 19 generations, showing that broad-responding males could be important for the evolution of novel communication systems in ECB. We did not find a broader range of mating acceptance of broad males by females of the base population, however, suggesting that broad response would be unlikely to increase in frequency without the involvement of other factors. However, we found that ECB selection-line females accepted a broader range of courting males, including those of ACB, than did females of the base population. Thus, a genetic correlation exists between broad, long-range response to female sex pheromone and the breadth of female acceptance of males at close range. These results are discussed in the context of evolution of novel communication systems in *Ostrinia*.

Folcher, L., A. Weissenberger and M. Delos (2012). "Quantitative relationships between *Ostrinia nubilalis* activity and deoxynivalenol contamination in French maize." *International Journal of Pest Management* 58(4): 302-309.

We investigated the indirect effect of an insecticide spray against the European Corn Borer (*Ostrinia nubilalis* Hubner; Lepidoptera: Crambidae) on mycotoxin contaminations of grain maize at the harvest stage. Between 2004 and 2009, 45 paired plots comparing insecticide treatment with untreated control were studied in Alsace administrative region, in the northeast of France. An average reduction of 78% in *O. nubilalis* larval densities was observed in insecticide-treated plots compared with control plots. Mean levels of deoxynivalenol mycotoxin in harvested grain were significantly reduced from 849 ppb in the control samples to 152 ppb in the insecticide-treated samples. A statistical modelling approach involving Generalized Linear Models (GLMs) was employed to identify and rank the associated variables for damage and pest density on different plant parts, on deoxynivalenol levels in harvested grain at harvest. The modelling

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revealed that the occurrence and the density of *O. nubilalis* larvae in maize stalks and in ears are the best indicators for deoxynivalenol contamination. The identification of these deoxynivalenol contamination risk factors, along with other factors such as genetic background, harvest date and crop rotation allows improvement of the risk assessment and risk forecasting in maize crops in order to manage crop safety and maintain maize deoxynivalenol mycotoxin levels below the European Regulation (EC) No. 1126/2007 threshold.

Gardner, J., M. G. Wright, T. P. Kuhar, S. A. Pitcher and M. P. Hoffmann (2012). "Dispersal of *Trichogramma ostrinae* in field corn." *Biocontrol Science and Technology* 22(10): 1221-1233.

Trichogramma ostrinae has shown success as a biological control agent for European corn borer (*Ostrinia nubilalis*) in sweet corn and the species offers potential for suppression of lepidopteran pests of field corn. Field corn is typically planted at higher densities, is taller, and has greater leaf area than sweet corn, presenting a possible restriction on *T. ostrinae* dispersal and efficacy. Therefore, parasitoid dispersal in field corn from the centre of a 6.25 ha square grid was determined using sticky cards to capture adult *T. ostrinae* and sentinel eggs of *O. nubilalis* to monitor parasitism after releases of similar to 1 million of *T. ostrinae* each into four fields of corn. Dispersal was rapid and extensive, achieving distances of similar to 175 m within 4-7 days after release. The pattern of movement fit well with a diffusion model of dispersal, with the greatest level of dispersal occurring from 7 to 10 days post-release. Parasitism of *O. nubilalis* sentinel egg masses declined linearly with distance from the release foci, and was also greatest 7-10 days post-release. However, measurement of association showed no significant differences between the spatial distributions of sticky trap captures and percentage parasitism of *O. nubilalis* egg masses. The distances from the release point that encompassed 98% of re-captured *T. ostrinae* increased over time and were estimated to range from a low of 100 m at 4 days post-release to 365 m at 14 days post-release. The results of this research suggest that *T. ostrinae* relies initially on random movement to locate host patches, and that a single release locus per hectare would be sufficient in field corn.

Kang, J., D. W. Onstad, R. L. Hellmich, S. E. Moser, W. D. Hutchison and J. R. Prasifka (2012). "Modeling the Impact of Cross-pollination and Low Toxin Expression in Corn Kernels on Adaptation of European Corn Borer (Lepidoptera: Crambidae) to Transgenic Insecticidal Corn." *Environmental Entomology* 41(1): 200-211.

We used a mathematical model with processes reflecting larval mortality resulting from feeding on cross-pollinated ears or Bt ears of corn to analyze the risk of evolution of Cry-toxin resistance in *Ostrinia nubilalis* (Hubner). In the simulations, evolution of resistance was delayed equally well by both seed mixtures and blocks with the same proportion of refuge. Our results showed that Bt-pollen drift has little impact on the evolution of Bt resistance in *O. nubilalis*. However, low-toxin expression in ears of transgenic corn can reduce the durability of transgenic corn expressing single toxin, whereas durability of pyramided corn hybrids is not significantly reduced. The toxin-survival rate of heterozygous larvae in Bt-corn ears expressing one or two proteins has more impact on evolution of Bt resistance in *O. nubilalis* than the parameters related to larval movement to Bt ears or the toxin-survival rate of the homozygous susceptible larvae in Bt ears. Bt resistance evolves slower when toxin mortality is distributed across the first two larval stadia than when only the first instars are susceptible to Bt toxins. We suggest that stakeholders examine toxin-survival rates for insect pests and take into account that instars may feed on different parts of Bt corn.

Kocourek, F. and J. Stara (2012). "Efficacy of Bt Maize against European Corn Borer in Central Europe." *Plant Protection Science* 48: S25-S35.

KOCOUREK F., STARA J. (2012): Efficacy of Bt maize against European corn borer in Central Europe. *Plant Protection Science*, 48 (Special Issue): S25-S35. The efficacy of Bt maize MON 810-YieldGard (R) and of *Trichogramma* wasp against European corn borer (ECB) (*Ostrinia nubilalis* Hubner) was evaluated in the period of 2002-2008 in field trials on three localities in the Czech Republic. The efficacy of Bt maize on the reduction of the number of tunnels caused by ECB per 100 maize plants before harvest was always 100% and that in *Trichogramma* treatment was on average 50%. The mean increase of the yield of 15% and 10% was obtained in Bt maize and *Trichogramma* treatments, respectively in comparison with the untreated control. The damage curve and economic injury level by ECB on maize was developed for the evaluation of the yield losses and management of the pest control. The higher economic efficacy of growing Bt maize as compared to other control measures is documented.

Leppik, E. and B. Frerot (2012). "Volatile organic compounds and host-plant specialization in European corn borer E and Z pheromone races." *Chemoecology* 22(2): 119-129.

Plant volatile cues are considered the main source of information for ovipositing moths, which use chemical information to locate and recognize the host plant. In Europe, two sympatric populations of European corn borer (ECB; *Ostrinia nubilalis*, Hubner), the Z and E-pheromone races, feed mainly on maize and hop or mugwort, respectively. We studied the mechanisms of host-plant recognition and fidelity in ECB pheromone races by testing the attractiveness of host plants to gravid females in a flight tunnel and by analyzing the volatiles released from maize, mugwort, and hop during the scotophase, when the ovipositing flight of the ECB females occurs. In the wind tunnel bioassay, the Z-race and E-race females engaged in upwind flight and expressed a strong host fidelity to their respective main host plants; all three of these host plants possess distinctive volatile profiles specific as to blend and ratio. The host plants shared a certain number of ubiquitous volatiles present in various ratios that likely constitute a species-specific cue to host-seeking ECB moths. Our observations therefore suggest that ECB host fidelity is steered by plant volatiles that are present in species-specific ratios of ubiquitous volatile organic compounds.

Maiorano, A. (2012). "A physiologically based approach for degree-day calculation in pest phenology models: the case of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in Northern Italy." *International Journal of Biometeorology* 56(4): 653-659.

Phenological models based on degree-day accumulation have been developed to support the integrated pest management of many insects. Most of these models are based on linear relationships between temperature and development, and on daily time step simulations using daily minimum and maximum temperatures. This approach represents an approximation that does not take into account the insect physiological response to temperature, and daily temperature fluctuations. The objective of this work has been to develop a phenological model for the European corn borer (ECB) based on the insect physiological response to temperature and running at an hourly time step. Two modeling solutions based on the same generic compartmental system have been compared: the first based on a physiologically based relationship between temperature and development, and using hourly derived temperatures as input (HNL modeling solution); and the second based on a linear relationship between temperature and degree-day accumulation and using daily temperature (DL modeling solution). The two approaches have been compared using ECB moth capture data from the Piemonte region in Northern Italy. The HNL modeling solution showed the best results for all the accuracy indicators. The DL modeling solution showed a tendency to anticipate ECB phenological development too early. This tendency is attributable to the linear relationship between temperature and development, which does not take into account (1) the decline of this relationship at high temperatures, and (2) the daily fluctuation of temperature. As a consequence, degree-days accumulation is accelerated in the DL modeling solution and the phenological development anticipated.

Maiorano, A., S. Bregaglio, M. Donatelli, D. Fumagalli and A. Zucchini (2012). "Comparison of modelling approaches to simulate the phenology of the European corn borer under future climate scenarios." *Ecological Modelling* 245: 65-74.

The phenological development of insects is simulated predominantly via models based on the response of the organisms to air temperature. Despite of a large body of literature supporting the evidence that the organism physiological response to temperature is nonlinear, including a declining phase, most of these models calculate the rate of development using a linear approach, implying that air temperatures mostly does not fall outside of the linear region of response to temperature of the organism. Another simplification is represented by the calculation of the rate of development using daily mean air temperature, which has already been demonstrated being a reliable method only in limited conditions. It can be hypothesized that the use of developmental models based on linear developmental rates, which can be successfully applied under climate conditions to which organisms are well adapted, could be inadequate under either future climatic scenarios or when extreme events occur (e.g., heat waves). In such contexts, linear responses might lead to interpretations of climate effects not consistent with the real organism physiological response to temperature. In this work the case of *Ostrinia nubilalis* Hubner (European corn borer, ECB) development was taken as an example to compare (i) a nonlinear approach with hourly air temperature as input (HNL approach), (ii) a linear based approach with hourly air temperature as input (HL approach), (iii) a linear based approach with daily air temperature as input (averaging method, DL approach), and (iv) a linear based approach using a cutoff temperature with daily air temperature as input (DLcutoff approach). The comparison was performed under the IPCC (Intergovernmental Panel for Climate Change) emission scenario A1B, and three time frames in Europe: 1995-2004 (baseline-2000s), 2015-2024

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(2020s), and 2045-2054 (2050s). The SRES A1B was selected as one of those for which the projected raise of temperature is estimated to be one of the highest, although the projected difference comparing to the other SRES is estimated as evident in the 2050s time frame, among the ones considered. Using degree-days as a proxy for the rate of development, results showed that the DL approach predicts more than the HNL in all the time frames in almost all Europe with the exception of Southern Italy and the Mediterranean coasts of France and Spain where the differences were negligible. These effects were due (i) to the linear relationship used by the DL approach, and partially (ii) to the averaging operation that decrease the effects of high temperatures in regions with high (but not extreme) warm temperatures. The HNL and HL approach predicted the same pattern of degree-days accumulation in all Europe with the exception of the regions of Southern Iberian peninsula (across all the timeframes), Balkans, and Turkey (under the 2050 scenario). This effect was due to the different HNL and HL accumulation of degree-days at temperatures higher than the ECB optimum temperature. The comparison between the DLcutoff and the HNL approaches showed similar results to the DL vs HNL approach in central and Northern Europe, while in Southern Europe a negative difference (more DD accumulated for the HNL approach) were observed: in regions characterized by high temperatures, the cutoff temperature, setting a limit to the maximum temperatures diminished the calculated average temperature and as a consequence the calculated degree-days. The results of this work showed that according to the method chosen for simulations, different results can be obtained, hence leading to different conclusions about the effect of a warming climate on pest development. These results stress the need of reconsidering the appropriateness of models to be used, which cannot be assumed as correct on the basis of their effectiveness under current conditions. (C) 2012 Elsevier B.V. All rights reserved.

Orsini, E., L. M. Krchov, J. Uphaus and A. E. Melchinger (2012). "Mapping of QTL for resistance to first and second generation of European corn borer using an integrated SNP and SSR linkage map." *Euphytica* 183(2): 197-206.

The European corn borer (ECB, *Ostrinia nubilalis* Hubner) is a major pest of maize (*Zea mays* L.) in North America and Europe. In this study, we mapped and characterized QTL affecting the resistance to the first (ECB1) and second generation (ECB2) of ECB and plant height with the aid of 164 SNP and 88 SSR markers. A total of 144 testcross (TC) progenies of double haploid (DH) lines developed from a cross of two parental lines from the Stiff Stalk germplasm pool were tested at six different locations in the USA under both natural and artificial infestation with ECB larvae. Resistance to ECB1 and ECB2 was assessed by measuring leaf feeding and stalk breakage, respectively, using a visual rating scale from 1 (severe damage) to 9 (no damage). Genotypic variance among the TC progenies was significant for all traits. Heritabilities were moderately high (0.69) for stalk breakage and plant height (0.75), but only moderate for leaf feeding (0.43). For stalk breakage, three QTL were detected that together explained 36% of the genetic variance, whereas for leaf feeding only one QTL was mapped, which explained 25% of the genotypic variance. For plant height, two QTL were identified, explaining 20% of the genotypic variance. The QTL for leaf feeding and stalk breakage mapped by us were located in chromosomal regions adjacent to those reported for other maize germplasm and therefore might be suitable candidates for marker-assisted selection (MAS) during line development.

Razze, J. M. and C. E. Mason (2012). "Dispersal Behavior of Neonate European Corn Borer (Lepidoptera: Crambidae) on Bt Corn." *Journal of Economic Entomology* 105(4): 1214-1223.

European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), has historically been a significant economically important insect pest of corn (*Zea mays* L.) in the United States and Canada. The development in the 1990s of genetically modified corn expressing genes derived from *Bacillus thuringiensis* (Bt) that encodes insecticidal crystalline (Cry) proteins has proven to be effective in controlling this insect as well as other corn pests. The purpose of this study was to assess the movement and dispersal behavior of neonate European corn borer on Bt corn. We examined differences in neonate European corn borer dispersal behavior for the first 4 h after eclosion in the field among a stacked pyramid (Cry1F x Cry1Ab x Cry34/35Ab1) Bt corn, a Cry1F Bt corn, and a non-Bt sweet corn; and in the laboratory among a Bt corn hybrid containing Cry1F, a hybrid containing Cry1Ab, a pyramid combining these two hybrids (Cry1F x Cry1Ab), and a non-Bt near isoline corn. In field experiments, we found that dispersal was significantly higher on Bt corn compared with sweet corn. In laboratory experiments, dispersal was significantly higher on Cry1Ab Bt corn and Cry1F x Cry1Ab Bt corn than on non-Bt near isoline corn. Results indicated that neonate dispersal may be significantly greater in Bt cornfields compared with non-Bt cornfields. The findings on dispersal behavior in this study

will be useful in evaluating the efficacy of a blended seed refuge system for managing European corn borer resistance in Bt corn.

Secil, E. S., A. Sevim, Z. Demirbag and I. Demir (2012). "Isolation, characterization and virulence of bacteria from *Ostrinia nubilalis* (Lepidoptera: Pyralidae)." *Biologia* 67(4): 767-776.

Isolation, characterization and virulence of the culturable bacteria from entire tissues of larval *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae) were studied to obtain new microbes for biological control. A total of 16 bacteria were isolated from living and dead larvae collected from different maize fields in the Eastern Black Sea Region of Turkey. The bacterial microbiota of *O. nubilalis* were identified as *Pseudomonas aeruginosa* (On1), *Brevundimonas aurantiaca* (On2), *Chryseobacterium formosense* (On3), *Acinetobacter* sp. (On4), *Microbacterium thalassium* (On5), *Bacillus megaterium* (On6), *Serratia* sp. (On7), *Ochrobactrum* sp. (On8), *Variovorax paradoxus* (On9), *Corynebacterium glutamicum* (On10), *Paenibacillus* sp. (On11), *Alcaligenes faecalis* (On12), *Microbacterium testaceum* (On13), *Leucobacter* sp. (On14), *Leucobacter* sp. (On15) and *Serratia marcescens* (On16) based on their morphological and biochemical characteristics. A partial sequence of the 16S rRNA gene was also determined to confirm strain identification. The highest insecticidal activities were obtained from *P. aeruginosa* On1 (80%), *Serratia* sp. On7 (60%), *V. paradoxus* On9 (50%) and *S. marcescens* On16 (50%) against larvae 14 days after treatment ($p < 0.05$). Also, the highest activity from previously isolated *Bacillus* species was observed from *Bacillus thuringiensis* subsp. *tenebrionis* Xd3 with 80% mortality within the same period ($p < 0.05$). Our results indicate that *P. aeruginosa* On1, *Serratia* sp. On7, *V. paradoxus* On9, *S. marcescens* On16 and *B. thuringiensis* subsp. *tenebrionis* Xd3 show potential for biocontrol of *O. nubilalis*.

Xue, B. Y., A. P. Rooney and W. L. Roelofs (2012). "Genome-wide screening and transcriptional profile analysis of desaturase genes in the European corn borer moth." *Insect Science* 19(1): 55-63.

Acyl-coenzyme A (Acyl-CoA) desaturases play a key role in the biosynthesis of female moth sex pheromones. Desaturase genes are encoded by a large multigene family, and they have been divided into five subgroups on the basis of biochemical functionality and phylogenetic affinity. In this study both copy numbers and transcriptional levels of desaturase genes in the European corn borer (ECB), *Ostrinia nubilalis*, were investigated. The results from genome-wide screening of ECB bacterial artificial chromosome (BAC) library indicated there are many copies of some desaturase genes in the genome. An open reading frame (ORF) has been isolated for the novel desaturase gene ECB ezi-Delta 11 beta from ECB gland complementary DNA and its functionality has been analyzed by two yeast expression systems. No functional activities have been detected for it. The expression levels of the four desaturase genes both in the pheromone gland and fat body of ECB and Asian corn borer (ACB), *O. furnacalis*, were determined by real-time polymerase chain reaction. In the ECB gland, Delta 11 is the most abundant, although the amount of Delta 14 is also considerable. In the ACB gland, Delta 14 is the most abundant and is 100 times more abundant than all the other three combined. The results from the analysis of evolution of desaturase gene transcription in the ECB, ACB and other moths indicate that the pattern of Delta 11 gene transcription is significantly different from the transcriptional patterns of other desaturase genes and this difference is tied to the underlying nucleotide composition bias of the genome.

Yao, J. X., L. L. Buschman, B. Oppert, C. Khajuria and K. Y. Zhu (2012). "Characterization of cDNAs Encoding Serine Proteases and Their Transcriptional Responses to Cry1Ab Protoxin in the Gut of *Ostrinia nubilalis* Larvae." *Plos One* 7(8).

Serine proteases, such as trypsin and chymotrypsin, are the primary digestive enzymes in lepidopteran larvae, and are also involved in *Bacillus thuringiensis* (Bt) protoxin activation and protoxin/toxin degradation. We isolated and sequenced 34 cDNAs putatively encoding trypsins, chymotrypsins and their homologs from the European corn borer (*Ostrinia nubilalis*) larval gut. Our analyses of the cDNA-deduced amino acid sequences indicated that 12 were putative trypsins, 12 were putative chymotrypsins, and the remaining 10 were trypsin and chymotrypsin homologs that lack one or more conserved residues of typical trypsins and chymotrypsins. Reverse transcription PCR analysis indicated that all genes were highly expressed in gut tissues, but one group of phylogenetically-related trypsin genes, OnTry-G2, was highly expressed in larval foregut and midgut, whereas another group, OnTry-G3, was highly expressed in the midgut and hindgut. Real-time quantitative PCR analysis indicated that several trypsin genes (OnTry5 and OnTry6) were significantly up-regulated in the gut of third-instar larvae after feeding on Cry1Ab protoxin from 2 to 24 h, whereas one trypsin (OnTry2) was down-regulated at all time points. Four chymotrypsin and chymotrypsin homolog genes (OnCTP2, OnCTP5, OnCTP12 and OnCTP13) were up-regulated at least 2-fold in the gut of the larvae after feeding on Cry1Ab

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protoxin for 24 h. Our data represent the first in-depth study of gut transcripts encoding expanded families of protease genes in *O. nubilalis* larvae and demonstrate differential expression of protease genes that may be related to Cry1Ab intoxication and/or resistance.

Belda, E., L. Pedrola, J. Pereto, J. F. Martinez-Blanch, A. Montagud, E. Navarro, J. Urchueguia, D. Ramon, A. Moya and M. Porcar (2011). "Microbial Diversity in the Midguts of Field and Lab-Reared Populations of the European Corn Borer *Ostrinia nubilalis*." *Plos One* 6(6).

Background: Insects are associated with microorganisms that contribute to the digestion and processing of nutrients. The European Corn Borer (ECB) is a moth present world-wide, causing severe economical damage as a pest on corn and other crops. In the present work, we give a detailed view of the complexity of the microorganisms forming the ECB midgut microbiota with the objective of comparing the biodiversity of the midgut-associated microbiota and explore their potential as a source of genes and enzymes with biotechnological applications. Methodological/Principal Findings: A high-throughput sequencing approach has been used to identify bacterial species, genes and metabolic pathways, particularly those involved in plant-matter degradation, in two different ECB populations (field-collected vs. lab-reared population with artificial diet). Analysis of the resulting sequences revealed the massive presence of *Staphylococcus warneri* and *Weissella paramesenteroides* in the lab-reared sample. This enabled us to reconstruct both genomes almost completely. Despite the apparently low diversity, 208 different genera were detected in the sample, although most of them at very low frequency. By contrast, the natural population exhibited an even higher taxonomic diversity along with a wider array of cellulolytic enzyme families. However, in spite of the differences in relative abundance of major taxonomic groups, not only did both metagenomes share a similar functional profile but also a similar distribution of non-redundant genes in different functional categories. Conclusions/Significance: Our results reveal a highly diverse pool of bacterial species in both *O. nubilalis* populations, with major differences: The lab-reared sample is rich in gram-positive species (two of which have almost fully sequenced genomes) while the field sample harbors mainly gram-negative species and has a larger set of cellulolytic enzymes. We have found a clear relationship between the diet and the midgut microbiota, which reveals the selection pressure of food on the community of intestinal bacteria.

Burkness, E. C., P. K. O'Rourke and W. D. Hutchison (2011). "Cross-Pollination of Nontransgenic Corn Ears With Transgenic Bt Corn: Efficacy Against Lepidopteran Pests and Implications for Resistance Management." *Journal of Economic Entomology* 104(5): 1476-1479.

The efficacy of nontransgenic sweet corn, *Zea mays* L., hybrids cross-pollinated by *Bacillus thuringiensis* (Bt) sweet corn hybrids expressing Cry1Ab toxin was evaluated in both field and laboratory studies in Minnesota in 2000. Non-Bt and Bt hybrids (maternal plants) were cross-pollinated with pollen from both non-Bt and Bt hybrids (paternal plants) to create four crosses. Subsequent crosses were evaluated for efficacy in the field against European corn borer, *Ostrinia nubilalis* (Hubner), and corn earworm, *Helicoverpa zea* (Boddie), and in laboratory bioassays against *O. nubilalis*. Field studies indicated that crosses with maternal Bt plants led to low levels of survival for both *O. nubilalis* and *H. zea* compared with the non-Bt X non-Bt cross. However, the cross between non-Bt ears and Bt pollen led to survival rates of 43 and 63% for *O. nubilalis* and *H. zea* larvae, respectively. This intermediate level of survival also was reflected in the number of kernels damaged. Laboratory bioassays for *O. nubilalis*, further confirmed field results with larval survival on kernels from the cross between non-Bt ears and Bt pollen reaching 60% compared with non-Bt crossed with non-Bt. These results suggest that non-Bt refuge plants, when planted in proximity to Bt plants, and cross-pollinated, can result in sublethal exposure of *O. nubilalis* and *H. zea* larvae to Bt and may undermine the high-dose/refuge resistance management strategy for corn hybrids expressing Cry1Ab.

Coates, B. S., D. V. Sumerford, M. D. Lopez, H. C. Wang, L. M. Fraser, J. A. Kroemer, T. Spencer, K. S. Kim, C. A. Abel, R. L. Hellmich and B. D. Siegfried (2011). "A single major QTL controls expression of larval Cry1F resistance trait in *Ostrinia nubilalis* (Lepidoptera: Crambidae) and is independent of midgut receptor genes." *Genetica* 139(8): 961-972.

The European corn borer, *Ostrinia nubilalis* (Lepidoptera: Crambidae), is an introduced crop pest in North America that causes major damage to corn and reduces yield of food, feed, and biofuel materials. The Cry1F toxin from *Bacillus thuringiensis* (Bt) expressed in transgenic hybrid corn is highly toxic to *O. nubilalis* larvae and effective in minimizing feeding damage. A laboratory colony of *O. nubilalis* was selected for high levels of Cry1F resistance (> 12,000-fold

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compared to susceptible larvae) and is capable of survival on transgenic hybrid corn. Genetic linkage maps with segregating AFLP markers show that the Cry1F resistance trait is controlled by a single quantitative trait locus (QTL) on linkage group 12. The map position of single nucleotide polymorphism (SNP) markers indicated that midgut Bt toxin-receptor genes, alkaline phosphatase, aminopeptidase N, and cadherin, are not linked with the Cry1F QTL. Evidence suggests that genes within this genome interval may give rise to a novel Bt toxin resistance trait for Lepidoptera that appears independent of known receptor-based mechanisms of resistance.

Crespo, A. L. B., A. Rodrigo-Simon, H. A. A. Siqueira, E. J. G. Pereira, J. Ferre and B. D. Siegfried (2011). "Cross-resistance and mechanism of resistance to Cry1Ab toxin from *Bacillus thuringiensis* in a field-derived strain of European corn borer, *Ostrinia nubilalis*." *Journal of Invertebrate Pathology* 107(3): 185-192.

The cross-resistance spectrum and biochemical mechanism of resistance to the *Bacillus thuringiensis* Cry1Ab toxin was studied in a field-derived strain of *Ostrinia nubilalis* (Hilbner) (Lepidoptera: Crambidae) that was further selected in the laboratory for high levels (> 1000-fold) of resistance to Cry1Ab. The resistant strain exhibited high levels of cross-resistance to Cry1Ac and Cry1Aa but only low levels of cross-resistance (< 4-fold) to CryIF. In addition, there was no significant difference between the levels of resistance to full-length and trypsin-activated Cry1Ab protein. No differences in activity of luminal gut proteases or altered proteolytic processing of the toxin were observed in the resistant strain. Significantly reduced binding of radiolabeled Cry1Aa was observed in the resistant strain whereas binding of Cry1Ab and Cry1Ac was practically the same in both resistant and susceptible strains. The interpretation of the overall data seems to suggest the involvement of an alteration in the binding of Cry1A toxins to a common receptor, which is more clearly revealed by the binding assays using radiolabeled Cry1Aa. (C) 2011 Elsevier Inc. All rights reserved.

Dafoe, N. J., A. Huffaker, M. M. Vaughan, A. J. Duehl, P. E. Teal and E. A. Schmelz (2011). "Rapidly Induced Chemical Defenses in Maize Stems and Their Effects on Short-term Growth of *Ostrinia nubilalis*." *Journal of Chemical Ecology* 37(9): 984-991.

Plants damaged by insect herbivory often respond by inducing a suite of defenses that can negatively affect an insect's growth and fecundity. *Ostrinia nubilalis* (European corn borer, ECB) is one of the most devastating insect pests of maize, and in the current study, we examined the early biochemical changes that occur in maize stems in response to ECB herbivory and how these rapidly induced defenses influence the growth of ECB. We measured the quantities of known maize defense compounds, benzoxazinoids and the kauralexin class of diterpenoid phytoalexins. ECB herbivory resulted in decreased levels of the benzoxazinoid, 2, 4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one)-beta-D-glucopyranose (DIMBOA-Glc), and a corresponding increase in 2-(2-hydroxy-4,7-dimethoxy-1,4-benzoxazin-3-one)-beta-D-glucopyranose (HDMBOA-Glc). Total quantities of benzoxazinoids and kauralexins were increased as early as 24 h after the initiation of ECB feeding. The plant hormones, jasmonic acid (JA) and ethylene (ET), and the transcripts encoding their key biosynthetic enzymes also accumulated in response to ECB herbivory, consistent with a role in defense regulation. The combined pharmacological application of JA and the ET precursor, 1-aminocyclopropane-1-carboxylic acid to stem internode tissue likewise resulted in changes in benzoxazinoids similar to that observed with ECB damage. Despite the fact that maize actively mounts a defense response to ECB stem feeding, no differences in percent weight gain were observed between ECB larvae that fed upon non-wounded control tissues compared to tissues obtained from plants previously subjected to 24 h ECB stem herbivory. These rapid defense responses in maize stems do not appear to negatively impact ECB growth, thus suggesting that ECB have adapted to these induced biochemical changes.

Dopman, E. (2011). "Genetic hitchhiking associated with life history divergence and colonization of North America in the European corn borer moth." *Genetica* 139(5): 565-573.

A primary goal for evolutionary biology is to reveal the genetic basis for adaptive evolution and reproductive isolation. Using Z and E pheromone strains the European corn borer (ECB) moth, I address this problem through multilocus analyses of DNA polymorphism. I find that the locus Triose phosphate isomerase (Tpi) is a statistically significant outlier in coalescent simulations of demographic histories of population divergence, including strict allopatric isolation, restricted migration, secondary contact, and population growth or decline. This result corroborates a previous QTL study that identified the Tpi chromosomal region as a repository for gene(s) contributing to divergence in life history. Patterns of nucleotide polymorphism at Tpi suggest a recent selective sweep and genetic hitchhiking associated with

colonization of North America from Europe similar to 200 generations ago. These results indicate that gene genealogies initially diverge during speciation because of selective sweeps, but differential introgression may play a role in the maintenance of differentiation for sympatric populations.

Dorhout, D. L., T. W. Sappington, L. C. Lewis and M. E. Rice (2011). "Flight behaviour of European corn borer infected with *Nosema pyrausta*." *Journal of Applied Entomology* 135(1-2): 25-37.

The microsporidian *Nosema pyrausta* Paillot is a common and widespread pathogen of European corn borer, *Ostrinia nubilalis* (Hubner), in North America and Europe. *Nosema* negatively affects European corn borer longevity and fecundity. In this study, we used flight mills to examine the effects of *Nosema* infection on flight activity of unmated males and females at 1 and 3 days after pupal eclosion, taking the level of infection, as measured by number of *Nosema* spores per mg of tissue, into consideration. *Nosema* infection had a significant negative effect on distance, duration and speed of the longest uninterrupted flight, as well as on total distance and duration of flight of 1-day-old males, but not of 3-day-old males or females of either age. However, when insects with a light infection (< 15 spores/mg) were pooled with uninfected moths, significant negative effects of a moderate/heavy infection (\geq 15 spores/mg) were observed for most flight parameters in 1-day-old, but not 3-day-old, moths of both sexes. The magnitude of reduction was often substantial: e.g., distance and duration were sevenfold, and 3.5-fold less, respectively, in 1-day-old females with a moderate/heavy infection. Flight distance and duration were significantly negatively correlated with level of *Nosema* infection in 1-day-old, but not 3-day-old, moths of both sexes. The percentage of moths of either sex or age with a moderate/heavy *Nosema* infection flying given distances was less than that of lightly infected (< 15 spores/mg) moths. Among uninfected adults, forewing length was positively correlated with several measures of flight performance in males, but not females. However, some performance measures were correlated with wing length in females when infected with *Nosema*. *Nosema* infection was associated with reduced adult weight, but not forewing length, suggesting that negative effects of *Nosema* infection on flight performance are related to reduced energy reserves rather than smaller body size per se.

Folcher, L., D. Bourguet, D. Thiery, L. Pelozuelo, M. Phalip, A. Weissenberger, N. Eychenne, C. Regnault-Roger and M. Delos (2011). "Changes in Parasitoid Communities Over Time and Space: A Historical Case Study of the Maize Pest *Ostrinia nubilalis*." *Plos One* 6(9).

Understanding the ways in which human environmental modifications affect biodiversity is a key challenge in conservation planning, pest control and evolutionary ecology. Parasitoid communities, particularly those associated with agricultural pests, may be susceptible to such modifications. We document here changes in the larval parasitoid communities of *Ostrinia nubilalis* - the main pest of maize - and its sibling species *O. scapularis*, based on two historical datasets, one collected from 1921-1928 and the other from 2001-2005. Each of these datasets encompasses several years and large geographical areas and was based on several thousands/millions of host larvae. The 80-year interval between the two datasets was marked by a decrease in *O. nubilalis* parasitism to about two thirds its initial level, mostly due to a decrease in the rate of parasitism by hymenopterans. However, a well balanced loss and gain of species ensured that species richness remained stable. Conversely, *O. scapularis* displayed stable rates of parasitism over this period, with a decline in the species richness of its parasitoid community. Rates of parasitism and species richness in regions colonized by *O. nubilalis* during the 1950s were one half to one third those in regions displaying long-term colonisation by this pest. During the recent human activity-driven expansion of its range, *O. nubilalis* has neither captured native parasitoids nor triggered parasite spill back or spill over.

Fujii, T., K. Ito, M. Tatematsu, T. Shimada, S. Katsuma and Y. Ishikawa (2011). "Sex pheromone desaturase functioning in a primitive *Ostrinia* moth is cryptically conserved in congeners' genomes." *Proceedings of the National Academy of Sciences of the United States of America* 108(17): 7102-7106.

(E)-11- and (Z)-11-tetradecenyl acetate are the most common female sex pheromone components in *Ostrinia* moths. The Delta 11-desaturase expressed in the pheromone gland (PG) of female moths is a key enzyme that introduces a double bond into pheromone molecules. A single Delta 11-desaturase of *Ostrinia nubilalis*, OnubZ/E11, has been shown to produce a similar to 7: 3 mixture of (E)-11- and (Z)-11-tetradecenoate from the substrate tetradecanoate. In contrast, the sex pheromone of *Ostrinia latipennis*, a primitive species of *Ostrinia*, is (E)-11-tetradecenol. This pheromone is unique in that it is not acetylated, and includes no Z isomer. In the present study, through the cloning

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and functional analysis of a PG-specific Delta 11-desaturase in *O. latipennis*, we showed that the absence of the Z isomer in the pheromone is attributable to the strict product specificity of the Delta 11-desaturase in this species, LATPG1. Phylogenetic analysis revealed that LATPG1 was not closely related to OnubZ/E11. Rather, it was closely related to retroposon-linked cryptic Delta 11-desaturases (ezi-Delta 11) found in the genomes of *O. nubilalis* and *Ostrinia furnacalis*. Taken together, the results showed that an unusual Delta 11-desaturase is functionally expressed in *O. latipennis*, although the genes encoding this enzyme appear to be cryptic in congeners.

Gardner, J., M. P. Hoffmann, S. A. Pitcher and J. K. Harper (2011). "Integrating insecticides and *Trichogramma ostrinae* to control European corn borer in sweet corn: Economic analysis." *Biological Control* 56(1): 9-16.

We compared the economics of controlling European corn borer (*Ostrinia nubilalis*) in sweet corn by using the egg parasitoid, *Trichogramma ostrinae*, alone and integrated with insecticidal sprays. An initial experiment in 2003 compared *T. ostrinae* alone against insecticide alone and a second set of experiments conducted over 3 years (2006-2008) compared (1) insecticide alone [Insecticide]; (2) no insecticide, no *T. ostrinae* [Untreated Check]; (3) *T. ostrinae* alone [*T. ostrinae* 1X]; and (4) *T. ostrinae* + insecticide [Integrated]. In 2007 and 2008, a fifth treatment was added consisting of three approximately weekly releases of *T. ostrinae* [*T. ostrinae* 3X]. Parasitism of *O. nubilalis* eggs was higher in plots receiving *T. ostrinae*; *O. nubilalis* eclosion was lower with *T. ostrinae*; there was no interaction of *T. ostrinae* and insecticide on parasitism, *O. nubilalis* eclosion, or total *O. nubilalis* larvae at harvest time. Partial crop budgets were conducted for each treatment. In three of the 4 years, Untreated Checks had the highest sweet corn ear damage. Ear damage after a single release of *T. ostrinae* was statistically no different than using insecticides. In two of the three years, the Integrated treatment (*T. ostrinae* 1X + insecticide) generated the largest increase in profitability. The insecticide only treatment generated the second best increase in profitability. When comparing a single release of *T. ostrinae* to the insecticide only, the latter provided a better combination of efficacy and profitability. The breakeven costs of the *T. ostrinae* justified their use relative to the Untreated Check treatment, but not when compared to the Insecticide treatment. The breakeven costs for *T. ostrinae* in the Integrated treatment exceeded the actual cost in two out of three years, suggesting again that conventional growers could benefit from integrating *T. ostrinae* with insecticidal treatments. Projected profitability based on ear packout obtained by combining data among years suggests that in general, for low prices and yields, the increase in profit is quite modest. In the lowest price-yield combination, the change in profit is *T. ostrinae* 3X > Integrated > Insecticide > *T. ostrinae* 1X >= Untreated Check. At high prices and high yields, the differences between the management options when compared to Untreated Check are considerable. In the highest price-yield combination, the change in profit is *T. ostrinae* 3X > Integrated >= Insecticide > *T. ostrinae* 1X >= Untreated Check. (C) 2010 Elsevier Inc. All rights reserved.

Gaspers, C., B. D. Siegfried, T. Spencer, A. P. Alves, N. P. Storer, I. Schuphan and S. Eber (2011). "Susceptibility of European and North American populations of the European corn borer to the Cry1F insecticidal protein." *Journal of Applied Entomology* 135(1-2): 7-16.

Baseline susceptibility to the Cry1F toxin from *Bacillus thuringiensis* was determined for 11 European Union (EU) and 24 United States (US) populations of European corn borer, *Ostrinia nubilalis* (Hubner). The response to Cry1F exposure was measured as mortality and growth inhibition for each population. The aim of this study was to characterize inter-population variation in the susceptibility of EU and US European corn borer (*O. nubilalis*) neonates to Cry1F protein and additionally, intra-population variation for the EU European corn borer to help develop effective and sensitive resistance monitoring methods. In this study, neonate European corn borer were exposed to a range of concentration of microbially-produced Cry1F protein applied to the surface of artificial diet. Measures of mortality and growth inhibition of larvae on surface-treated diet relative to untreated control diet were taken after 7 days. A comparison between European and American corn borer populations showed that the range of variation in Cry1F toxin susceptibility assessed by mortality and growth inhibition was similar. Differences in Cry1F susceptibility between European corn borer populations across continents and among the various populations within each geography were apparent although similar variation among replicates for the same population were also observed in two EU populations. It is likely that these small differences reflect natural variation in sensitivity among populations of European corn borer as well as methodological differences and are not influenced by geographic location. The importance of establishing baseline susceptibilities to resistance detection is discussed.

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Hu, Y. and D. A. Andow (2011). "Field observations of *Ostrinia nubilalis* eclosion and post-eclosion activity of females around their natal plants." *Insect Science* 18(6): 712-718.

The early part of the post-eclosion, pre-mating period were examined under field conditions for *Ostrinia nubilalis*. Post-eclosion behavior of 25 and 21 females during the first and second flight periods were observed until they left their natal site. Summer generation larvae were reared under field conditions and the timing of adult eclosion was observed. Eclosion occurred at two times during the day, peaking before dawn and before dusk; 46% of females and 56% of males eclosed during the morning period and the rest eclosed during the evening period. After eclosion, females spent 3060 min expanding their wings. Their typical behavior was to remain calmly on their natal site. None of the females exhibited calling behavior before leaving. All females left their natal sites sometime before dawn. The probability of leaving increased with time. Leaving rates were not significantly different between females of the first and second flight. These field observations indicate that females have several possibilities for pre-mating movement, which might allow females to move out from their natal field before mating. In addition, we also discuss the influence of pre-mating movements in relation to the rate of *Bacillus thuringiensis* (Bt) resistance evolution.

Huang, F. N., D. A. Andow and L. L. Buschman (2011). "Success of the high-dose/refuge resistance management strategy after 15 years of Bt crop use in North America." *Entomologia Experimentalis Et Applicata* 140(1): 1-16.

Transgenic maize and cotton expressing *Bacillus thuringiensis* (Bt) toxins were first commercialized in 1996. By 2009, Bt crops were planted on ca. 47.6 Mha in 22 countries worldwide, with the USA and Canada accounting for 54% of this area. Resistance (virulence) development in target insect pests is a major threat to the sustainable use of Bt crops. Four major target pests of Bt crops in the USA and Canada - European corn borer, *Ostrinia nubilalis* (Hubner), southwestern corn borer, *Diatraea grandiosella* Dyar (both Lepidoptera: Crambidae), tobacco budworm, *Heliothis virescens* Fabricius (Lepidoptera: Noctuidae), and pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) - remain susceptible to Bt toxins after 15 years of intensive use of Bt maize and Bt cotton. The success in sustaining susceptibility in these major pests is associated with successful implementation of the 'high-dose/refuge' insecticide resistance management (IRM) strategy: (i) Bt crop cultivars express a 'high dose', (ii) initial frequency of resistance alleles is very low, and (iii) a refuge is maintained nearby in the environment. Field resistance (including control failure) to a Bt crop has been clearly documented in three situations: fall armyworm [*Spodoptera frugiperda* JE Smith] in Puerto Rico, African stem borer [*Busseola fusca* Fuller (Lepidoptera: Noctuidae)] in South Africa, and *P. gossypiella* in India. Factors associated with these cases of field resistance include: failure to use high-dose Bt cultivars and lack of sufficient refuge. These observations support the claim that implementation of the 'high-dose/refuge' IRM strategy has been successful in substantially delaying field resistance to Bt crops.

Huffaker, A., F. Kaplan, M. M. Vaughan, N. J. Dafoe, X. Z. Ni, J. R. Rocca, H. T. Alborn, P. E. A. Teal and E. A. Schmelz (2011). "Novel Acidic Sesquiterpenoids Constitute a Dominant Class of Pathogen-Induced Phytoalexins in Maize." *Plant Physiology* 156(4): 2082-2097.

Nonvolatile terpenoid phytoalexins occur throughout the plant kingdom, but until recently were not known constituents of chemical defense in maize (*Zea mays*). We describe a novel family of ubiquitous maize sesquiterpenoid phytoalexins, termed zealexins, which were discovered through characterization of *Fusarium graminearum*-induced responses. Zealexins accumulate to levels greater than 800 mg g⁻¹ fresh weight in *F. graminearum*-infected tissue. Their production is also elicited by a wide variety of fungi, *Ostrinia nubilalis* herbivory, and the synergistic action of jasmonic acid and ethylene. Zealexins exhibit antifungal activity against numerous phytopathogenic fungi at physiologically relevant concentrations. Structural elucidation of four members of this complex family revealed that all are acidic sesquiterpenoids containing a hydrocarbon skeleton that resembles beta-macrocarpene. Induced zealexin accumulation is preceded by increased expression of the genes encoding TERPENE SYNTHASE6 (TPS6) and TPS11, which catalyze beta-macrocarpene production. Furthermore, zealexin accumulation displays direct positive relationships with the transcript levels of both genes. Microarray analysis of *F. graminearum*-infected tissue revealed that *Tps6/Tps11* were among the most highly up-regulated genes, as was *An2*, an ent-copalyl diphosphate synthase associated with production of kauralexins. Transcript profiling suggests that zealexins cooccur with a number of antimicrobial proteins, including chitinases and pathogenesis-related proteins. In addition to zealexins, kauralexins and the benzoxazinoid 2-hydroxy-4,7-dimethoxy-1,4-benzoxazin-3-one-glucose (HDMBOA-glucose) were produced in fungal-infected tissue. HDMBOA-glucose accumulation occurred in both wild-type and benzoxazine-deficient1 (*bx1*) mutant lines, indicating

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that Bx1 gene activity is not required for HDMBOA biosynthesis. Together these results indicate an important cooperative role of terpenoid phytoalexins in maize biochemical defense.

Ikten, C., S. R. Skoda, T. E. Hunt, J. Molina-Ochoa and J. E. Foster (2011). "Genetic Variation and Inheritance of Diapause Induction in Two Distinct Voltine Ecotypes of *Ostrinia nubilalis* (Lepidoptera: Crambidae)." *Annals of the Entomological Society of America* 104(3): 567-575.

European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), displays a larval diapause in response to short photoperiods and is adapted to a variety of local conditions throughout North America. Hence, the effective photoperiod inducing larval diapause will differ among geographic ecotypes. This study considers the inheritance of photoperiodic larval diapause induction by hybridization and backcrossing two latitudinally distinct ecotypes of the European corn borer collected between 41 degrees N, 96 degrees W and 48 degrees N, 96 degrees W and under a range of photoperiods representative of their respective locations: from 14:10 to 16:8 (L:D) h. The ecotype adapted to a bivoltine habitat (southeastern Nebraska) exhibited a shorter critical photoperiod (1480 h) than the ecotype (1533 h), originating from a univoltine habitat (northwestern Minnesota). Reciprocal F(1) crosses exhibited intermediate values with indication of sex-linked inheritance. In addition, the male parent had significantly more influence on diapause incidence of subsequent progeny than the female. The F(2) and backcross progeny further supported the supposition that diapause response is a sex-linked inheritance. The minimum number of genes estimates, and the response from backcross progeny, suggest that diapause response of European corn borer larva may be controlled by only a few loci. The overall results indicated that both ecotypes had adopted unique diapause responses, which ultimately lead to seasonal synchrony in their ecosystems.

Khajuria, C., L. L. Buschman, M. S. Chen, B. D. Siegfried and K. Y. Zhu (2011). "Identification of a Novel Aminopeptidase P-Like Gene (OnAPP) Possibly Involved in Bt Toxicity and Resistance in a Major Corn Pest (*Ostrinia nubilalis*)." *Plos One* 6(8).

Studies to understand the *Bacillus thuringiensis* (Bt) resistance mechanism in European corn borer (ECB, *Ostrinia nubilalis*) suggest that resistance may be due to changes in the midgut-specific Bt toxin receptor. In this study, we identified 10 aminopeptidase-like genes, which have previously been identified as putative Bt toxin receptors in other insects and examined their expression in relation to Cry1Ab toxicity and resistance. Expression analysis for the 10 aminopeptidase-like genes revealed that most of these genes were expressed predominantly in the larval midgut, but there was no difference in the expression of these genes in Cry1Ab resistant and susceptible strains. This suggested that altered expression of these genes was unlikely to be responsible for resistance in these ECB strains. However, we found that there were changes in two amino acid residues of the aminopeptidase-P like gene (OnAPP) involving Glu(305) to Lys(305) and Arg(307) to Leu(307) in the two Cry1Ab-resistant strains as compared with three Cry1Ab-susceptible strains. The mature OnAPP contains 682 amino acid residues and has a putative signal peptide at the N-terminus, a predicted glycosylphosphatidyl-inositol (GPI)-anchor signal at the C-terminal, three predicted N-glycosylation sites at residues N178, N278 and N417, and an O-glycosylation site at residue T653. We used a feeding based-RNA interference assay to examine the role of the OnAPP gene in Cry1Ab toxicity and resistance. Bioassays of Cry1Ab in larvae fed diet containing OnAPP dsRNA resulted in a 38% reduction in the transcript level of OnAPP and a 25% reduction in the susceptibility to Cry1Ab as compared with larvae fed GFP dsRNA or water. These results strongly suggest that the OnAPP gene could be involved in binding the Cry1Ab toxin in the ECB larval midgut and that mutations in this gene may be associated with Bt resistance in these two ECB strains.

Khajuria, C., L. L. Buschman, M. S. Chen, L. Zurek and K. Y. Zhu (2011). "Characterization of six antibacterial response genes from the European corn borer (*Ostrinia nubilalis*) larval gut and their expression in response to bacterial challenge." *Journal of Insect Physiology* 57(3): 345-355.

Six cDNAs encoding putative antibacterial response proteins were identified and characterized from the larval gut of the European corn borer (*Ostrinia nubilalis*). These antibacterial response proteins include four peptidoglycan recognition proteins (PGRPs), one beta-1,3-glucanase-1 (beta glu-1), and one lysozyme. Tissue-specific expression analysis showed that these genes were highly expressed in the midgut, except for lysozyme. Analysis of expression of these genes in different developmental stage showed that they were expressed in larval stages, but little or no detectable expression was found in egg, pupa and adult. When larvae were challenged with Gram-negative bacteria (*Enterobacter aerogenes*), the expression of all six genes was up-regulated in the fatbodies. However, when larvae were

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challenged with Gram-positive bacteria (*Micrococcus luteus*), only PGRP-C and lysozyme genes were up-regulated. This study provides additional insights into the expression of antibacterial response genes in *O. nubilalis* larvae and helps us better understand the immune defense response in *O. nubilalis*. (C) 2010 Elsevier Ltd. All rights reserved.

Kocmankova, E., M. Trnka, J. Eitzinger, M. Dubrovsky, P. Stepanek, D. Semeradova, J. Balek, P. Skalak, A. Farda, J. Juroch and Z. Zalud (2011). "Estimating the impact of climate change on the occurrence of selected pests at a high spatial resolution: a novel approach." *Journal of Agricultural Science* 149: 185-195.

The present study is focused on the potential occurrence of the Colorado potato beetle (*Leptinotarsa decemlineata*, Say 1824), an important potato pest, and the European corn borer (*Ostrinia nubilalis*, Hubner 1796), the most important maize pest, during climate change. Estimates of the current potential distribution of both pest species as well as their distribution in the expected climate conditions are based on the CLIMEX model. The study covers central Europe, including Austria, the Czech Republic, Hungary, and parts of Germany, Poland, Romania, Slovakia, Switzerland, Ukraine, Slovenia, the northern parts of Serbia, parts of Croatia and northern Italy. The validated model of the pests' geographical distribution was applied within the domain of the regional climate model (RCM) ALADIN, at a resolution of 10 km. The weather series that was the input for the CLIMEX model was prepared by a weather generator (WG) which was calibrated with the RCM-simulated weather series (for the period of 1961-90). To generate a weather series for two future time periods (2021-50 and 2071-2100), the WG parameters were modified according to 12 climate change scenarios produced by the pattern scaling method. The standardized scenarios derived from three global climate models (HadCM, NCAR-PCM and ECHAM) were scaled by low, middle and high values of global temperature change estimated by the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) model (assuming three combinations of climatic sensitivity and emission scenarios). The results of present study suggest the likely widening of the pests' habitats and an increase in the number of generations per year. According to the HadCM-high scenario, the area of arable land affected by a third generation per season of Colorado potato beetle in 2050 is c. 45% higher, and by a second generation of the European corn borer is nearly 61% higher, compared to present levels.

Kroemer, J. A., B. S. Coates, T. Nusawardani, S. D. Rider, L. M. Fraser and R. L. Hellmich (2011). "A rearrangement of the Z chromosome topology influences the sex-linked gene display in the European corn borer, *Ostrinia nubilalis*." *Molecular Genetics and Genomics* 286(1): 37-56.

Males are homogametic (ZZ) and females are heterogametic (WZ) with respect to the sex chromosomes in many species of butterflies and moths (insect order Lepidoptera). Genes on the Z chromosome influence traits involved in larval development, environmental adaptation, and reproductive isolation. To facilitate the investigation of these traits across Lepidoptera, we developed 43 degenerate primer pairs to PCR amplify orthologs of 43 *Bombyx mori* Z chromosome-linked genes. Of the 34 orthologs that amplified by PCR in *Ostrinia nubilalis*, 6 co-segregated with the Z chromosome anchor markers *kettin* (*ket*) and *lactate dehydrogenase* (*ldh*), and produced a consensus genetic linkage map of similar to 89 cM in combination with 5 AFLP markers. The *O. nubilalis* and *B. mori* Z chromosomes are comparatively co-linear, although potential gene inversions alter terminal gene orders and a translocation event disrupted synteny at one chromosome end. Compared to *B. mori* orthologs, *O. nubilalis* Z chromosome-linked genes showed conservation of tissue-specific and growth-stage-specific expression, although some genes exhibited species-specific expression across developmental stages or tissues. The *O. nubilalis* Z chromosome linkage map provides new tools for isolating quantitative trait loci (QTL) involved in sex-linked traits that drive speciation and it exposes genome rearrangements as a possible mechanism for differential gene regulation in Lepidoptera.

Kroemer, J. A., T. Nusawardani, M. A. Rausch, S. E. Moser and R. L. Hellmich (2011). "Transcript analysis and comparative evaluation of shaker and slowmo gene homologues from the European corn borer, *Ostrinia nubilalis*." *Insect Molecular Biology* 20(4): 493-506.

The movement and dispersal of larval Lepidoptera impact their survival and distribution within the natural landscape. Homologues of the *Drosophila* behaviour-linked genes *shaker* (*shkr*) and *slowmo* (*slmo*) were identified from *Ostrinia nubilalis* (Lepidoptera: Crambidae). *Onshkr* was isolated as a 1610-nucleotide (nt) constitutively expressed transcript encoding a membrane-localized 469-amino-acid (aa) protein with a conserved tetramerization domain and the six-domain architecture necessary for the molecule to fold into an active K⁺ channel. Three expressed splice variants of 682, 970 and 1604 nt were identified for the *Onslmo* gene, and encode predicted 141 and 228 aa proteins with a

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conserved protein of relevant evolutionary and lymphoid interest (PRELI) domain that may function in mitochondrial protein sorting and perinuclear protein localization. Onshkr and Onslmo protein sequences aligned within monophyletic lepidopteran groups.

Lassance, J. M., S. M. Bogdanowicz, K. W. Wanner, C. Lofstedt and R. G. Harrison (2011). "GENE GENEALOGIES REVEAL DIFFERENTIATION AT SEX PHEROMONE OLFACTORY RECEPTOR LOCI IN PHEROMONE STRAINS OF THE EUROPEAN CORN BORER, *OSTRINIA NUBILALIS*." *Evolution* 65(6): 1583-1593.

Males of the E and Z strains of the European corn borer *Ostrinia nubilalis* (Lepidoptera: Crambidae) are attracted to different blends of the same pheromone components. The difference in male behavioral response is controlled by the sex-linked locus *Resp*. The two types of males have identical neuroanatomy but their physiological specificity is reversed, suggesting that variation at the periphery results in behavioral change. Differences in the olfactory receptors (ORs) could explain the strain-specific antennal response and blend preference. Gene genealogies can provide insights into the processes involved in speciation and allow delineation of genome regions that contribute to reproductive barriers. We used intronic DNA sequences from five OR-encoding genes to investigate whether they exhibit fixed differences between strains and therefore might contribute to reproductive isolation. Although two genealogies revealed shared polymorphism, molecular polymorphism at three genes revealed nearly fixed differences between strains. These three OR genes map to the sex chromosome, but our data indicate that the distance between *Resp* and the ORs is > 20 cM, making it unlikely that variation in pheromone-sensitive OR genes is directly responsible for the difference in behavioral response. However, differences in male antennal response may have their origin in the selection of strain-specific alleles.

Lopez-Alonso, C., M. Eizaguirre and R. Albajes (2011). "Short communication. Mutual pheromone antagonism in two sympatric corn borers, *Sesamia nonagrioides* and *Ostrinia nubilalis*, under field conditions." *Spanish Journal of Agricultural Research* 9(1): 308-312.

In previous studies, we demonstrated cross-antagonism in pheromone perception between pheromone components of the two corn (*Zea mays* L.) borers *Sesamia nonagrioides* Lefebvre (Lepidoptera: Noctuidae) and *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) in the laboratory and in the field. The two pheromone components identified as responsible for this cross-antagonism were Z 11-16:Ald, a minor component of *S. nonagrioides* pheromone, and Z 1114:Ac, the main component of the pheromone of the Z-strain of *O. nubilalis*, which inhibited the response of *O. nubilalis* and *S. nonagrioides*, respectively. Here, we study this antagonism phenomenon in the field by air permeation of maize plots with each of the two components separately and measurement of mating in caged couples of the two corn borers on treated and untreated plots during three years. A significant reduction in mating rates was observed on the permeated plots: 7% for *S. nonagrioides* and 12% for *O. nubilalis*. When dispenser charges (200 ng) were increased by 50% and 75% in the third year, no decrease in mating rates was recorded at either of the increased concentrations. On the other hand, the use of large cages resulted in an increase of 8% to 12% in the percentage of unmated females in each of the two corn borers suggesting that at more realistic field corn borer densities, 0,1 couples/plant instead of the 2 couples/plant used in this experiment, cross-antagonism in the two corn borers could be higher than that recorded in small cages.

Mazzoni, E., A. Scandolara, P. Giorni, A. Pietri and P. Battilani (2011). "Field control of *Fusarium* ear rot, *Ostrinia nubilalis* (Hubner), and fumonisins in maize kernels." *Pest Management Science* 67(4): 458-465.

BACKGROUND: A 6 year study was conducted to evaluate the possible support of pesticides in mitigating mycotoxin contamination in maize grown in northern Italy. Different pesticides to control *Ostrinia nubilalis* (Hubner) (ECB), *Fusarium verticillioides* (Sacc.) Nirenb. and *Aspergillus flavus* Link were considered to check their efficacy and the best schedule to reduce fumonisin and aflatoxin contamination. **RESULTS:** Fumonisin B(1) (FB(1)) contamination at harvest has been reduced by ECB control, while the addition of ingredients targeted to *F. verticillioides* gave a limited advantage, mainly with low FB(1) contamination; nevertheless, fusaria control is relevant in high-risk conditions, when FB(1) is likely to exceed the legal limit. The combination of fungal and pest control in a single spray at silk browning stage (BBCH 67) is the best way of application. These results are robust because they were obtained in a 6 year trial, with relevant differences in meteorological conditions, ECB and fungal presence and mycotoxin contamination. **CONCLUSION:** Insecticides have been shown to give advantages in their application, while the low FB(1) contamination

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in the final years of the study did not lead to conclusive data on the advantage of adding a fungicide. Chemicals applied did not modify *A. flavus* incidence or aflatoxin contamination (only detected in trace amounts). (C) 2011 Society of Chemical Industry

Meissle, M., J. Romeis and F. Bigler (2011). "Bt maize and integrated pest management - a European perspective." *Pest Management Science* 67(9): 1049-1058.

The European corn borer (*Ostrinia nubilalis*), the Mediterranean corn borer (*Sesamia nonagrioides*) and the western corn rootworm (*Diabrotica virgifera virgifera*) are the main arthropod pests in European maize production. Practised pest control includes chemical control, biological control and cultural control such as ploughing and crop rotation. A pest control option that is available since 1996 is maize varieties that are genetically engineered (GE) to produce insecticidal compounds. GE maize varieties available today express one or several genes from *Bacillus thuringiensis* (Bt) that target corn borers or corn rootworms. Incentives to growing Bt maize are simplified farm operations, high pest control efficiency, improved grain quality and ecological benefits. Limitations include the risk of resistance evolution in target pest populations, risk of secondary pest outbreaks and increased administration to comply with licence agreements. Growers willing to plant Bt maize in the European Union (EU) often face the problem that authorisation is denied. Only one Bt maize transformation event (MON810) is currently authorised for commercial cultivation, and some national authorities have banned cultivation. Spain is the only EU member state where Bt maize adoption levels are currently delivering farm income gains near full potential levels. In an integrated pest management (IPM) context, Bt maize can be regarded as a preventive (host plant resistance) or a responsive pest control measure. In any case, Bt maize is a highly specific tool that efficiently controls the main pests and allows combination with other preventive or responsive measures to solve other agricultural problems including those with secondary pests. (c) 2011 Society of Chemical Industry

Midamegbe, A., R. Vitalis, T. Malausa, E. Delava, S. Cros-Arteil and R. Streiff (2011). "Scanning the European corn borer (*Ostrinia* spp.) genome for adaptive divergence between host-affiliated sibling species." *Molecular Ecology* 20(7): 1414-1430.

It has recently been shown that the European corn borer, a major pest of maize crops, is actually composed of two genetically differentiated and reproductively isolated taxa, which are found in sympatry over a wide geographical range in Eurasia. Each taxon is adapted to specific host plants: *Ostrinia nubilalis* feeds mainly on maize, while *O. scapularis* feeds mainly on hop or mugwort. Here, we present a genome scan approach as a first step towards an integrated molecular analysis of the adaptive genomic divergence between *O. nubilalis* and *O. scapularis*. We analysed 609 AFLP marker loci in replicate samples of sympatric populations of *Ostrinia* spp. collected on maize, hop and mugwort, in France. Using two genome scan methods based on the analysis of population differentiation, we found a set of 28 outlier loci that departed from the neutral expectation in one or the other method (of which a subset of 14 loci were common to both methods), which showed a significantly increased differentiation between *O. nubilalis* and *O. scapularis*, when compared to the rest of the genome. A subset of 12 outlier loci were sequenced, of which 7 were successfully re-amplified as target candidate loci. Three of these showed homology with annotated lepidopteran sequences from public nucleotide databases.

O'Rourke, M. E. and L. E. Jones (2011). "Analysis of landscape-scale insect pest dynamics and pesticide use: an empirical and modeling study." *Ecological Applications* 21(8): 3199-3210.

Diverse agricultural landscapes help support many ecosystem services, including insect pest suppression. Yet questions remain about how landscape diversification affects insects with differing life histories, and how interactions between pest management and land use alter insect population dynamics. Here we introduce empirical data illustrating how population dynamics and pest management of two economically important insect pests in maize (*Zea mays*), the European corn borer (ECB; *Ostrinia nubilalis*) and the western corn rootworm (WCR; *Diabrotica virgifera*), may vary with land use. We then explore the role of landscape in agricultural pest suppression with a spatially explicit computational model of herbivore population dynamics that includes pest management measures and insect life-history parameters (diet breadth, dispersal distance, and reproductive rate). While field results showed that WCR densities were lower in diverse than in simple agricultural landscapes, ECB damage to maize appeared unrelated to land use. Indeed, our stable carbon isotope analysis shows that one critical difference in the life histories of the two insects is host utilization: WCR utilized non-maize hosts (0%) at a lower rate than ECB (11%). However, management for both pests was consistently

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related to land use: less transgenic Bt maize and less insecticide is used per maize hectare in U. S. states with less maize. Consistent with field observations, our model predicts that landscape diversification results in reduced insecticide use and suggests that specialist pests are more affected by land-use changes than generalists. The model further predicts that insects with high reproductive rates are less sensitive to land-use change than insects with low reproductive rates and that dispersal distance is not an important factor regulating densities of highly dispersive insect pests in agricultural landscapes. While our study suggests that landscape diversification may not suppress all pests, it also suggests that diverse agricultural landscapes are correlated with consistently lower pesticide usage.

O'Rourke, M. E., K. Rienzo-Stack and A. G. Power (2011). "A multi-scale, landscape approach to predicting insect populations in agroecosystems." *Ecological Applications* 21(5): 1782-1791.

Landscape composition affects ecosystems services, including agricultural pest management. However, relationships between land use and agricultural insects are not well understood, and many complexities remain to be explored. Here we examine whether nonagricultural landscapes can directly suppress agricultural pests, how multiple spatial scales of land use concurrently affect insect populations, and the relationships between regional land use and insect populations. We tracked densities of three specialist corn (*Zea mays*) pests (*Ostrinia nubilalis*, European corn borer; *Diabrotica virgifera*, western corn rootworm; *Diabrotica barberi*, northern corn rootworm), and two generalist predator lady beetles (*Coleomegilla maculata* and *Propylea quatuordecimpunctata*) in field corn and determined their relationships to agricultural land use at three spatial scales (field perimeter, 1-km, and 20-km radius areas). Pest densities were either higher (*D. virgifera* and *D. barberi*) or unchanged (*O. nubilalis*) in landscapes with more corn, while natural enemy densities were either lower (*C. maculata*) or unchanged (*P. quatuordecimpunctata*). Results for *D. virgifera* and *D. barberi* indicate that decreasing the area of preferred crop in the landscape can directly suppress specialist insect pests. Multiple scales of land use affected populations of *D. virgifera* and *C. maculata*, and *D. virgifera* populations showed strong relationships with regional, 20-km-scale land use. These results suggest that farm planning and government policies aimed at diversifying local and regional agricultural landscapes show promise for increasing biological control and directly suppressing agricultural pests.

Pereira, E. J. G., N. P. Storer and B. D. Siegfried (2011). "Fitness costs of Cry1F resistance in laboratory-selected European corn borer (Lepidoptera: Crambidae)." *Journal of Applied Entomology* 135(1-2): 17-24.

The study of fitness costs associated with resistance to toxins from *Bacillus thuringiensis* Berliner (Bt) is important for understanding resistance evolution and for evaluating resistance management practices that prevent or mitigate resistance. A strain of European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) obtained from field collections throughout the U.S. Corn Belt in 1996, was selected in the laboratory for resistance to Cry1F by exposure to the toxin incorporated into artificial diet. The selected strain developed more than 3000-fold resistance to Cry1F after 35 generations of selection and readily consumed Cry1F expressing maize tissue. Using this resistant strain, a susceptible strain with similar genetic background and reciprocal crosses between them, we estimated fitness costs and their dominance by measuring fitness components and population parameters determined by fertility life tables. Comparison of life-history traits and population growth rates of genotypes homozygous and heterozygous for resistance relative to susceptible genotypes indicated existence of weak and recessive fitness costs associated with resistance. The significance of these results in relation to current resistance management practices is discussed.

Razze, J. M., C. E. Mason and T. D. Pizzolato (2011). "Feeding Behavior of Neonate *Ostrinia nubilalis* (Lepidoptera: Crambidae) on Cry1Ab Bt Corn: Implications for Resistance Management." *Journal of Economic Entomology* 104(3): 806-813.

The European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), is an economically important insect pest of corn, *Zea mays* L., in the United States and Canada. The development of genetically modified corn expressing genes derived from *Bacillus thuringiensis* (Bt) that encodes insecticidal crystalline (Cry) proteins has proven to be effective in controlling this insect. To assess the feeding behavior of neonate *O. nubilalis* on Bt corn, we examined differences in feeding behavior, based on presence of plant material in the gut, between Cry1Ab Bt corn and non-Bt near isolate corn for four intervals over a 48-h period. Feeding experiments revealed that there was significantly less feeding on Bt corn compared with non-Bt near isolate corn. The behavior of neonates on the plant corresponded with the differences in feeding on the two corn lines. The findings also showed that >50% of the larvae initially left the plant before there was evidence in the gut of feeding regardless of whether the source was Bt or non-Bt corn. A higher quantity of plant

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material was found in the gut of larvae recovered from leaves of non-Bt compared with Bt corn. At the end of 48 h among the larvae that had left the plant, a greater proportion from Bt corn had plant material in the gut than did those from non-Bt corn.

Selwet, M. (2011). "Maize Plants Infestation by *Fusarium* spp. and Deoxynivalenol in Genetically Modified Corn Hybrid and Traditional Maize Cultivars." *Polish Journal of Microbiology* 60(4): 317-321.

The objective of the performed investigations was to isolate pathogenic fungi from contaminated maize cobs, to assess the appearance of maize cob fusariosis and to determine grain contamination with deoxynivalenol in the cultivation of genetically modified maize containing a gene resistance against European corn borer (*Ostrinia nubilalis* Hbn) as well as selected non-modified cultivars. The plant material comprised the following genetically modified maize cultivar: DKC 3421 YG (MON 810) and non-modified cultivars obtained from Smolice Plant Breeding Ltd., IHAR Group: Junak (FAO 210-220), Prosna (FAO 220), SMH (FAO 230), Baca (FAO 220). Prior to harvesting, the occurrence of maize cob fusariosis was determined in the 89 (BBCH) developmental ripening stage. Microbiological assessment was carried out on grains selected from cobs characterized by various pathological symptoms. In 2008, a total of 133 isolates was obtained from the examined samples of infected maize plants, of which 51 isolates were species-identified, while in 2009, the total of 123 isolates were determined, of which 63 were species-identified. In both experimental years, the majority of isolates contained fungi from the *Fusarium* genus. The performed analysis of mean levels of cob contamination by fusarioses revealed that DKC 3421 YG (MON 810) and SMH (FAO 230) cultivars showed the smallest levels of contamination as well as the lowest percent of cob contamination per plant, while Junak (FAO 210-220) and Baca (FAO 220) cultivars were characterized by the highest degree of contamination. The lowest deoxynivalenol concentrations were determined in years 2008 and 2009 in the case of the DKC 3421 YG (MON 810) cultivar, whereas Prosna (FAO 220) cultivar was characterized by the highest deoxynivalenol concentration.

Shklyaruck, D. and E. Matiushenkov (2011). "Stereoselective synthesis of (3S,5S,6S)-tetrahydro-6-isopropyl-3,5-dimethylpyran-2-one; a C5-epimer of a component of a natural sex pheromone of the wasp *Macrocentrus grandii*, the larval parasitoid of the European corn borer *Ostrinia nubilalis*." *Tetrahedron-Asymmetry* 22(13): 1448-1454.

(3S,5S,6S)-Tetrahydro-6-isopropyl-3,5-dimethylpyran-2-one, a C5-epimer of a component of the natural sex pheromone of the wasp *Macrocentrus grandii*, the larval parasitoid of the European corn borer *Ostrinia nubilalis*, was synthesized starting from methyl L-valinate. The transformation includes a Kulinkovich cyclopropanation reaction, a cationic cyclopropyl-allyl rearrangement of cyclopropyl methanesulfonate, a diastereoselective alkylation of Oppolzer's (N-propionyl)-(2R)-bornane-10,2-sultam and a diastereoselective hydrogenation using Wilkinson's catalyst as the key steps. (C) 2011 Elsevier Ltd. All rights reserved.

Tabashnik, B. E., F. N. Huang, M. N. Ghimire, B. R. Leonard, B. D. Siegfried, M. Rangasamy, Y. J. Yang, Y. D. Wu, L. J. Gahan, D. G. Heckel, A. Bravo and M. Soberon (2011). "Efficacy of genetically modified Bt toxins against insects with different genetic mechanisms of resistance." *Nature Biotechnology* 29(12): 1128-U1198.

Transgenic crops that produce *Bacillus thuringiensis* (Bt) toxins are grown widely for pest control(1), but insect adaptation can reduce their efficacy(2-6). The genetically modified Bt toxins Cry1AbMod and Cry1AcMod were designed to counter insect resistance to native Bt toxins Cry1Ab and Cry1Ac(7). Previous results suggested that the modified toxins would be effective only if resistance was linked with mutations in genes encoding toxin-binding cadherin proteins(7). Here we report evidence from five major crop pests refuting this hypothesis. Relative to native toxins, the potency of modified toxins was >350-fold higher against resistant strains of *Plutella xylostella* and *Ostrinia nubilalis* in which resistance was not linked with cadherin mutations. Conversely, the modified toxins provided little or no advantage against some resistant strains of three other pests with altered cadherin. Independent of the presence of cadherin mutations, the relative potency of the modified toxins was generally higher against the most resistant strains.

Tan, S. Y., B. F. Cayabyab, E. P. Alcantara, Y. B. Ibrahim, F. Huang, E. E. Blankenship and B. D. Siegfried (2011). "Comparative susceptibility of *Ostrinia furnacalis*, *Ostrinia nubilalis* and *Diatraea saccharalis* (Lepidoptera: Crambidae) to *Bacillus thuringiensis* Cry1 toxins." *Crop Protection* 30(9): 1184-1189.

Transgenic corn hybrids that express toxins from *Bacillus thuringiensis* (Bt) are highly effective against the European corn borer, *Ostrinia nubilalis* (Hubner), and the closely related Asian corn borer, *Ostrinia furnacalis* (Guenee). Since the

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registration of Bt corn hybrids in the U.S. in 1996, there has been a great deal of information generated on *O. nubilalis*. However, relatively little information exists for *O. furnacalis*. To help determine whether the information generated for *O. nubilalis* can be leveraged for decisions regarding the use of transgenic Bt corn against *O. furnacalis*, experiments were designed to determine whether the pattern of sensitivity to various Bt Cry1 toxins is similar between the two species. Test insects included laboratory-reared *O. furnacalis* originating from Malaysia, a Bt-susceptible laboratory colony of *O. nubilalis* maintained at the University of Nebraska-Lincoln (UNL) and an out-group consisting of the sugarcane borer, *Diatraea saccharalis* (F.), from Louisiana which represents a different genus from the same family. *O. furnacalis* and *O. nubilalis* exhibited a similar pattern of susceptibility to all the Cry1 toxins and were highly susceptible to the range of Bt toxins tested including Cry1Aa, Cry1Ab, Cry1Ac and Cry1F. Both of the *Ostrinia* species were more tolerant to Cry1Ba compared with *D. saccharalis*, although sensitivity of *O. furnacalis* was intermediate and did not differ significantly from that of *O. nubilalis* and *D. saccharalis*. *D. saccharalis* was also susceptible to the range of toxins tested but unlike the two *Ostrinia* species, was more tolerant to Cry1F and more susceptible to Cry1Ba. These results indicate that both of the *Ostrinia* corn borer species are similar in sensitivity to the Cry1Aa, Cry1Ab, Cry1Ac, Cry1Ba and Cry1F toxins, thus suggesting shared toxin receptors and mechanisms of toxicity for the two species. (C) 2011 Elsevier Ltd. All rights reserved.

Yanni, S. F., J. K. Whalen, B. L. Ma and Y. Gelinis (2011). "European corn borer injury effects on lignin, carbon and nitrogen in corn tissues." *Plant and Soil* 341(1-2): 165-177.

Plant herbivores often stimulate lignin deposition in injured plant tissue, but it is not known whether corn (*Zea mays* L.) reacts to European corn borer (ECB, *Ostrinia nubilalis* Hubner) injury in this manner. Bt (*Bacillus thuringiensis*) genetic modification is also reported to affect lignin in corn. This study evaluated the effects of ECB injury and the Bt gene on the chemical composition and decomposition of corn tissues. Eight near isolines (Bt and NBT) were grown in pots and half were infested with ECB. The experiment was repeated in 2 years. ECB injury increased the lignin concentration in corn leaves in one of 2 years and lowered the C:N ratio in injured stems. Lignin concentration in leaves was greater in Bt than NBT corn in 1 year and Bt stems had greater N concentration than NBT stems in 1 year of the 2 year study. ECB injury affected the composition of lignin-derived phenols, however ECB infested and non-infested stems lost the same amount of mass after 5 months in buried field litterbags. In conclusion ECB injury and the Bt gene had subtle effects on the chemical composition of corn tissue, which did not alter the short-term decomposition of corn residues.

Yasukochi, Y., N. Miura, R. Nakano, K. Sahara and Y. Ishikawa (2011). "Sex-Linked Pheromone Receptor Genes of the European Corn Borer, *Ostrinia nubilalis*, Are in Tandem Arrays." *Plos One* 6(4).

BACKGROUND: Tuning of the olfactory system of male moths to conspecific female sex pheromones is crucial for correct species recognition; however, little is known about the genetic changes that drive speciation in this system. Moths of the genus *Ostrinia* are good models to elucidate this question, since significant differences in pheromone blends are observed within and among species. Odorant receptors (ORs) play a critical role in recognition of female sex pheromones; eight types of OR genes expressed in male antennae were previously reported in *Ostrinia* moths. **METHODOLOGY/PRINCIPAL FINDINGS:** We screened an *O. nubilalis* bacterial artificial chromosome (BAC) library by PCR, and constructed three contigs from isolated clones containing the reported OR genes. Fluorescence in situ hybridization (FISH) analysis using these clones as probes demonstrated that the largest contig, which contained eight OR genes, was located on the Z chromosome; two others harboring two and one OR genes were found on two autosomes. Sequence determination of BAC clones revealed the Z-linked OR genes were closely related and tandemly arrayed; moreover, four of them shared 181-bp direct repeats spanning exon 7 and intron 7. **CONCLUSIONS/SIGNIFICANCE:** This is the first report of tandemly arrayed sex pheromone receptor genes in Lepidoptera. The localization of an OR gene cluster on the Z chromosome agrees with previous findings for a Z-linked locus responsible for *O. nubilalis* male behavioral response to sex pheromone. The 181-bp direct repeats might enhance gene duplications by unequal crossovers. An autosomal locus responsible for male response to sex pheromone in *Heliothis virescens* and *H. subflexa* was recently reported to contain at least four OR genes. Taken together, these findings support the hypothesis that generation of additional copies of OR genes can increase the potential for male moths to acquire altered specificity for pheromone components, and accordingly, facilitate differentiation of sex pheromones.

Blandino, M., A. Peila and A. Reyneri (2010). "Timing clorpirifos plus cypermethrin and indoxacarb applications to control European corn borer damage and fumonisin contamination in maize kernels." *Journal of the Science of Food and Agriculture* 90(3): 521-529.

BACKGROUND: European corn borer (ECB) is the main maize pest in central and southern Europe and it promotes the infection of maize with *Fusarium verticillioides*, which is able to produce fumonisins. Field experiments were performed from 2006 to 2007 in northwestern Italy to determine the effects of the timing of insecticide applications on maize fungal ear rot and fumonisin contamination in natural infection conditions. Four application timings and two insecticides (clorpirifos + cypermethrin and indoxacarb) were compared each year. **RESULTS:** In both years, the treatments applied at the beginning of a consistent ECB flight activity and at the flight peak showed the best efficacy to control the insect damage on ears. Fungal ear rot and fumonisin contamination were clearly affected by ECB control. The efficacy of the best application timing to control fumonisin occurrence was 73% in 2006 and 84% in 2007. Earlier insecticide applications showed lower fumonisin contamination than treatments applied after the adult flight peak. **CONCLUSION:** The production of maize and maize-based foods with a low fumonisin content maybe enhanced through correct insecticide application against the second ECB generation. The optimum timing of insecticides is between the beginning of a consistent adult flight activity and the flight peak. (C) 2009 Society of Chemical Industry

Blandino, M., M. A. Saladini, A. Alma and A. Reyneri (2010). "Pyrethroid Application Timing to Control European Corn Borer (Lepidoptera: Crambidae) and Minimize Fumonisin Contamination in Maize Kernels." *Cereal Research Communications* 38(1): 75-82.

Ostrinia nubilalis (Hubner) (European corn borer) is the main maize pest in Central and South Europe and it promotes *Fusarium verticillioides* infection on maize grains, which is able to produce fumonisins. The objective of this study was to determine the effect of the timing of pyrethroid treatments on European corn borer damage, fungal ear rot and fumonisin contamination. The field experiments were performed from 2005 to 2007 in NW Italy. Four application timings were compared to an untreated control. The insecticide treatments were applied at approximately 10 days intervals, starting from the end of flowering. The last treatment was performed approximately 15 days after the ECB flight peak. At harvest, the ears were rated for the incidence and severity of European corn borer damage and fungal ear rot symptoms, and the harvested kernels were analyzed for fumonisins B(1) + B(2). In all the years, the treatments applied 7-10 days before the European corn borer adult flight peak showed the best efficacy to control insect damage on ears. Fungal ear rot and fumonisin contamination were clearly affected by European corn borer control. The occurrence of this mycotoxin in plots treated at the best pyrethroid application timing was significantly reduced, on average by 76%, compared to the untreated control. Furthermore, early insecticide applications, at the end of maize flowering, showed significantly lower fumonisin contamination than treatments applied at approximately 15 days after the adult flight peak. This research indicates that the production of maize kernels with low fumonisin content may be enhanced by a correct timing of the insecticide application against second generation European corn borer.

Boisclair, J., E. Lucas, D. Cormier, S. Todorova and E. Etilé (2010). Optimisation de la lutte biologique contre la pyrale du maïs et les pucerons dans la culture du maïs sucré frais. I. d. r. e. d. d. e. agroenvironnement. PSIA-806110: 3.

Lien : http://www.mapaq.gouv.qc.ca/SiteCollectionDocuments/Recherche_Innovation/Legumesdechamp/806110.pdf

Calcagno, V., V. Bonhomme, Y. Thomas, M. C. Singer and D. Bourguet (2010). "Divergence in behaviour between the European corn borer, *Ostrinia nubilalis*, and its sibling species *Ostrinia scapularis*: adaptation to human harvesting?" *Proceedings of the Royal Society B-Biological Sciences* 277(1694): 2703-2709.

Divergent adaptation to host plant species may be the major mechanism driving speciation and adaptive radiations in phytophagous insects. Host plants can differ intrinsically in a number of attributes, but the role of natural enemies in host plant specialization is often underappreciated. Here, we report behavioural divergence between the European corn borer (ECB, *Ostrinia nubilalis*) and its sibling species *Ostrinia scapularis*, in relation to a major enemy: humans. Harvesting maize imposes selective mortality on *Ostrinia* larvae: those located above the cut-off line of the stalk face almost certain death. We show that ECB larvae diapause closer to the ground than those of *O. scapularis*, which is sympatric but feeds mainly on weeds. The difference in diapause height results from genetically determined differences in geotactic behaviour. ECB larvae descend towards the ground specifically at harvest time, increasing their chances of surviving harvesting by about 50 per cent over *O. scapularis* larvae. Natural enemies appear as a major driver of host-

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plant specialization in this example, stressing the need to consider 'tri-trophic' ecological niches to understand insect diversification. Our results also strongly suggest that geotaxis evolved as a singular instance of behavioural resistance in a major agricultural pest.

Crava, C. M., Y. Bel, S. F. Lee, B. Manachini, D. G. Heckel and B. Escriche (2010). "Study of the aminopeptidase N gene family in the lepidopterans *Ostrinia nubilalis* (Hubner) and *Bombyx mori* (L.): Sequences, mapping and expression." *Insect Biochemistry and Molecular Biology* 40(7): 506-515.

Aminopeptidases N (APNs) are a class of ectoenzymes present in lepidopteran larvae midguts, involved in the *Bacillus thuringiensis* (Bt) toxins mode of action. In the present work, seven aminopeptidases have been cloned from the midgut of *Ostrinia nubilalis*, the major Lepidopteran corn pest in the temperate climates. Six sequences were identified as APNs because of the presence of the HEXXH(X)(18)E and GAMEN motifs, as well as the signal peptide and the GPI-anchor sequences. The remaining sequence did not contain the two cellular targeting signals, indicating it belonged to the puromycin-sensitive aminopeptidase (PSA) family. An in silico analysis allowed us to find orthologous sequences in *Bombyx mori*. A phylogenetic study of lepidopteran aminopeptidase sequences resulted in their clustering into nine classes. Linkage analysis revealed that the onapn genes as well as all bmapn genes clustered in a single linkage group. *O. nubilalis* aminopeptidases were expressed in all larval instars. In 5th instar larvae tissues, apns transcripts were found mainly in midguts while apn8 was also highly expressed in Malpighian tubules, and psa showed an ubiquitous expression pattern in *O. nubilalis* and *B. mori*. The sequence homology and gene organization of apns suggest a single origin from an ancestral lepidopteran apn gene. (c) 2010 Elsevier Ltd. All rights reserved.

Crespo, A. L. B., T. A. Spencer, S. Y. Tan and B. D. Siegfried (2010). "Fitness Costs of Cry1Ab Resistance in a Field-Derived Strain of *Ostrinia nubilalis* (Lepidoptera: Crambidae)." *Journal of Economic Entomology* 103(4): 1386-1393.

The study of fitness costs associated with resistance to toxins from *Bacillus thuringiensis* Berliner (Bt) in *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) is important for understanding resistance evolution and for evaluating resistance management practices that prevent or mitigate resistance to transgenic corn, *Zea mays* L. Resistant individuals identified from a field collection in Kandiyohi, MN, were used to generate a Cry1Ab-resistant strain. We used susceptible and resistant strains with similar genetic background to establish crosses and estimate dominance of fitness costs by measuring fitness components and population parameters determined by fertility life tables. Spermatophore volume and mating frequency also were compared to identify potential effects of resistance on fertility. Inheritance of fitness costs in *O. nubilalis* varied from recessive to incompletely recessive among the parameters evaluated. Selection for resistance to Cry1Ab significantly reduced the fitness of *O. nubilalis*. Resistant insects exhibited reduced pupal weight and increased developmental time compared with susceptible and F(1) larvae derived from reciprocal crosses of resistant and susceptible parents. In addition, it was observed that resistant insects exhibited a higher proportion of unsuccessful matings and lower fertility than the susceptible strain. Despite the differences observed in resistant insects, our results did not indicate strong evidence of fitness costs in the F(1) progeny.

Domingue, M. J., C. J. Musto, C. E. Linn, W. L. Roelofs and T. C. Baker (2010). "Homology of olfactory receptor neuron response characteristics inferred from hybrids between Asian and European corn borer moths (Lepidoptera: Crambidae)." *Journal of Insect Physiology* 56(1): 73-80.

First generation hybrid males from crosses between the Asian corn borer (ACB), *Ostrinia furnacalis*, and the "univoltine Z-strain" European corn borer (ECB), *Ostrinia nubilalis*, were examined with respect to behavioral and physiological responses to ACB and ECB pheromones. The hybrid males often flew to the pheromone of ECB Z-strain, but very rarely to the ACB pheromone. We mapped the tuning profiles of each ORN of the F(1) hybrids with respect to the relevant pheromone components and a common behavioral antagonist by employing differential cross-adaptation and varying doses of the ligands. In the trichoid sensilla of F(1) hybrid males, the three co-compartmentalized ORNs produced spikes that were very difficult to distinguish by size, unlike the parental populations. Comparing the responses to ACB and ECB components at different doses reveals overlapping profiles similar to males of both parental types, but more responsiveness to the ECB pheromone components. We were unable to detect any differences in the ORN tuning profiles when comparing males with different behavioral phenotypes. While the two ECB pheromone races have similar ORN tuning properties that are different from those in ACB, the spike-amplitude patterns of ECB E-strain and ACB have greater homology when compared to ECB Z-strain. (C) 2009 Elsevier Ltd. All rights reserved.

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Dopman, E. B., P. S. Robbins and A. Seaman (2010). "COMPONENTS OF REPRODUCTIVE ISOLATION BETWEEN NORTH AMERICAN PHEROMONE STRAINS OF THE EUROPEAN CORN BORER." *Evolution* 64(4): 881-902.

Of 12 potential reproductive isolating barriers between closely related Z-and E-pheromone strains of the European corn borer moth (*Ostrinia nubilalis*), seven significantly reduced gene flow but none were complete, suggesting that speciation in this lineage is a gradual process in which multiple barriers of intermediate strength accumulate. Estimation of the cumulative effect of all barriers resulted in nearly complete isolation (> 99%), but geographic variation in seasonal isolation allowed as much as similar to 10% gene flow. With the strongest barriers arising from mate-selection behavior or ecologically relevant traits, sexual and natural selection are the most likely evolutionary processes driving population divergence. A recent multilocus genealogical study corroborates the roles of selection and gene flow (Dopman et al. 2005), because introgression is supported at all loci besides *Tpi*, a sex-linked gene. *Tpi* reveals strains as exclusive groups, possesses signatures of selection, and is tightly linked to a QTL that contributes to seasonal isolation. With more than 98% of total cumulative isolation consisting of prezygotic barriers, Z and E strains of ECB join a growing list of taxa in which species boundaries are primarily maintained by the prevention of hybridization, possibly because premating barriers evolve during early stages of population divergence.

Engels, H., D. Bourguet, L. Cagan, B. Manachini, I. Schuphan, T. J. Stodola, A. Micoud, C. Brazier, C. Mottet and D. A. Andow (2010). "Evaluating Resistance to Bt Toxin Cry1Ab by F-2 Screen in European Populations of *Ostrinia nubilalis* (Lepidoptera: Crambidae)." *Journal of Economic Entomology* 103(5): 1803-1809.

The large-scale cultivation of transgenic crops producing *Bacillus thuringiensis* (Bt) toxins have already lead to the evolution of Bt resistance in some pest populations targeted by these crops. We used the F-2 screening method for further estimating the frequency of resistance alleles of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), to Bt maize, *Zea mays* L., producing the Cry1Ab toxin. In France, Germany, and Italy, 784, 455, and 80 lines of European corn borer were screened for resistance to Mon810 maize, respectively. In Slovakia, 26 lines were screened for resistance to the Cry1Ab toxin. The cost of F-2 screen performed in the four countries varied from US\$300 to \$1,300 per line screened. The major difference in cost was mostly due to a severe loss of univoltine lines during the screen in Germany and Slovakia. In none of the screened lines did we detect alleles conferring resistance to Mon810 maize or to the Cry1Ab toxin. The frequency of resistance alleles were $<1.0 \times 10^{-3}$, $<1.6 \times 10^{-3}$, $<9.2 \times 10^{-3}$, and $<2.6 \times 10^{-2}$ in France, Germany, Italy, and Slovakia, with 95% probability, respectively. The average detection probability over all lines was Making the assumption that European corn borer populations in these countries belong to the same genetic entity, the frequency of alleles conferring resistance to the Cry1Ab produced by the Mon810 maize in western and central Europe was 1.0×10^{-4} , with a 95% confidence interval of $0-3.0 \times 10^{-4}$.

Geiler, K. A. and R. G. Harrison (2010). "A Delta 11 desaturase gene genealogy reveals two divergent allelic classes within the European corn borer (*Ostrinia nubilalis*)." *Bmc Evolutionary Biology* 10.

Background: Moth pheromone mating systems have been characterized at the molecular level, allowing evolutionary biologists to study how changes in protein sequence or gene expression affect pheromone phenotype, patterns of mating, and ultimately, the formation of barriers to gene exchange. Recent studies of *Ostrinia* pheromones have focused on the diversity of sex pheromone desaturases and their role in the specificity of pheromone production. Here we produce a Delta 11 desaturase genealogy within *Ostrinia nubilalis*. We ask what has been the history of this gene, and whether this history suggests that changes in Delta 11 desaturase have been involved in the divergence of the E and Z *O. nubilalis* pheromone strains. Results: The Delta 11 desaturase gene genealogy does not differentiate *O. nubilalis* pheromone strains. However, we find two distinct clades, separated by 2.9% sequence divergence, that do not sort with pheromone strain, geographic origin, or emergence time. We demonstrate that these clades do not represent gene duplicates, but rather allelic variation at a single gene locus. Conclusions: Analyses of patterns of variation at the Delta 11 desaturase gene in ECB suggest that this enzyme does not contribute to reproductive isolation between pheromone strains (E and Z). However, our genealogy reveals two deeply divergent allelic classes. Standing variation at loci that contribute to mate choice phenotypes may permit novel pheromone mating systems to arise in the presence of strong stabilizing selection.

Goldstein, J. A., C. E. Mason and J. Pesek (2010). "Dispersal and Movement Behavior of Neonate European Corn Borer (Lepidoptera: Crambidae) on Non-Bt and Transgenic Bt Corn." *Journal of Economic Entomology* 103(2): 331-339.

Neonate movement and dispersal behavior of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), were investigated under controlled conditions on *Bacillus thuringiensis* (Bt) and non-Bt corn, Zen mays L., to assess plant abandonment, dispersal from their natal plant, and silking behavior after Bt and non-Bt preexposure. With continuous airflow, neonates on a Bt corn plant for 24 h abandoned that plant 1.78 times more frequently than neonates on a non-Bt corn plant. Indirect evidence indicated that at least one third of the neonates were capable of ballooning within 24 h. In the greenhouse, some neonates were recovered after 24 h from plants 76 and 152 cm away that likely ballooned from their natal plant. After 1 h of preexposure on a Bt corn leaf, neonates placed on a new corn leaf and observed for 10 min began silking off of a new Bt leaf significantly sooner than a new non-Bt leaf. Results suggest that neonates are unable to detect Bt in the corn within 10 min but that they can detect it within the first hour.

Hutchison, W. D., E. C. Burkness, P. D. Mitchell, R. D. Moon, T. W. Leslie, S. J. Fleischer, M. Abrahamson, K. L. Hamilton, K. L. Steffey, M. E. Gray, R. L. Hellmich, L. V. Kaster, T. E. Hunt, R. J. Wright, K. Pecinovsky, T. L. Rabaey, B. R. Flood and E. S. Raun (2010). "Areawide Suppression of European Corn Borer with Bt Maize Reaps Savings to Non-Bt Maize Growers." *Science* 330(6001): 222-225.

Transgenic maize engineered to express insecticidal proteins from the bacterium *Bacillus thuringiensis* (Bt) has become widely adopted in U. S. agriculture. In 2009, Bt maize was planted on more than 22.2 million hectares, constituting 63% of the U. S. crop. Using statistical analysis of per capita growth rate estimates, we found that areawide suppression of the primary pest *Ostrinia nubilalis* (European corn borer) is associated with Bt maize use. Cumulative benefits over 14 years are an estimated \$3.2 billion for maize growers in Illinois, Minnesota, and Wisconsin, with more than \$2.4 billion of this total accruing to non-Bt maize growers. Comparable estimates for Iowa and Nebraska are \$3.6 billion in total, with \$1.9 billion for non-Bt maize growers. These results affirm theoretical predictions of pest population suppression and highlight economic incentives for growers to maintain non-Bt maize refugia for sustainable insect resistance management.

Kares, E. A., I. A. El-Sappagh, G. H. Ebaid and I. M. Sabra (2010). "Efficacy of Releasing *Bracon brevicornis* Wesm. (Hymenoptera: Braconidae) for Controlling Hibernated *Ostrinia nubilalis* (Hubner) and *Sesamia cretica* Led. Larvae in Stored Corn Stalks." *Egyptian Journal of Biological Pest Control* 20(2): 155-159.

Field experiments were conducted during years 2009 and 2010 to test efficacy of the parasitoid *B. brevicornis* release for controlling hibernated *O. nubilalis* and *S. cretica* larvae at the experimental, farm of the Faculty of Agriculture at Moshtohor, Qalubia Governorate. Three groups of stored corn stalks' each resulted from half feddan of maize variety (30 k 9) cultivated on July 2008 and 2009 were kept in farm under open area at a distance of 500 m apart between them. Two of the three stored corn stalks received parasitoid release while the third served as control. In each treatment, two successive releases at 7 days intervals, each of 900 parasitoid cocoons were done. Releases were carried out by the end of first and second week of January 2009 and 2010 in the first treatment. Second treatment received the same application but by the end of first and second weeks of February. Weekly samples each of 200 stored corn stalks from each treatment were carefully dissected and the counts of healthy and parasitized larvae were recorded. Percentages of parasitism on *Ostrinia* larvae during December to April, in control treatment were 6.6, 7.4, 10.0, 13.0 and 13.8 in first season and 0.4, 2.6, 3.7, 7.8 and 14.6 in second one. The recorded parasitism rate for *Sesamia* larvae in the first season were (7.1, 5.7, 10.0, 17.4 and 0.0) while in second season they were (0.0, 2.4, 3.4, 8.3 and 0.0). Treatments that received parasitoid release in January recorded 11.2, 25.9, 38.0, 58.0 and 77.0 % parasitism in the first season and 1.5, 13.5, 25.9, 28.4 and 59.2 % in second seasons on *Ostrinia* larvae. Corresponding percentages on *Sesamia* larvae were 9.0, 16.3, 21.0, 20.0 and 0.0 and 3.1, 3.8, 9.4, 18.5 and 0.0 in the same period of the two years, respectively. Treatments that received parasitoid release in February recorded 7.8, 13.0, 20.2, 32.6 and 69.0 % parasitism in first season and 0.3, 2.9, 8.4, 28.3 and 39.5 % in second season on *Ostrinia* larvae; opposed to 10.0, 5.7, 11.4, 35.7 and 0.0 % in first season and 0.0, 3.1, 7.7, 14.2 and 0.0 % in second season on *Sesamia* larvae for December, January February, March and April, respectively. January and February parasitoid releasing treatments successfully increased the percentages of parasitism on *Ostrinia* larvae than control by 71.5 and 54.8 % in the first season and by 80.2 and 54.7 % in second season. In case of *Sesamia* larvae, the recorded increases in percentages of parasitism than control were 44.7 and 35.0 % and 72.2 and 33.3 % in the two treatments of the two years, respectively.

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Karpati, Z., S. Olsson, B. S. Hansson and T. Dekker (2010). "Inheritance of central neuroanatomy and physiology related to pheromone preference in the male European corn borer." *Bmc Evolutionary Biology* 10.

Background: The European corn borer (ECB), *Ostrinia nubilalis*, is a textbook example of pheromone polymorphism. Males of the two strains (Z and E) prefer opposite ratios of the two pheromone components, Z11- and E11-tetradecenyl acetate, with a sex-linked factor underlying this difference in preference. The male antennal lobes of the two strains contain a pheromone sensitive macroglomerular complex (MGC) that is identical in morphology, but reversed in functional topology. However, hybrids prefer intermediate ratios. How a topological arrangement of two glomeruli can accommodate for an intermediate preference was unclear. Therefore we studied the neurophysiology of hybrids and paternal backcrosses to see which factors correlated with male behavior. Results: Projection neuron (PN) recordings and stainings in hybrids and backcrosses show a dominance of the E-type MGC topology, notwithstanding their intermediate preference. Apparently, the topological arrangement of glomeruli does not directly dictate preference. However, two other factors did correlated very well with preference. First, volumetric measurements of MGC glomeruli demonstrate that, whereas in the parental strains the medial MGC glomerulus is more than 2 times larger than the lateral, in hybrids they are intermediate between the parents, i.e. equally sized. Paternal backcrosses showed that the volume ratio is sex-linked and co-dominant. Second, we measured the summed potential difference of the antennae in response to pheromone stimulation using electroantennogram recordings (EAG). Z-strain antennae responded 2.5 times stronger to Z11 than to E11-14: OAc, whereas in E-strain antennae the ratio was approximately equal. Hybrid responses were intermediate to the parents, and also here the antennal response of the paternal backcrosses followed a pattern similar to the behavioral phenotype. We found no differences in frequency and types of projection and local interneurons encountered between the two strains and their hybrids. Conclusions: Male pheromone preference in the ECB strains serves as a strong prezygotic reproductive isolation mechanism, and has contributed to population divergence in the field. Our results demonstrate that male pheromone preference is not directly affected by the topological arrangement of olfactory glomeruli itself, but that male preference may instead be mediated by an antennal factor, which causes the MGC glomeruli to be differentially sized. We postulate that this factor affects readout of blend information from the MGC. The results are an illustration of how pheromone preference may be 'spelled out' in the ALs, and how evolution may modulate this.

Khajuria, C., L. L. Buschman, M. S. Chen, S. Muthukrishnan and K. Y. Zhu (2010). "A gut-specific chitinase gene essential for regulation of chitin content of peritrophic matrix and growth of *Ostrinia nubilalis* larvae." *Insect Biochemistry and Molecular Biology* 40(8): 621-629.

Chitinases belong to a large and diverse family of hydrolytic enzymes that break down glycosidic bonds of chitin. However, very little is known about the function of chitinase genes in regulating the chitin content in peritrophic matrix (PM) of the midgut in insects. We identified a cDNA putatively encoding a chitinase (OnCht) in European corn borer (ECB; *Ostrinia nubilalis*). The OnCht transcript was predominately found in larval midgut but undetectable in eggs, pupae, or adults. When the larvae were fed on an artificial diet, the OnCht transcript level increased by 4.4-fold but the transcript level of a gut-specific chitin synthase (OnCHS2) gene decreased by 2.5-fold as compared with those of unfed larvae. In contrast, when the larvae were fed with the food and then starved for 24 h, the OnCht transcript level decreased by 1.8-fold but the transcript level of OnCHS2 increased by 1.8-fold. Furthermore, there was a negative relationship between OnCht transcript level and chitin content in the midgut. By using a feeding-based RNAi technique, we were able to reduce the OnCht transcript level by 63-64% in the larval midgut. Consequently, these larvae showed significantly increased chitin content (26%) in the PM but decreased larval body weight (54%) as compared with the control larvae fed on the diet containing GFP dsRNA. Therefore, for the first time, we provide strong evidence that OnCht plays an important role in regulating chitin content of the PM and subsequently affecting the growth and development of the ECB larvae. (C) 2010 Elsevier Ltd. All rights reserved.

Kojic, D., J. Purac, Z. D. Popovic, E. Pamer and G. Grubor-Lajsic (2010). "IMPORTANCE OF THE BODY WATER MANAGEMENT FOR WINTER COLD SURVIVAL OF THE EUROPEAN CORN BORER *OSTRINIA NUBILALIS* HUBN. (LEPIDOPTERA: PYRALIDAE)." *Biotechnology & Biotechnological Equipment* 24(2): 648-654.

Winter diapause, a common strategy of many insect species occupying temperate regions, is usually closely related to and coincides with their cold hardness. Freezing of body fluids represents one of the major obstacles for sub-zero

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temperatures survival and thus the body water management is an important part of cold hardiness. In this study, we examined some cryobiological parameters, as well as content of glycerol and trehalose in non-diapausing and freeze tolerant diapausing larvae of the European corn borer, *Ostrinia nubilalis*. Diapausing larvae were divided into two experimental groups - a group exposed to field temperatures (which were in average above 0 degrees C) and a group exposed to -8 degrees C for ten days. Contents of the total body water, osmotically active (OA) and inactive (OI), as well as the supercooling point (SCP) of hemolymph and fat body, were measured by differential scanning calorimetry (DSC). The content of glycerol and trehalose was analysed by gas chromatography. Compared to diapausing groups, non - diapausing larvae had higher SCP, lower content of trehalose and glycerol in both tissues. The content of total and OA water in both tissues of diapausing larvae had changed with low temperatures exposure. At -8 degrees C, the amount of total and OA body water was decreased in hemolymph and increased in fat body while the content of OI water was slightly increased in hemolymph but remained unchanged in fat body. Mean SCPs of both tissues were significantly different - for hemolymph it was around -21 degrees C, which was almost two times lower than for fat body (-10 degrees C). However, the SCPs of fat body and hemolymph had not significantly changed after the exposure to low temperature. The content of glycerol and trehalose was far greater in hemolymph than in fat body for all groups, which is in accordance with the difference between the SCPs of these tissues. Furthermore, exposure of diapausing larvae to sub-zero temperatures (-8 degrees C) had simultaneously provoked an increase in glycerol/ trehalose concentration in hemolymph and the decrease in fat body. These adjustments of water and cryoprotectors distribution are an important part of cold hardiness mechanisms.

Larue, E. and C. Welty (2010). "Oviposition Behavior and Larval Development of the European Corn Borer (Lepidoptera: Crambidae) on Sweet Versus Hot Peppers." *Journal of Entomological Science* 45(4): 353-365.

Infestation of European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), a key pest of peppers (*Capsicum annuum* L.), was studied to explore the cause of infestation differences in pungent versus sweet types of peppers. Our objectives were to determine whether *O. nubilalis* adults show an ovipositional preference or larval development effects among pepper types that vary in levels of capsaicin and dihydrocapsaicin, which is measured in Scoville heat units (SHU). Five pepper types with a range in hotness were tested: bell (0 SHU), sweet banana (0 SHU), hot wax (1125 SHU), jalapeno (5,000 SHU), and cayenne (40,000 SHU). Oviposition was studied after artificial infestation in laboratory cages, small and large field cages, and after natural infestation in choice and no-choice field trials. No ovipositional preference was detected for cage no-choice or choice assays. Field choice oviposition trials with 5 pepper types had no differences in either egg mass density or larval infestation. A no-choice field trial with 3 pepper types found there was no difference in oviposition, but larval infestation varied significantly, with bell peppers having the highest infestation and jalapenos the least. It is concluded that *O. nubilalis* females show no ovipositional preference among the pepper types tested. Larval development time was significantly longer on jalapenos and significantly longer on pungent than on sweet peppers. Larval survival was not significantly different among types. These results suggest that the difference in infestation must be due to behavioral or physical factors after egg laying and before larvae enter the fruit.

Lopez, M. D., D. V. Sumerford and L. C. Lewis (2010). "Effects of infection with *Nosema pyrausta* on survival and development of offspring of laboratory selected Bt-resistant and Bt-susceptible European corn borers." *Journal of Invertebrate Pathology* 105(3): 248-253.

Infection with *Nosema pyrausta* Paillot lengthens developmental period of Bt-susceptible *Ostrinia nubilalis* (Hubner) to a similar extent as feeding on Cry1Ab-incorporated diet in Cry1Ab-resistant *O. nubilalis*, and these two factors combined lengthen developmental period further than either alone. Resistant *O. nubilalis* mating with infected susceptible, or infected resistant partners would produce partially- and fully-resistant offspring, respectively, infected with *N. pyrausta*. To investigate the impacts on the progeny of such matings, test crosses were set up to produce partially- and fully Cry1Ab-resistant *O. nubilalis* offspring transovarially infected and not infected with *N. pyrausta*, which were exposed to Cry1Ab toxin at doses of 0, 3, or 30 ng/cm(2) for 7 days. Transovarial infection with *N. pyrausta* significantly decreased 7 day survival of partially and fully-resistant *O. nubilalis* feeding on 30 ng/cm(2) Cry1Ab. In addition, *N. pyrausta* infection delayed larval development (as measured by weight) of partially- and fully-resistant *O. nubilalis* feeding on 3 and 30 ng/cm(2) Cry1Ab. Impacts of natural enemies on target pests may have the potential to impact evolution of resistance. *N. pyrausta*-infected *O. nubilalis* are more strongly affected by feeding on Bt, and would

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be less likely to survive to adulthood to pass on resistance to the next generation. This indigenous microsporidium may work to delay evolution of resistance in *O. nubilalis* by lowering their ability to survive on Bt. Published by Elsevier Inc.

Lopez, M. D., D. V. Sumerford and L. C. Lewis (2010). "Nosema pyrausta and Cry1Ab-incorporated diet led to decreased survival and developmental delays in European corn borer." *Entomologia Experimentalis Et Applicata* 134(2): 146-153.

The high dose/refuge strategy for delaying evolution of resistance to Bt maize [*Zea mays* L. (Poaceae)] relies on random mating between resistant European corn borers, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), and susceptible *O. nubilalis* from the refuge. However, differences in developmental rate caused by feeding on Bt maize, or infection with the microsporidium *Nosema pyrausta* Paillot (Microsporidia: Nosematidae) may result in assortative mating. Developmental delays and mortality caused by infection with *N. pyrausta* and feeding on Bt maize were quantified alone and in combination in Cry1Ab-resistant and susceptible *O. nubilalis*. Feeding on Cry1Ab-incorporated diet significantly increased number of days from hatch to pupation and decreased survival in the resistant population. Infection with *N. pyrausta* increased mortality and lengthened development in both the resistant and susceptible populations. The combination of Cry1Ab-incorporated diet and infection with *N. pyrausta* in resistant *O. nubilalis* lengthened development and increased mortality to a greater extent than either factor alone. Greater larval delays of resistant *O. nubilalis* feeding on Bt maize could lead to temporal isolation from adults emerging from refuge maize. The resulting assortative mating would hasten the evolution of resistance. Developmental delays caused by infection with *N. pyrausta* may increase the likelihood of mating between resistant and infected susceptible adults emerging from refuge maize, producing infected offspring that are also more susceptible to Bt maize.

Masoero, F., A. Gallo, C. Zanfi, G. Giuberti and M. Spanghero (2010). "Chemical composition and rumen degradability of three corn hybrids treated with insecticides against the European corn borer (*Ostrinia nubilalis*)." *Animal Feed Science and Technology* 155(1): 25-32.

This experiment determined the chemical composition, rumen degradability (aNDF in stalks and starch in kernels) and in vitro gas production of kernels from three Corn hybrids treated (17) or not treated (control, CTR) with insecticides against the European corn borer (ECB, *Ostrinia nubilalis*). Two whole-plant silage hybrids belonging to the FAO rating 600 and 700 maturity class (S600 and S700, respectively) and one selected for grain production (G600, FAO rating 600, Dekalb-Monsanto Agricoltura S.p.A., Lodi, Italy) were sown in two main plots (TT and CTR) of an experimental field. Two Subsequent treatments of pyrethroids (25 and 1.2 g/ha of cyfluthrin and deltamethrin, respectively) were applied to the Tr plots. The insecticide treatment reduced the number of damaged plants (4.5 broken plants/plot versus 0.3 broken plants/plot, $P < 0.01$) and increased the total grain yield by 11% (13.8 t/ha versus 12.4 t/ha), while hybrids did not differ. ECB larvae which bored into the stalk tunnels modified the chemical composition of stalks and kernels. In stalks, total sugars content (i.e. glucose, fructose, sucrose) was about twice that in TT versus CTR plants (123 g/kg versus 60g/kg DM, $P < 0.01$), while aNDF content was higher in CTR stalks (765 versus 702g/kg DM, $P < 0.01$). DM degradability after 48 h of incubation of stalks was higher in TT than in CTR, both in vitro (0.360 versus 0.298, $P < 0.01$) and in situ (0.370 versus 0.298, $P < 0.05$), while there were no differences in aNDF clegradability. Kernels from Tr plots contained less DM (615 g/kg versus 651 g/kg, $P < 0.01$) and more CP (84 g/kg and 78 g/kg DM, $P < 0.05$) than those from CTR plots, while in situ rumen starch disappearance and in vitro gas production were similar. Corn hybrid selected for yield of grain (G600) differed from S600 and S700 due to a higher ($P < 0.01$) content of aNDF, ADF and lignin(sa) in the stalks, and a higher starch content (696 g/kg versus 674 and 671 g/kg DM, $P < 0.01$) and CP (87 g/kg versus 77 and 76 g/kg DM, $P < 0.05$) in grain. The G600 hybrid produced stalks with a lower ($P < 0.01$) aNDF rumen clegradability than the S600 and S700. On field ECB insecticide treatment improved corn grain yield, reduced broken plants and increased stalk Sugars content at harvesting, but did not change the rumen degradation of either stalks or grain. (C) 2009 Elsevier B.V. All rights reserved.

Meissle, M., P. Mouron, T. Musa, F. Bigler, X. Pons, V. P. Vasileiadis, S. Otto, D. Antichi, J. Kiss, Z. Palinkas, Z. Dorner, R. van der Weide, J. Groten, E. Czembor, J. Adamczyk, J. B. Thibord, B. Melander, G. C. Nielsen, R. T. Poulsen, O. Zimmermann, A. Verschwele and E. Oldenburg (2010). "Pests, pesticide use and alternative options in European maize production: current status and future prospects." *Journal of Applied Entomology* 134(5): 357-375.

Political efforts are made in the European Union (EU) to reduce pesticide use and to increase the implementation of integrated pest management (IPM). Within the EU project ENDURE, research priorities on pesticide reduction are defined. Using maize, one of the most important crops in Europe, as a case study, we identified the most serious weeds,

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arthropod pests, and fungal diseases as well as classes and amounts of pesticides applied. Data for 11 European maize growing regions were collected from databases, publications and expert estimates. Silage maize dominates in northern Europe and grain production in central and southern Europe. Crop rotations range from continuous growing of maize over several years to well-planned rotation systems. Weeds, arthropod pests and fungal diseases cause economic losses in most regions, even though differences exist between northern countries and central and southern Europe. Several weed and arthropod species cause increasing problems, illustrating that the goal of reducing chemical pesticide applications is challenging. Pesticides could potentially be reduced by the choice of varieties including genetically modified hybrids, cultural control including crop rotation, biological control, optimized application techniques for chemicals, and the development of more specific treatments. However, restrictions in the availability of alternative pest control measures, farm organization, and the training and knowledge of farmers need to be overcome before the adoption of environmentally friendly pest control strategies can reduce chemical pesticides in an economically competitive way. The complex of several problems that need to be tackled simultaneously and the link between different control measures demonstrates the need for IPM approaches, where pest control is seen in the context of the cropping system and on a regional scale. Multicriteria assessments and decision support systems combined with pest monitoring programs may help to develop region-specific and sustainable strategies that are harmonized within a EU framework.

Milonas, P. G. and D. A. Andow (2010). "Virgin male age and mating success in *Ostrinia nubilalis* (Lepidoptera: Crambidae)." *Animal Behaviour* 79(2): 509-514.

It is generally assumed that age is potentially an important aspect affecting the mating biology of insects. Some theoretical models correlate mating success with male age, and predict female preference for either older males, as they have proven viability, or younger partners, to avoid age-related fitness costs. Differences in mating success of males in relation to age have been observed in Lepidoptera. We investigated the mating success of males in relation to their age, controlling for mating experience, and the fitness of their female mates in the European corn borer, *Ostrinia nubilalis*. In a laboratory experiment we examined mating success in relation to age and the consequences of male age for female fitness parameters. Male age had no significant influence on mating success for *O. nubilalis* males: 0-day-old virgin males were as likely to mate as 3-, 6- and 9-day-old males. Testes size decreased and spermatophore size increased with virgin male age. Lifetime fecundity was highest for females that mated with 3-day-old virgin males, which was related to their greater longevity. There was no trade-off between daily fecundity and longevity for females mating with different-aged males. These results suggest that direct benefits from males are insufficient to account for the observed female mating preferences for different-aged males. (C) 2009 The Association for the Study of Animal Behaviour. Published by Elsevier Ltd. All rights reserved.

Obopile, M., R. B. Hammond and P. A. Paul (2010). Interaction Between Maize Phenology and Transgenic Maize Hybrids on *Gibberella* Ear Rot Following European Corn Borer Infestation.

Field studies were conducted at Hoytville and Wooster, Ohio, USA from 2006 to 2008 to determine the influence of three planting dates and transgenic Bt maize on incidence and severity of ear rots following European corn borer infestation. Significant linear correlations were obtained between European corn borer ear damage and *Gibberella* ear rot. The use of Bt maize reduced incidence and severity of ear rot compared to non-Bt hybrids. Compared with short season hybrids, significant reduction in ear rots occurred on full season hybrids. The benefit of using Bt hybrids to control ear rot was more evident as planting was delayed than early planting.

Olsson, S. B., S. Kesevan, A. T. Groot, T. Dekker, D. G. Heckel and B. S. Hansson (2010). "Ostrinia revisited: Evidence for sex linkage in European Corn Borer *Ostrinia nubilalis* (Hubner) pheromone reception." *Bmc Evolutionary Biology* 10.

Background: The European Corn Borer, *Ostrinia nubilalis* (Hubner), is a keystone model for studies on the evolution of sex pheromone diversity and its role in establishing reproductive isolation. This species consists of two sympatric races, each utilizing opposite isomers of the same compound as their major pheromone component. Female production and male response are congruent in each race, and males from each strain exhibit phenotypic differences in peripheral physiology. Both strains possess co-localized pheromone-sensitive olfactory sensory neurons characterized by a larger amplitude action potential (spike) responding to the major pheromone component, and a smaller spike amplitude cell responding to the minor component, i.e. the opposite isomer. These differences in amplitude correspond to differences

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in dendritic diameter between the two neurons. Previous studies showed that behavioral response to the pheromone blend was sex-linked, but spike amplitude response to pheromone components matched autosomal, not sex-linked inheritance. Results: As part of a larger study to finely map the loci responsible for pheromone communication in this species, we have reanalyzed peripheral physiology among parental, and first and second generation hybrids between the two pheromone strains using tungsten electrode electrophysiology. Our results reveal that differences in spike amplitude ratio between male pheromone-sensitive sensory neurons in *O. nubilalis* races are controlled, at least partially, by sex-linked genes that exhibit E-strain dominance. Conclusions: We propose that peripheral olfactory response in *O. nubilalis* may be affected both by autosomal and sex-linked genes exhibiting a cross-locus dominance effect, and suggest that the genetic basis for pheromone reception and response in the species is more closely linked than previously thought.

Ordas, B., R. A. Malvar, R. Santiago and A. Butron (2010). "QTL mapping for Mediterranean corn borer resistance in European flint germplasm using recombinant inbred lines." *Bmc Genomics* 11.

Background: *Ostrinia nubilalis* (ECB) and *Sesamia nonagrioides* (MCB) are two maize stem borers which cause important losses in temperate maize production, but QTL analyses for corn borer resistance were mostly restricted to ECB resistance and maize materials genetically related (mapping populations derived from B73). Therefore, the objective of this work was to identify and characterize QTLs for MCB resistance and agronomic traits in a RILs population derived from European flint inbreds. Results: Three QTLs were detected for stalk tunnel length at bins 1.02, 3.05 and 8.05 which explained 7.5% of the RILs genotypic variance. The QTL at bin 3.05 was co-located to a QTL related to plant height and grain humidity and the QTL at bin 8.05 was located near a QTL related to yield. Conclusions: Our results, when compared with results from other authors, suggest the presence of genes involved in cell wall biosynthesis or fortification with effects on resistance to different corn borer species and digestibility for dairy cattle. Particularly, we proposed five candidate genes related to cell wall characteristics which could explain the QTL for stalk tunnelling in the region 3.05. However, the small proportion of genotypic variance explained by the QTLs suggest that there are also many other genes of small effect regulating MCB resistance and we conclude that MAS seems not promising for this trait. Two QTLs detected for stalk tunnelling overlap with QTLs for agronomic traits, indicating the presence of pleiotropism or linkage between genes affecting resistance and agronomic traits.

O'Rourke, M. E., T. W. Sappington and S. J. Fleischer (2010). "Managing resistance to Bt crops in a genetically variable insect herbivore, *Ostrinia nubilalis*." *Ecological Applications* 20(5): 1228-1236.

To slow the resistance evolution of the European corn borer (ECB) to Cry proteins expressed in transgenic *Bacillus thuringiensis* (Bt) corn, the United States Environmental Protection Agency (EPA) has adopted an insect resistance management (IRM) plan that relies on a "high dose/refuge" strategy. However, this IRM plan does not consider possible ecological differences between the two ECB pheromone races (E and Z). Using carbon isotope analysis, we found that unstructured (non-corn) refuges contribute more to E race (18%) than to Z race (4%) populations of ECB in upstate New York (USA). Furthermore, feeding on non-corn hosts is associated with decreased body mass and reduced fecundity. We also show that the geographic range of E-race ECB is restricted within the range of the Z race and that E-race ECB are increasingly dominant in regions with increasing non-corn habitat. While the proportion of E-race ECB developing in unstructured refuges is higher than previously assumed, low rates of unstructured refuge use by the Z race, evidence for reduced fecundity when reared on non-corn hosts, and complete sympatry within the E race range all argue against a relaxation of current IRM refuge standards in corn based on alternative-host use. We also discuss implications of this research for integrated pest management in vegetables and IRM in Bt cotton.

Pelissie, B., S. Ponsard, Y. S. Tokarev, P. Audiot, C. Pelissier, R. Sabatier, S. Meusnier, J. Chaufaux, M. Delos, E. Campan, J. M. Malysh, A. N. Frolov and D. Bourguet (2010). "Did the introduction of maize into Europe provide enemy-free space to *Ostrinia nubilalis*? Parasitism differences between two sibling species of the genus *Ostrinia*." *Journal of Evolutionary Biology* 23(2): 350-361.

We examined whether maize offers enemy-free space (EFS) to its pest *Ostrinia nubilalis*, and may thereby have contributed to its divergence from the sibling species, *Ostrinia scapularis*, feeding mainly on mugwort, when introduced into Europe five centuries ago. We collected *Ostrinia* larvae on maize (70 populations, 8425 individuals) and mugwort (10 populations, 1184 individuals) and recorded parasitism using both traditional (counting emerging parasitoids) and

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molecular methods (detection by specific polymerase chain reaction). The main parasitoid was *Macrocentrus cingulum* (Braconidae). On mugwort, parasitism was twice that on maize, and parasitoid-related mortality was 8 times higher. This suggests that maize affords substantial EFS to *Ostrinia* feeding on it. The lower Mortality:Infestation ratio in maize suggests that *O. nubilalis*' immune response might be stronger than that of *O. scapularis*. If so, adapting to maize and diverging from *O. scapularis* would decrease the impact of parasitism on *O. nubilalis* at both ecological and evolutionary levels.

Pereira, E. J. G., H. A. A. Siqueira, M. B. Zhuang, N. P. Storer and B. D. Siegfried (2010). "Measurements of Cry1F binding and activity of luminal gut proteases in susceptible and Cry1F resistant *Ostrinia nubilalis* larvae (Lepidoptera: Crambidae)." *Journal of Invertebrate Pathology* 103(1): 1-7.

The biochemical mechanism of resistance to the *Bacillus thuringiensis* Cry1F toxin was studied in a laboratory-selected strain of *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) showing more than 3000-fold resistance to Cry1F and limited cross resistance to other Cry toxins. Analyses of Cry1F binding to brush border membrane vesicles of midgut epithelia from susceptible and resistant larvae using ligand immunoblotting and Surface Plasmon Resonance (SPR) suggested that reduced binding of Cry1F to insect receptors was not associated with resistance. Additionally, no differences in activity of luminal gut proteases or altered proteolytic processing of the toxin were observed in the resistant strain. Considering these results along with previous evidence of relatively narrow spectrum of cross resistance and monogenic inheritance, the resistance mechanism in this Cry1F selected strain of *O. nubilalis* appears to be specific and may be distinct from previously identified resistance mechanisms reported in other Lepidoptera. (C) 2009 Elsevier Inc. All rights reserved.

Prasifka, J. R., R. L. Hellmich, A. L. B. Crespo, B. D. Siegfried and D. W. Onstad (2010). "Video-tracking and On-plant Tests Show Cry1Ab Resistance Influences Behavior and Survival of Neonate *Ostrinia nubilalis* Following Exposure to Bt Maize." *Journal of Insect Behavior* 23(1): 1-11.

To examine how resistance to *Bacillus thuringiensis* (Bt) toxins influences movement and survival of European corn borer (*Ostrinia nubilalis* [Hubner]) neonates, the responses of Cry1Ab-resistant, -susceptible, and hybrid (F1) larvae were examined using two different techniques. First, using an automated video-tracking system, aspects of *O. nubilalis* movement were quantified in the presence of artificial diet incorporating 50% non-Bt or insect-resistant Cry1Ab maize tissue. Second, *O. nubilalis* dispersal and survival were measured 48-72 h after hatching on a Cry1Ab maize plant surrounded by two non-Bt maize plants. Video tracking indicated the presence of Cry1Ab tissue increased the total distance moved (m), time moving (%), and time away from the diet (%) for *O. nubilalis* while decreasing meander (degrees/cm). However, resistant larvae showed reduced movement and increased meander (a parts per thousand localized searching) relative to susceptible or hybrid larvae on diet incorporating Cry1Ab tissue. Conversely, when placed onto Cry1Ab maize plants, resistant larvae were more likely than susceptible *O. nubilalis* to disperse onto adjacent non-Bt plants. The difference in on-plant dispersal seems to reflect greater survival after toxin exposure for resistant larvae rather than increased activity. These results suggest that simplified 'Petri dish' tests may not be predictive of larval movement among non-Bt and insect-resistant Bt maize plants. Because models of *O. nubilalis* resistance evolution incorporate various movement and survival parameters, improved data for on-plant behavior and survival of Bt-resistant, -susceptible, and hybrid larvae should help preserve the efficacy of transgenic insect-resistant maize.

Rahman, K. M. A., M. Barta and L. Cagan (2010). "Effects of combining *Beauveria bassiana* and *Nosema pyrausta* on the mortality of *Ostrinia nubilalis*." *Central European Journal of Biology* 5(4): 472-480.

We tested the combined effect of the fungus *Beauveria bassiana* and the microsporidium *Nosema pyrausta* on the European corn borer larvae, *Ostrinia nubilalis*, in the laboratory. The first instar of *O. nubilalis* larvae was the most sensitive to the *B. bassiana* infection followed by the fifth, second, third, and fourth instar (LC(50)s were 4.91, 6.67, 7.13, 9.15, and 6.51 x 10⁵ conidia/ml for the first to fifth instars, respectively). Mortality of each instar increases positively with concentration of conidia. When *B. bassiana* and *N. pyrausta* were used in combination, mortality increased significantly in all instars. Relative to the *B. bassiana* treatment alone, the *B. bassiana* + *N. pyrausta* treatment decreased the LC(50)s by 42.16%, 37.63%, 21.60%, 27.11%, and 33.95% for the first to fifth instars, respectively. The combined effects of the two pathogens were mostly additive. However, at the two highest concentrations the pathogens

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interacted synergistically in the first and second instar. Individuals that survived the *B. bassiana* and *B. bassiana* + *N. pyrausta* treatments and developed into adults had significantly shorter lifespans and females oviposited fewer eggs than non-exposed insects. The effects on the longevity and the egg production were most pronounced at high concentration of *B. bassiana* conidia.

Safavi, S. A., A. Kharrazi, G. R. Rasouljan and A. R. Bandani (2010). "Virulence of Some Isolates of Entomopathogenic Fungus, *Beauveria bassiana* on *Ostrinia nubilalis* (Lepidoptera: Pyralidae) Larvae." *Journal of Agricultural Science and Technology* 12(1): 13-21.

The European Corn Borer (ECB) is one of the most important insect pests of corn and some other crops such as rice in Iran. This pest is one of the most important hosts of the entomopathogenic fungus *Beauveria bassiana*, a well known fungal entomopathogen with high host range and considerable potential in insect pest control. In an isolate selection program of fungal isolates against ECB, ten isolates consisting of eight isolates from Iran and two from other countries were assayed using the dipping method on third instar larvae of ECB. Inoculum concentrations were 10(4), 10(5), 10(6), 10(7), and 10(8) conidia ml⁻¹. For each concentration, 30 larvae were dipped into the conidial suspension for 30 seconds. Control larvae were treated with distilled water containing 0.03 percent Tween-80 as surfactant. Each experiment was repeated three times. Results showed that BEH isolate which was isolated from the soil of insects living in the field, caused the highest mortality in larvae in comparison with other isolates with a mean of 57.67 percent mortality using 10(8) conidia ml⁻¹. Other isolates, such as DEB1007 and EVIN I, were scored in the lower position with producing 53.43 and 42.67 percent mortality, respectively. EVIN II, DEBI002, and DEBI008 caused the lowest mortality in assayed larvae. A decrease in larval feeding was detectable a few days before death. Possible causes for the low mortality in isolates are discussed.

Sandoya, G., R. A. Malvar, R. Santiago, A. Alvarez, P. Revilla and A. Butron (2010). "Effects of selection for resistance to *Sesamia nonagrioides* on maize yield, performance and stability under infestation with *Sesamia nonagrioides* and *Ostrinia nubilalis* in Spain." *Annals of Applied Biology* 156(3): 377-386.

A maize synthetic population was improved for resistance to the Mediterranean corn borer (MCB, *Sesamia nonagrioides*) while maintaining yield. The objectives of this research were to investigate whether yield and yield stability of the maize synthetic population named EPS12 were affected by selection for MCB resistance; also to determine which genotypic and environmental covariates could explain the genotype (G), environment (E) and genotype x environment (GE) effects for yield under corn borer infestation. Plants from three cycles of selection and their testcrosses to three inbred testers (A639, B93 and EP42) were evaluated at two locations in 2 years, under MCB and European corn borer infestations. After selection EPS12 was a more stable genotype. Hybrids derived from crosses between B93 and inbreds obtained from the initial cycles of selection could be recommended for cultivation in northern Spain. The yield of crosses between cycles of selection and testers increased when there were fewer days with temperatures > 25 degrees C and higher mean maximum temperatures. Differences in yield among these genotypes were mostly explained by resistance to corn borer attack. In general, among EPS12-derived materials, genetic characteristics that contribute to increased grain yield were also responsible for increased abiotic stress tolerance.

Sole, J., A. Sans, M. Riba and A. Guerrero (2010). "Behavioural and electrophysiological responses of the European corn borer *Ostrinia nubilalis* to host-plant volatiles and related chemicals." *Physiological Entomology* 35(4): 354-363.

The European corn borer *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) is a worldwide pest of maize (*Zea mays* L.) and other crops. The semiochemicals released by maize plants and structurally-related compounds can be used by adult female *O. nubilalis* for host-plant location and oviposition. Headspace volatile compounds emitted by watered and water-deprived maize plants are collected and identified by their retention indices and mass spectra. The most abundant compounds from watered plants are limonene, linalool, benzoic acid, indole, beta-caryophyllene and acetophenone, whereas, in water-deprived plants, limonene, acetophenone, hexanoic acid, benzoic acid and indole are dominant. In addition, (E)-4,8-dimethyl-1,3,7-nonatriene, 6-methyl-5-hepten-2-one, anisole and 1-carvone are undetected in the water-deprived plants. Some of the identified compounds show electrophysiological activity (electroantennogram) in the antennae of both sexes, with the responses elicited by tridecane, tetradecane, dodecane, nonanal, decanal and 2-ethylhexanol on males being particularly noteworthy. In a dual-choice olfactometer, adult females show a preference for 2-hexanol, heptanal, methyl salicylate, hexyl acetate, nonanal, methyl dodecanoate, beta-

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pinene and (E)-2-hexenyl acetate over hexane controls. Tetradecane, linalool, methyl hexanoate, methyl nonanoate, (Z)-3-hexenyl benzoate, tridecane, 2-cyclopentylcyclopentanone, 3-methylbutyl acetate, beta-myrcene and (Z)-3-hexenyl butanoate result in fewer females in the test arm compared with the control arm. No single compound displays an activity similar to watered maize plants, supporting the hypothesis that blends of volatiles in specific ratios are more effective than single volatile chemicals. The results of the present study suggest that methyl salicylate, which elicits also one of the highest electrophysiological responses in female antennae, plays a role in host preference by *O. nubilalis* females.

Sumerford, D. V., J. Glasser and L. C. Lewis (2010). "MATING ARENA DYNAMICS FOR OSTRINIA NUBILALIS (LEPIDOPTERA: CRAMBIDAE)." *Florida Entomologist* 93(3): 432-436.

Many bioassays of insect species are dependent on the use of laboratory-reared insects. If the purpose of the research is to assess the genetic variance present for an insect trait, e.g., insecticide-resistance monitoring, it is imperative to understand the potential mating dynamics and genetic contributions of adults to the larvae evaluated in bioassays. We report the results of a study utilizing a laboratory-reared colony of *Ostrinia nubilalis* (Hubner). The changes in the population dynamics (e.g., numbers of males, females, fertile egg masses, mated females) were evaluated. Although the numbers of emerging females, living females, mated females and fertile egg masses changed during the experiment, the percentage of total females that were mated did not change (similar to 54%). The first of the females to emerge were beginning to die as later-emerging females were mating. Results suggest that experimental designs that rely on laboratory-reared *O. nubilalis* will need to test larvae from several nights of oviposition to better ensure that the total genetic composition of the population is sampled.

Suverkropp, B. P., F. Bigler and J. C. van Lenteren (2010). "Movement and host finding of *Trichogramma brassicae* on maize plants." *Bulletin of Insectology* 63(1): 115-127.

Direct observation of searching patterns and residence times of *Trichogramma brassicae* Bezdenko on maize plants were made at 18 degrees C and 25 degrees C. Temperature had a strong effect on the residence times: parasitoids spent an average of 44.9 minutes on the plant at 18 degrees C and 20.8 minutes at 25 degrees C. Observations on single plants showed that parasitoids mainly walked from one leaf to another. The leaf part closest to the stem was the most often visited and longest searched leaf area. At 18 degrees C, many parasitoids went to the lower leaf side and stopped searching. Leaf level, leaf side or size of the leaf where the parasitoid landed had no effect on residence time. Although about 20% of total searching time was spent in following the leaf edge and mid rib, *Ostrinia* (Hubner) egg masses touching the mid rib were not found more often than those away from the mid rib. Host finding was also not influenced by the position of egg masses relative to the stem, or by the leaf height. Naturally laid egg masses were found twice as often as artificially placed egg masses. The scales that *O. nubilalis* adults left in small patches on the plant seemed to be as effective a cue as host cues artificially confined to a small area around the host egg mass. When maize plants were covered with fine netting and a number of *O. nubilalis* kept close to the plant for one night in such a way that the moths were unable to touch the plants, host finding and residence times of *T. brassicae* were significantly higher on these plants than on untreated plants. This indicates that volatile cues left by *O. nubilalis* had an arresting effect and were used in host finding by *T. brassicae*.

Tiwari, S., R. R. Youngman, T. A. Jordan and C. A. Laub (2010). "A Technique Using Reusable Components for Hand-Infesting Cornstalks With European Corn Borer (Lepidoptera: Crambidae) Larvae." *Journal of Economic Entomology* 103(6): 2080-2086.

Field trials were conducted in 2005 and 2006 to evaluate the use of reusable wire nuts and nonreusable gelatin capsules for hand-infesting cornstalks with European corn borer, *Ostrinia nubilalis* (Hubner), (Lepidoptera: Crambidae) larvae. The reusable technique, which consists of a modified Wing Gard plastic wire connector (i.e., wire nut) as a containment device for larvae, was compared over three plant growth stages to a gelatin capsule technique. In 2005 and 2006, the wire nut technique resulted in significantly higher number of wire nuts still intact (i.e., undamaged, with or without a larva) on the stalk at 72 h after infestation compared with the gelatin capsule technique. In addition, the wire nut technique resulted in significantly higher number of tunnels per stalk compared with the gelatin capsule technique at all three corn growth stages during both years. In 2005, the mean +/- SEM number of tunnels per stalk was 0.53 +/- 0.03 in the wire nut technique compared with 0.13 +/- 0.03 tunnels per stalk in the gelatin capsule technique. In 2006, the mean number of tunnels per stalk was 0.45 +/- 0.03 in the wire nut technique compared with

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0.08 +/- 0.02 tunnels per stalk in the gelatin capsule technique. In addition, the relative net precision in the wire-nut technique was approximate to 2 times higher compared with the gelatin capsule technique.

Wanner, K. W., A. S. Nichols, J. E. Allen, P. L. Bungler, S. F. Garczynski, C. E. Linn, H. M. Robertson and C. W. Luetje (2010). "Sex Pheromone Receptor Specificity in the European Corn Borer Moth, *Ostrinia nubilalis*." Plos One 5(1).

Background: The European corn borer (ECB), *Ostrinia nubilalis* (Hubner), exists as two separate sex pheromone races. ECB(Z) females produce a 97:3 blend of Z11- and E11-tetradecenyl acetate whereas ECB(E) females produce an opposite 1:99 ratio of the Z and E isomers. Males of each race respond specifically to their conspecific female's blend. A closely related species, the Asian corn borer (ACB), *O. furnacalis*, uses a 3:2 blend of Z12- and E12-tetradecenyl acetate, and is believed to have evolved from an ECB-like ancestor. To further knowledge of the molecular mechanisms of pheromone detection and its evolution among closely related species we identified and characterized sex pheromone receptors from ECB(Z). Methodology: Homology-dependent (degenerate PCR primers designed to conserved amino acid motifs) and homology-independent (pyrophosphate sequencing of antennal cDNA) approaches were used to identify candidate sex pheromone transcripts. Expression in male and female antennae was assayed by quantitative real-time PCR. Two-electrode voltage clamp electrophysiology was used to functionally characterize candidate receptors expressed in *Xenopus* oocytes. Conclusion: We characterized five sex pheromone receptors, OnOrs1 and 3-6. Their transcripts were 14-100 times more abundant in male compared to female antennae. OnOr6 was highly selective for Z11-tetradecenyl acetate ($EC_{50} = 0.86 \pm 0.27 \mu M$) and was at least three orders of magnitude less responsive to E11-tetradecenyl acetate. Surprisingly, OnOr1, 3 and 5 responded to all four pheromones tested (Z11- and E11-tetradecenyl acetate, and Z12- and E12-tetradecenyl acetate) and to Z9-tetradecenyl acetate, a behavioral antagonist. OnOr1 was selective for E12-tetradecenyl acetate based on an efficacy that was at least 5-fold greater compared to the other four components. This combination of specifically- and broadly-responsive pheromone receptors corresponds to published results of sensory neuron activity in vivo. Receptors broadly-responsive to a class of pheromone components may provide a mechanism for variation in the male moth response that enables population level shifts in pheromone blend use.

Wraight, S. P., M. E. Ramos, P. B. Avery, S. T. Jaronski and J. D. Vandenberg (2010). "Comparative virulence of *Beauveria bassiana* isolates against lepidopteran pests of vegetable crops." Journal of Invertebrate Pathology 103(3): 186-199.

Forty-three isolates of the entomopathogenic fungus *Beauveria bassiana* were screened for virulence against second-instar larvae of diamondback moth (*Plutella xylostella*) (DBM), European corn borer (*Ostrinia nubilalis*) (ECB), corn earworm (*Helicoverpa zea*) (CEW), and fall armyworm (*Spodoptera frugiperda*) (FAW); 30 of these isolates were tested against beet armyworm (*Spodoptera exigua*) (BAW). Highly virulent isolates were also tested against black cutworm (*Agrotis ipsilon*) (BCW), and the most virulent isolate was also assayed against imported cabbage worm (*Pieris rapae*) (ICW) and cabbage looper (*Trichoplusia ni*) (CL). All lepidopteran species tested were susceptible to *B. bassiana*. Corn earworm and beet armyworm were most susceptible to fungal infection, and fall armyworm was least susceptible. Limited testing suggested low susceptibility of black cutworm and cabbage looper. *B. bassiana* isolate 1200 exhibited virulence against all pest species greater than or equal to commercial strain GHA of *B. bassiana* currently registered in the USA as BotaniGard (R). In assays in which larvae were topically sprayed and maintained on the treated substrate for 24 h at 100% relative humidity, 6-day (25 degrees C) median lethal concentrations (LC(50)s) of this isolate against CEW, BAW, DBM, FAW, ICW, ECB, CL, and BCW were 4, 5, 7, 11, 12, 98, 125, and 273 conidia/mm², respectively. The respective LC(50)s of commercial strain GHA against these pest species were 9, 67, 97, 1213, 29, 1668, 541, and 3504 conidia/mm². Use of LC(50) versus median lethal concentration ratios (comparing LC(50)s of each isolate to a "standard" strain) generated similar rankings of isolate virulence. Results from parametric ANOVAs of log LC(50) values followed by Tukey HSD multiple comparisons tests and those from Kruskal-Wallis nonparametric analyses followed by sequential Bonferroni tests for means comparisons were nearly identical. Published by Elsevier Inc.

Zaman, F. U., D. D. Calvin, E. G. Rajotte and D. V. Sumerford (2010). "Can a Specialist Parasitoid, *Macrocentrus cingulum* (Hymenoptera: Braconidae), Influence the Ecotype Structure of Its Preferred Host *Ostrinia nubilalis* (Lepidoptera: Crambidae)?" Journal of Economic Entomology 103(2): 249-256.

Synchronization between a parasitoid and its preferred host is an essential strategy for successful biological control. Two ecotypes of *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) in North America are distinguished by their

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voltinism. In this study, the differential impact of a specialist parasitoid, *Macrocentrus cingulum* Brischke (Hymenoptera: Braconidae), on the univoltine and multivoltine populations of *O. nubilalis* is investigated. Four years of field and laboratory study suggested that *M. cingulum* emergence was synchronized with the spring emergence of the multivoltine ecotypes of *O. nubilalis* in Pennsylvania. Univoltine populations experienced minimal parasitism from *M. cingulum*. Field-collected data suggested that the postdiapause multivoltine *O. nubilalis* field population was male biased, whereas the univoltine population was female biased. *M. cingulum*-parasitized postdiapause *O. nubilalis* larvae were significantly heavier than the male and nonparasitized female larvae. Sex ratio differences observed in overwintered *O. nubilalis* populations in the presence or absence of *M. cingulum* parasitism suggested preferential parasitism between male and female *O. nubilalis* larvae. Correlation between the larger parasitized *O. nubilalis* larval host and the number of adult parasitoids emerging per host suggested a potential evolutionary advantage to parasitizing female or larger hosts.

Bazok, R., J. I. Bareia, T. Kos, T. G. Euljak, M. Siloviae, S. Jelovean and A. Kozina (2009). "Monitoring and efficacy of selected insecticides for European corn borer (*Ostrinia nubilalis* Hubn., Lepidoptera: Crambidae) control." *Journal of Pest Science* 82(4): 311-319.

The European corn borer (ECB), *Ostrinia nubilalis* (H degrees bner) (Lepidoptera: Crambidae), is the major arthropod pest of corn in Croatia. However, chemical control is carried out only in maize for seed production, and in sweet corn. A 3-year investigation was carried out in corn fields in northwest Croatia to establish the most attractive pheromone lure for ECB monitoring, the optimal timing of insecticide applications, and the efficacy of selected insecticides against ECB. During each of the 3 years, the pheromone lures E, Z and E/Z (A << IsagroA >>) were evaluated in the field from May to July. Insecticides were sprayed 14-20 days after the maximal capture in 2002 and 2003. In 2004, three different trials were set up: one trial with one early treatment (when corn was in the R49 development stage according to the extended BBCH scale); one with one late treatment (when corn was in the R65 development stage according to the BBCH scale); and one with two treatments in both stages. In the trials studying *Bacillus thuringiensis* var. *kurstaki* (B.t.k.), insect growth regulators (IGR), spinosad and classical chemical insecticides were applied. Pheromone lure E was the most attractive for monitoring ECB flights throughout 2 years of investigation. Insecticide efficacy depended on application timing. The insecticides most suitable for integrated pest management (IPM) programs, including spinosad, B.t.k. and IGR, resulted in high (spinosad) to moderate (B.t.k.) efficacy. The efficacy of IGRs indicates the need for earlier application. The efficacy of chemical insecticides depended on the year and the insecticide. The organophosphate (OP) insecticides and pyrethroids gave moderate to good results; imidacloprid did not provide significant efficacy. One application of all insecticides based on proper (early) timing resulted in the same efficacy as two applications of the same insecticides.

Bel, Y., H. A. A. Siqueira, B. D. Siegfried, J. Ferre and B. Escriche (2009). "Variability in the cadherin gene in an *Ostrinia nubilalis* strain selected for Cry1Ab resistance." *Insect Biochemistry and Molecular Biology* 39(3): 218-223.

Transgenic corn expressing Cry1Ab (a *Bacillus thuringiensis* toxin) is highly effective in the control of *Ostrinia nubilalis*. For its toxic action, Cry1Ab has to bind to specific insect midgut proteins. To date in, three Lepidoptera species resistance to a Cry1Ab toxin has been conferred by Mull in cadherin, a protein of the Lepidoptera midgut membrane. The implication of cadherin in the resistance of an *Ostrinia nubilalis* colony (Europe-R) selected with *Bacillus thuringiensis* Cry1Ab protoxin was investigated. Several major mutations in the cadherin (*cdh*) gene were found, which introduced premature termination codons and/or large deletions (ranging from 1383 to 1701 bp). The contribution of these major mutations to the resistance was analyzed in resistant individuals that survived exposure to a high concentration of Cry1Ab protoxin. The result!; indicated that the presence of major mutations was drastically reduced in individuals that survived exposure. previous inheritance experiments with the Europe-R strain indicated the involvement of more than one genetic locus and reduced amounts of the cadherin receptor. The results of the present work support a polygenic inheritance of resistance in the Europe-R strain in which, mutations in the *cdh* gene would contribute to resistance by means of an additive effect. (C) 2008 Elsevier Ltd. All Rights reserved.

Blandino, M., A. Reyneri, F. Vanara, M. Pascale, M. Haidukowski and C. Campagna (2009). "Management of fumonisin contamination in maize kernels through the timing of insecticide application against the European corn borer *Ostrinia nubilalis* Hubner." *Food Additives and Contaminants Part a-Chemistry Analysis Control Exposure & Risk Assessment* 26(11): 1501-1514.

Cette veille bibliographique est réalisée par Nathalie Roullé et Nicolas Chatel-Launay, Pôle d'excellence en lutte intégrée (PELI).

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The European corn borer (ECB), *Ostrinia nubilalis*, is the principal pest of maize in Central and South Europe. It is known to promote *Fusarium verticillioides* infection in maize grain, a recognized producer of fumonisins. Field experiments were performed in 2006 and 2007 in two sites in NW Italy to determine the effects of the timing of insecticide application on ECB damage, fungal ear rot and fumonisin contamination under natural conditions. Different insecticide application timings were compared, from maize flowering to approximately 15 days after the flight peak of adult ECB. At harvest, the ears were rated for incidence and severity of ECB damage, fungal ear rot symptoms and fumonisin (FB1 + FB2) contamination. In all years/sites, treatments applied at the beginning of consistent ECB flight activity were most effective in controlling insect damage on ears. Fungal ear rot and fumonisin contamination were significantly affected by ECB control. The efficacy of the best timing of insecticide application in controlling fumonisin contamination was, on average, 93% compared to the untreated control. Contamination levels of these mycotoxins increased with either an earlier or later treatment. Furthermore, an earlier insecticide application showed lower fumonisin contamination than a treatment applied after the adult flight peak. Production of maize kernels and maize-based foods that do not exceed the maximum international and EU permitted levels for fumonisins could be enhanced by appropriate insecticide treatment against second generation ECB. The optimum time for insecticide application is between the beginning of consistent adult flight activity and the flight peak.

Boino, D. R. and J. R. Loomquist (2009). "TOXICITY AND DISRUPTION OF MIDGUT PHYSIOLOGY IN LARVAE OF THE EUROPEAN CORN BORER, *Ostrinia nubilalis*, BY ANION TRANSPORTER BLOCKERS." *Archives of Insect Biochemistry and Physiology* 70(3): 151-161.

In this study four blockers of anion transporters (ATs) belonging to four different classes of organic acids, including DIDS (4, 4'-diisothiocyanato-stilbene-2, 2'-disulfonic acid; a stilbene disulfonic acid), NPPB [(5-nitro-2-(3-phenylpropylamino) benzoic acid; an anthranilic acid)], 9-AC (anthracene-9-carboxylic acid; an aromatic carboxylic acid), and IAA-94 (indanyloxy acetic acid; an indanyloxy alkanic acid), were tested for their toxicity against the European corn borer (ECB), *Ostrinia nubilalis*. All the AT blockers inhibited the growth of larvae, increased the developmental time, and decreased survival compared to controls, when second-instar ECB larvae were fed, for seven days on treated diet. In general, DIDS and NPPB were the most active compounds, with the rank order of activity being DIDS > NPPB > IAA-94 > 9-AC. All the AT blockers decreased the midgut alkalinity in fifth-instar larvae when fed for 3 h on treated diet. Effective concentrations required for 50% decrease in midgut alkalinity (EC(50)) ranged between 29.1 and 41.2 ppm, and the rank order of activity was NPPB > DIDS > IAA-94 > 9-AC. Similarly, all the tested AT blockers inhibited (36)Cl(-) uptake from the midgut lumen, in fifth-instar larvae when fed for 3 h on treated diet. Concentrations required for 50% inhibition of (36)Cl(-) uptake (IC(50)) ranged between 7.4 and 11.0 ppm and the rank order of activity was DIDS > NPPB > 9-AC > IAA-94. Modest to highly strong positive correlations observed among growth, midgut alkalinity, and midgut Cl(-) ion transport in AT blocker-fed larvae suggested that these effects are causally related to each other. Finally, AT blockers have the potential to become good candidates for development of insecticides with a unique mode of action. (C) 2009 Wiley Periodicals, Inc.

Chapman, A. V., T. P. Kuhar, P. B. Schultz and C. C. Brewster (2009). "Dispersal of *Trichogramma ostriniae* (Hymenoptera: Trichogrammatidae) in Potato Fields." *Environmental Entomology* 38(3): 677-685.

The dispersal ability of *Trichogramma ostriniae* Pang and Chen, a biological control agent of *Ostrinia nubilalis* Hubner, was studied in commercial potato fields on the Eastern Shore of Virginia. The purpose was to quantify dispersal of *T. ostriniae* after an inundative release to aid in determining the number of release points needed per unit area for effective biological control of *O. nubilalis* in solanaceous crops. A single release of approximately 0.5 million wasps was made in two spatially separate potato fields in summer 2005 and 2006. Each release area contained 25 monitoring points at distances from 5 to 45 m from the release point bearing a yellow sticky card and *O. nubilalis* egg sentinels to observe for adult parasitoids and parasitism, respectively. Results showed that movement of *T. ostriniae* adults from the release point was rapid with individuals captured at 45 m within 1 d of emergence. High rates of parasitization (20-50%) also were observed at this distance, but the levels decreased with increasing distance from the release point. The distances that encompassed 98% recaptured *T. ostriniae* adults (x(98)) were 27.5 and 12.9 m from the release point in 2005 and 2006, respectively. The (x(98)) distances for parasitization of *O. nubilalis* were 21-26 m in 2005 and 8-10 m in 2006. However, the highest levels of parasitization in both years occurred nearest the release point. *T. ostriniae* showed uniform dispersal within an area of approximately 0.1 ha, indicating that multiple release points should be used for

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effective dispersal of *T. ostriniae* and control of *O. nubilalis* in solanaceous crops. Based on the assumption that a distance of 16 m represents the radius around a release point in which *T. ostriniae* activity was at its maximum, we estimate that approximately 12 release points/ha would be required in potato fields.

Chapman, A. V., T. P. Kuhar, P. B. Schultz, T. W. Leslie, S. J. Fleischer, G. P. Dively and J. Whalen (2009). "Integrating Chemical and Biological Control of European Corn Borer in Bell Pepper." *Journal of Economic Entomology* 102(1): 287-295.

Using multiple locations and a series of field trials over 2 yr, we evaluated an integrated pest management program for *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) management in peppers involving biorational chemistries, inundative releases of *Trichogramma ostriniae* (Pang & Chen), and conservation of generalist predators. In small plot trials, three biorational insecticides (spinosad, indoxacarb, and methoxyfenozide) provided comparable control of *O. nubilalis* as two broad-spectrum conventional insecticides (acephate and lambda-cyhalothrin). However, lambda-cyhalothrin at most locations, and indoxacarb at one location, resulted in outbreaks of green peach aphids. We also observed significant effects on the generalist predator community: beneficial communities in methoxyfenozide-treated plots were most similar to untreated controls, and acephate-treated plots were the least similar. Management systems comparing untreated controls, inundative release of *T. ostriniae* with methoxyfenozide applied when lepidopterans exceeded thresholds, or weekly applications of acephate or lambda-cyhalothrin, showed no effects on marketable fruit or percentage of fruit damaged, but the conventional insecticide approach caused aphid flares. Inundative releases of *T. ostriniae* and biorational chemistries provide a more environmentally sound approach to managing *O. nubilalis* in pepper, due, in part, to conservation of generalist predators.

Coates, B. S., D. V. Sumerford, R. L. Hellmich and L. C. Lewis (2009). "Repetitive genome elements in a European corn borer, *Ostrinia nubilalis*, bacterial artificial chromosome library were indicated by bacterial artificial chromosome end sequencing and development of sequence tag site markers: implications for lepidopteran genomic research." *Genome* 52(1): 57-67.

The European corn borer, *Ostrinia nubilalis*, is a serious pest of food, fiber, and biofuel crops in Europe, North America, and Asia and a model system for insect olfaction and speciation. A bacterial artificial chromosome library constructed for *O. nubilalis* contains 36 864 clones with an estimated average insert size of ≥ 120 kb and genome coverage of 8.8-fold. Screening OnB1 clones comprising approximately 2.76 genome equivalents determined the physical position of 24 sequence tag site markers, including markers linked to ecologically important and *Bacillus thuringiensis* toxin resistance traits. OnB1 bacterial artificial chromosome end sequence reads (GenBank dbGSS accessions ET217010 to ET217273) showed homology to annotated genes or expressed sequence tags and identified repetitive genome elements, *O. nubilalis* miniature subterminal inverted repeat transposable elements (OnMITE01 and OnMITE02), and ezi-like long interspersed nuclear elements. Mobility of OnMITE01 was demonstrated by the presence or absence in *O. nubilalis* of introns at two different loci. A (GTCT)_n tetranucleotide repeat at the 5' ends of OnMITE01 and OnMITE02 are evidence for transposon-mediated movement of lepidopteran microsatellite loci. The number of repetitive elements in lepidopteran genomes will affect genome assembly and marker development. Single-locus sequence tag site markers described here have downstream application for integration within linkage maps and comparative genomic studies.

Crespo, A. L. B., T. A. Spencer, A. P. Alves, R. L. Hellmich, E. E. Blankenship, L. C. Magalhaes and B. D. Siegfried (2009). "On-plant survival and inheritance of resistance to Cry1Ab toxin from *Bacillus thuringiensis* in a field-derived strain of European corn borer, *Ostrinia nubilalis*." *Pest Management Science* 65(10): 1071-1081.

BACKGROUND: The high dose plus refuge is one of the major components of the resistance management plan mandated for transgenic corn expressing Cry toxins from *Bacillus thuringiensis* Berliner (Bt) that targets the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae). This strategy was based on assumptions such as functional recessive inheritance, which has not been previously tested for *O. nubilalis*. The authors used a field-derived resistant strain of *O. nubilalis* to define the nature of resistance to Cry1Ab toxin by examining the inheritance and on-plant survival of susceptible and resistant insects and their F(1) progeny. **RESULTS:** The resistant strain exhibited >800-fold resistance to Cry1Ab. Resistance was primarily autosomal and controlled by more than one locus or multiple alleles at one locus. The degree of dominance *D* calculated on the basis of LC(50) values was -0.45 ($h' = 0.27$), indicating that resistance was incompletely recessive. No survivors were found on vegetative-stage Bt corn, although both resistant larvae and their F(1) progeny were able to survive on reproductive corn 15 days after infestation. **CONCLUSIONS:** A field derived *O. nubilalis* strain exhibited high levels of resistance to Cry1Ab and survived on transgenic corn by feeding on

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tissues with low Cry1Ab expression. The Cry1Ab resistance was primarily autosomal, incompletely recessive and polygenic. Tissue and on-plant survival data indicated that dominance varies depending on plant stage. (C) 2009 Society of Chemical Industry

Derron, J. O., G. Goy and S. Breitenmoser (2009). "Biological characterisation of the bivoltine race of the European corn borer (*Ostrinia nubilalis*) in the Lake Geneva region." *Revue Suisse D Agriculture* 41(3): 179-184.

The European corn borer can be subdivided into various local races differing in voltinism and in composition of pheromones emitted by females. In Switzerland, at the north side of the Alps, only the univoltine race with pheromones of Z type used to be detected until the year 2000. Since then, a bivoltine race with the same pheromone composition has been found regularly in the region of Lake Geneva. These two races can be distinguished by the duration of postdiapause development until pupation and by the critical photoperiod inducing diapause. Postdiapause development time at 20 degrees C is 15.6 days for the bivoltine race and 33.0 days for the univoltine race. The critical photoperiod at 20 degrees C is 15.8 hours for the bivoltine race. For the univoltine race the fraction of larvae entering diapause is > 90% under the same temperature conditions, no matter the photoperiod. The relative proportion of the two races varies from year to year as a function of climatic conditions, which makes the management of pest control measures particularly difficult.

Hallman, G. J. and R. L. Hellmich (2009). "Ionizing Radiation as a Phytosanitary Treatment Against European Corn Borer (Lepidoptera: Crambidae) in Ambient, Low Oxygen, and Cold Conditions." *Journal of Economic Entomology* 102(1): 64-68.

The European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), is a quarantine pest for several fresh commodities, including corn-on-the-cob, bell peppers, and green beans. Methyl bromide fumigation is the usual phytosanitary treatment, but the fumigant is under increasing regulation as a stratospheric ozone-depleting substance. Ionizing radiation is a relatively new commercial alternative that is currently used in several countries. The present research explored radiation doses that would provide quarantine security for commodities at risk of being infested by *O. nubilalis*. Radiotolerance of late pupae (the most tolerant stage infesting commodities) as determined by hatch of F-1 eggs was not affected by host (meridic diet versus ear corn) or temperature (1 versus 13 degrees C) but was positively affected by low oxygen. Longevity was shorter for adults of irradiated than nonirradiated pupae. The minimum absorbed dose for phytosanitary irradiation against *O. nubilalis* could vary from 233 Gy for prevention of F-1 pupation to 343 Gy for prevention of F-1 egg hatch. Lower doses might be possible if greater risk of treatment failure was acceptable.

Hu, Y. and D. A. Andow (2009). "A Technique for Distinguishing Virgin and Mated Males of *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae)." *Journal of Entomological Science* 44(3): 264-275.

Studies on the mating history of male Lepidoptera are generally lacking because of difficulties in determining male mating status. In previous studies, presence/absence of pigmented fluids inside the male primary simplex have been used successfully for determining mating status. However, males of European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), have creamy white fluids in the primary simplex instead of pigmented fluids, so presence/absence of pigmented fluids inside the primary simplex cannot be used to assess mating status in this species. We developed a scoring system for the fluids inside the primary simplex that allowed us to classify *O. nubilalis* male mating status and the timing of copulation. The scoring system relies on differences in the fluids in the 1(st), 2(nd) and 7(th) segments of the primary simplex. Males known to be virgins, mated <1d previously and mated >1d previously could be distinguished with a 6.3% error rate. The method was verified on 41 males in a blind study, with 100% accurate classification of the males.

Khajuria, C., Y. C. Zhu, M. S. Chen, L. L. Buschman, R. A. Higgins, J. X. Yao, A. L. B. Crespo, B. D. Siegfried, S. Muthukrishnan and K. Y. Zhu (2009). "Expressed sequence tags from larval gut of the European corn borer (*Ostrinia nubilalis*): Exploring candidate genes potentially involved in *Bacillus thuringiensis* toxicity and resistance." *Bmc Genomics* 10.

Background: Lepidoptera represents more than 160,000 insect species which include some of the most devastating pests of crops, forests, and stored products. However, the genomic information on lepidopteran insects is very limited. Only a few studies have focused on developing expressed sequence tag (EST) libraries from the guts of lepidopteran larvae. Knowledge of the genes that are expressed in the insect gut are crucial for understanding basic physiology of

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food digestion, their interactions with *Bacillus thuringiensis* (Bt) toxins, and for discovering new targets for novel toxins for use in pest management. This study analyzed the ESTs generated from the larval gut of the European corn borer (ECB, *Ostrinia nubilalis*), one of the most destructive pests of corn in North America and the western world. Our goals were to establish an ECB larval gut-specific EST database as a genomic resource for future research and to explore candidate genes potentially involved in insect-Bt interactions and Bt resistance in ECB. Results: We constructed two cDNA libraries from the guts of the fifth-instar larvae of ECB and sequenced a total of 15,000 ESTs from these libraries. A total of 12,519 ESTs (83.4%) appeared to be high quality with an average length of 656 bp. These ESTs represented 2,895 unique sequences, including 1,738 singletons and 1,157 contigs. Among the unique sequences, 62.7% encoded putative proteins that shared significant sequence similarities (E-value $\leq 10^{-3}$) with the sequences available in GenBank. Our EST analysis revealed 52 candidate genes that potentially have roles in Bt toxicity and resistance. These genes encode 18 trypsin-like proteases, 18 chymotrypsin-like proteases, 13 aminopeptidases, 2 alkaline phosphatases and 1 cadherin-like protein. Comparisons of expression profiles of 41 selected candidate genes between Cry1Ab-susceptible and resistant strains of ECB by RT-PCR showed apparently decreased expressions in 2 trypsin-like and 2 chymotrypsin-like protease genes, and 1 aminopeptidase genes in the resistant strain as compared with the susceptible strain. In contrast, the expression of 3 trypsin-like and 3 chymotrypsin-like protease genes, 2 aminopeptidase genes, and 2 alkaline phosphatase genes were increased in the resistant strain. Such differential expressions of the candidate genes may suggest their involvement in Cry1Ab resistance. Indeed, certain trypsin-like and chymotrypsin-like proteases have previously been found to activate or degrade Bt protoxins and toxins, whereas several aminopeptidases, cadherin-like proteins and alkaline phosphatases have been demonstrated to serve as Bt receptor proteins in other insect species. Conclusion: We developed a relatively large EST database consisting of 12,519 high-quality sequences from a total of 15,000 cDNAs from the larval gut of ECB. To our knowledge, this database represents the largest gut-specific EST database from a lepidopteran pest. Our work provides a foundation for future research to develop an ECB gut-specific DNA microarray which can be used to analyze the global changes of gene expression in response to Bt protoxins/toxins and the genetic difference(s) between Bt-resistant and susceptible strains. Furthermore, we identified 52 candidate genes that may potentially be involved in Bt toxicity and resistance. Differential expressions of 15 out of the 41 selected candidate genes examined by RT-PCR, including 5 genes with apparently decreased expression and 10 with increased expression in Cry1Ab-resistant strain, may help us conclusively identify the candidate genes involved in Bt resistance and provide us with new insights into the mechanism of Cry1Ab resistance in ECB.

Kim, K. S., M. J. Bagley, B. S. Coates, R. L. Hellmich and T. W. Sappington (2009). "Spatial and Temporal Genetic Analyses Show High Gene Flow Among European Corn Borer (*Lepidoptera*: Crambidae) Populations Across the Central US Corn Belt." *Environmental Entomology* 38(4): 1312-1323.

European corn borer, *Ostrinia nubilalis* (Hubner), adults were sampled at 13 sites along two perpendicular 720-km transects intersecting in central Iowa and for the following two generations at four of the same sites separated by 240 km in the cardinal directions. More than 50 moths from each sample location and time were genotyped at eight microsatellite loci. Spatial analyses indicated that there is no spatial genetic structuring between European corn borer populations sampled 720 km apart at the extremes of the transects and no pattern of genetic isolation by distance at that geographic scale. Although these results suggest high gene flow over the spatial scale tested, it is possible that populations have not had time to diverge since the central Corn Belt was invaded by this insect approximate to 60 yr ago. However, temporal analyses of genetic changes in single locations overtime suggest that the rate of migration is indeed very high. The results of this study suggest that the geographic dimensions of European corn borer populations are quite large, indicating that monitoring for resistance to transgenic Bt corn at widely separated distances is justified, at least in the central Corn Belt. High gene flow further implies that resistance to Bt corn may be slow to evolve, but once it does develop, it may spread geographically with such speed that mitigation strategies will have to be implemented quickly to be effective.

Kiraly, L. and G. Szocs (2009). "Diagnostic marker for E- and Z-strains of *Ostrinia nubilalis*, expressing differentially in larval Delta 11 desaturase transcript." *Journal of Applied Entomology* 133(4): 272-277.

Relationships between host plant and pheromone strains of the European corn borer (ECB), *Ostrinia nubilalis* Hbn. (Lep., Pyraustidae), as well as genetic features of these strains have been intensively studied. We compared expression of a Delta 11 desaturase and three Delta 14 desaturase genes in larvae and adults of a Z- and an E-strain of ECB,

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respectively, by reverse transcriptase-polymerase chain reaction (RT-PCR). The Z-strain originated from KEty, southern Hungary, whereas the E-strain was collected from Brezice, Slovenia. Cultures of both strains were maintained without diapause on semisynthetic diet, under identical conditions. Oligonucleotide primers were designed to amplify a 524-bp *Ostrinia nubilalis* Delta 11 desaturase (On11desat) cDNA fragment (AF441221) and three 297-bp *O. nubilalis* Delta 14 desaturase (On14desat) cDNA fragments (AF441220, and EF125927). We found that the expression of On11desat in the Z-strain was on a similarly high level in adult females and males, but was weak or non-detectable in larvae. In the E-strain, On11desat was expressed in uniformly high levels in larvae as well as in male and female adults. On the other hand, the three Delta 14 desaturases did not show significant differences in gene expression, when either larvae or adult females or males of either the Z- or E-strains of *O. nubilalis* were compared. The possibility of determining pheromone strain identity at larval stages from feral-collected, single individuals, by checking differential expression of On11desat is discussed.

Kojic, D., I. Spasojevic, M. Mojovic, D. Blagojevic, M. R. Worland, G. Grubor-Lajsic and M. B. Spasic (2009). "Potential role of hydrogen peroxide and melanin in the cold hardiness of *Ostrinia nubilalis* (Lepidoptera: Pyralidae)." *European Journal of Entomology* 106(3): 451-454.

The aim of this study was to investigate the relationship between antioxidant enzymes and reactive oxygen species production in diapausing larvae of the European corn borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae) kept at 5 degrees C, -3 degrees C and -16 degrees C for two weeks. The amount of hydrogen peroxide (H₂O₂), activity of antioxidant enzymes, copper zinc superoxide dismutase (CuZnSOD), manganese superoxide dismutases (MnSOD) and catalase (CAT) in whole body homogenates, as well as the electron paramagnetic resonance (EPR) spectroscopy of this insect's whole body were analysed. A higher level of melanin radical and lower CuZnSOD and CAT activities were found in larvae kept at -3 degrees C than at 5 degrees C and -16 degrees C. At the same temperature (-3 degrees C) an elevated H₂O₂ concentration was recorded. A possible regulatory role of H₂O₂ at -3 degrees C, which is the temperature that triggers freezing tolerance, is suggested.

Lassance, J. M. and C. Lofstedt (2009). "Concerted evolution of male and female display traits in the European corn borer, *Ostrinia nubilalis*." *Bmc Biology* 7.

Background: Sexual reproduction entails the encounter of the sexes and the multiplicity of rituals is parallel to the diversity of mating systems. Evolutionary mechanisms such as sexual selection and sexual conflict have led to the elaboration of traits to gain attention and favours from potential partners. A paradox exists about how coordinated systems can evolve and diverge when there would seem to be a stabilising selection acting. Moth display traits - pheromones - constitute an advantageous model with which to address questions about the evolution of mating systems in animals. Both males and females can possess pheromones that are involved either in close- or long-range communication. Female and male pheromones appear to have different origins and to be under different evolutionary constraints, thus they might be envisioned as independently evolving traits. We conducted laboratory experiments to explore the role of scents released during courtship by males of the European corn borer, *Ostrinia nubilalis*. Results: Information provided by the male pheromone appears critical for female acceptance. The composition of this male pheromone varies in an age-dependent manner and females show mating preference towards older males in choice experiments. Furthermore, male signals may allow species discrimination and reinforce reproductive isolation. Finally, we found evidence for a genetic correlation between male and female signals, the evolution of which is best explained by the constraints and opportunities resulting from the sharing of gene products. Conclusion: In this study we used an integrative approach to characterise the male sex pheromone in a moth. Interestingly, the male chemical signal is analogous to the female signal in that structurally similar compounds are being used by both sexes. Hence, in systems where both sexes possess display traits, the pleiotropy of genes generating the traits could influence the evolutionary trajectories of sexual signals and lead to their divergence, with speciation being the ultimate result.

Lewis, L. C., D. J. Bruck, D. V. Sumerford and R. D. Gunnarson (2009). "Technique to Assess Effectiveness of Control Tactics Against *Ostrinia nubilalis* (Lepidoptera: Crambidae) in Whorl-Stage Corn." *Journal of Economic Entomology* 102(2): 624-628.

Ostrinia nubilalis (Hubner) (Lepidoptera: Crambidae) is one of the most damaging insect pests of corn. Studies were conducted to determine whether live larval counts obtained from corn whorls were predictive of the amount of larval tunneling that would result in the stalk of the plant 40 d later at the end of larval development. Whorls from plants

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treated with Dipel 10G (6,400 IU per whorl) and untreated controls, both infested with *O. nubilalis* neonates, were evaluated for the number of live larvae in 50 whorls 5, 7, 9 and 12 d after *Bacillus thuringiensis* (Berliner) (Bacillales: Bacillaceae) application. Forty days after larval infestation, 25 plants from each plot were split from tassel to base, and the length of larval tunneling was recorded. There was a strong relationship between numbers of live larvae in the plant whorl and the length of larval tunneling that resulted. While linear at each location, there was significant variation in the relationship among locations, indicating that comparisons could not be made between years or locations within a year. Blocks within a location on a given year did not vary significantly and reproducible results were obtained each year within a given location as well as on any of the whorl pulling dates evaluated. Because of its ease of use, predictability, and rapid return of results, we propose this technique as an additional method to shot-hole feeding and stalk splitting to evaluate the effectiveness of *O. nubilalis* management strategies.

Orci, K. M. and G. Szocs (2009). "ULTRASONIC AND SONIC EMISSION DURING THE COURTSHIP BEHAVIOUR IN MALES OF Z- AND E-PHEROMONE STRAINS OF THE EUROPEAN CORN BORER OSTRINIA NUBILALIS HUBNER (LEPIDOPTERA, PYRAUSTIDAE)." *Bioacoustics-the International Journal of Animal Sound and Its Recording* 19(1-2): 93-107.

This study presents the first detailed description of the oscillographic structure and spectrographic features of sound emission produced by Z- and E-strain males of *Ostrinia nubilalis* during their courtship behaviour. Males simultaneously produce ultrasonic and low-frequency sonic sound emissions during their courtship, vibrating their wings at a distance of 1-2 cm from the female. The sound emission shows two characteristic types: a long courtship song is followed by a short precopulation song after a few seconds of silence. The ultrasonic courtship song is composed of pulses repeated in pairs or more typically in long series with an even repetition rate (which showed to be temperature dependent) or in irregular sequences. The precopulation song is a short crescendoing pulse-series. In both song types the ultrasonic carrier-wave has constant frequency spectrum containing components from 20 kHz to 80 kHz. The low-frequency sound emission has a harmonic frequency spectrum (fundamental frequency between 40-70 Hz). During the precopulation song the low-frequency component shows a characteristic frequency sweep from 80-100 Hz to 70-80 Hz. No significant difference has been noticed comparing the songs of Z- and E-strain males of *O. nubilalis*. However sound emission is clearly different from that described recently in the closely related *O. furnacalis*, where pulses are performed in groups forming chirps and no different courtship song and precopulation song has been described. The possible signal function of low-frequency near field sound emission is discussed.

Oztemiz, S. (2009). "Natural Parasitism and Release Efficiency of *Trichogramma evanescens* Westwood in *Ostrinia nubilalis* Hubner Attacking Maize in Turkey." *Journal of Entomological Science* 44(2): 132-140.

The natural parasitism rate and the release efficiency of the egg parasitoid, *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae), in the biological control of the European corn borer, *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae), was determined in field plots of maize in the Eastern Mediterranean, Turkey. Parasitoids were released in maize plots as parasitized eggs of laboratory-reared *Ephesia kuehniella* Zeller (Lepidoptera: Pyralidae). The parasitized eggs ($n = 150,000$) were released twice in a 10-d interval at the beginning of the oviposition period of the third generation of *O. nubilalis* in the second crop of maize in released treatment (without insecticides). Other treatments were an untreated control (without wasps and without insecticides) and an insecticide treatment (Lambda-Cyhalothrin, 50 g l(-1), 300 ml ha(-1); without wasps). *Ostrinia nubilalis* egg masses, larvae and plant damage were regularly assessed until crop harvest. Parasitization of egg masses by *T. evanescens* was determined in each sample. The mean (+/- SD) percentage of parasitized *O. nubilalis* eggs was 86.2 +/- 11.6 (+/- SD)%. Compared with the control treatment, the number of plants damaged by European corn borer larvae in the release treatment was reduced by 96%, whereas the number of larvae was reduced by 95.2%. Average grain yield was 8,800 +/- 15.2 kg ha(-1) (380.0 +/- 1.6 g per 1000 grain weight) in the *Trichogramma* release treatment without insecticide, 7,000 +/- 28.8 kg ha(-1) (314.8 +/- 2.9 g per 1000 grain weight) in the control treatment, and 8,533 +/- 8.8 kg ha(-1) (360.4 +/- 8.5 g per 1000 grain weight) in the insecticide treatment. The grain yield and 1000 grain weight differences differed significantly ($P \leq 0.01$) between the untreated control and the other two treatments (released treatment and insecticide treatment). Natural parasitization of *O. nubilalis* eggs by *T. evanescens* as observed in control and insecticide-treated plots was 30.2%. These results indicate that biological control of *O. nubilalis* with *T. evanescens* should be developed as an integral control method in integrated management programs for maize grown in Turkey.

Piesik, D., D. Rochat, J. van der Pers and F. Marion-Poll (2009). "Pulsed Odors from Maize or Spinach Elicit Orientation in European Corn Borer Neonate Larvae." *Journal of Chemical Ecology* 35(9): 1032-1042.

Lepidoptera larvae are capable of orienting towards or away from plants by using odors as cues but whether this attraction is innate or secondarily acquired remains unknown. We tested the hypothesis that European corn borer (ECB) neonate larvae express an innate attraction towards odors released from maize, and avoidance towards odors from spinach. Neonate larvae were placed on a locomotion compensator within a constant stream of humidified air that was loaded intermittently with airborne odors drawn from potted plants. The odor stream was delivered continuously or pulsed (1 to 10 sec pulses) at 40 ml/min. ECB larvae oriented toward maize odors pulsed at 2 to 6 sec but walked away from maize odors delivered at lower frequencies (9 and 10 sec pulses or to continuous ones). They consistently walked away from spinach odors, irrespective of the pulsing regime except at 1 sec pulses that did not elicit orientation. We further explored odor intensity on orientation towards maize odors by adjusting the odor stream intensity. At higher intensity (60 ml/min), the direction reversal started at the 6 sec half period, while at lower intensity (20 ml/min), it showed up only for the continuous stimulus. ECB larvae exhibit a striking ability to lock on to a direction, which they maintained despite gaps of up to 10 sec in the odor stream. Our results demonstrate that ECB neonate larvae express innate orientation preferences towards natural odors from plants. These reactions correlate well with the biological value of these plants for ECB: maize generally is accepted by ECB larvae and adults, while spinach represents a poor host because it produces (non-volatile) phytoecdysteroids that are toxic and deterrent.

Prasifka, J. R., R. L. Hellmich, D. V. Sumerford and B. D. Siegfried (2009). "Bacillus thuringiensis Resistance Influences European Corn Borer (Lepidoptera: Crambidae) Larval Behavior After Exposure to Cry1Ab." *Journal of Economic Entomology* 102(2): 781-787.

The behavior of pests targeted by *Bacillus thuringiensis* (Bt) crops has been recognized as an important factor to define resistance management plans. However, most data do not include the possible impact resistance may have on the behavior of pests. To examine whether resistance influences behavior of European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), neonates after exposure to dietary Bt, the responses of Cry1Ab-resistant, -susceptible, and hybrid (F1) lines from two populations were compared in laboratory tests by using artificial diet mixed with 10-50% Cry1Ab or non-Bt isolate corn, *Zea mays* L., tissue. In no-choice tests, resistant (and usually hybrid) lines were less likely to be irritated (i.e., to move away after physical contact with diet containing Cry1Ab) than susceptible larvae after exposure to diets containing 10-50% Cry1Ab leaf tissue. Early in the no-choice tests (8 h), neonate *O. nubilalis* also were more likely to move off of diets that contained 10% non-Bt tissue compared with diets with 25 or 50% non-Bt tissue. In agreement with results from no-choice tests, choice tests with 10 or 25% tissue indicated that resistant (and sometimes hybrid) larvae were more likely than susceptible neonates to be found on diet with Cry1Ab. For choice tests, differences among lines seemed dependent on the amount of Cry1Ab tissue incorporated into diets. Results suggest differences in behavior are a result of reduced physiological susceptibility to Cry1Ab and are not an independent behavioral component to resistance.

Priestley, A. L. and M. Brownbridge (2009). "Field trials to evaluate effects of Bt-transgenic silage corn expressing the Cry1Ab insecticidal toxin on non-target soil arthropods in northern New England, USA." *Transgenic Research* 18(3): 425-443.

Traditionally, control of European corn borer (*Ostrinia nubilalis*) Hubner has been achieved through the use of chemical insecticides. With increasing emphasis on reducing pesticide inputs in agricultural production, alternative management technologies are now being used including transgenic silage corn modified to express Cry1Ab protein toxins derived from *Bacillus thuringiensis* (Bt) Berliner. The Cry1Ab toxin is expressed by all plant cells and throughout the growing season. Furthermore, the toxins are exuded from corn plant roots into the rhizosphere, raising concerns over possible side-effects on non-target beneficial organisms in the same habitat. In addition, detritivores are exposed to crop residues containing the toxin when incorporated into the soil. The current 2-year study (2003, 2004) evaluated effects of two silage-corn varieties: Pioneer var. 38A25 (Bt-corn expressing the Cry1Ab toxin) and Pioneer var. 38A24 (parent isolate) on species diversity and evenness of carabid beetles and Collembola. Pitfall traps were used to collect surface-dwelling species on a bimonthly schedule from April to October. Soil cores were taken once a month from April to October to sample subterranean species, which were extracted using Berlese funnels. All individuals were recorded and identified where possible to species level for analysis in the Simpson's D and Shannon-Wiener H' diversity indices. Evenness was measured using Simpson's E', after which dominant species were analyzed in a multivariate ordination

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analysis. Results showed Bt-corn had no negative effects on any of the organisms analyzed. There was a significant year effect on the abundance of surface-dwelling Collembola and on species diversity of soil-dwelling Collembola. Our findings suggest that crop management practices and/or environmental conditions (e.g., heavy rainfall during the 2004 growing season) had the greatest impact on species diversity and evenness, rather than the crop itself (Bt or isolate).

Russell, K. and R. Bessin (2009). "Integration of *Trichogramma ostrinae* releases and habitat modification for suppression of European corn borer (*Ostrinia nubilalis* Hubner) in bell peppers." *Renewable Agriculture and Food Systems* 24(1): 19-24.

A two-year field study was conducted to evaluate the effectiveness of *Trichogramma ostrinae* Pang et Chen (To.) releases in combination with habitat modification, to enhance biological control of European corn borer (ECB), *Ostrinia nubilalis* Hubner, the key pest of bell peppers in Kentucky. A randomized block design with a split-plot treatment arrangement was used in both years. Buckwheat, *Fagopyrum esculentum* Moench, was inter-planted as a nectar source for the wasps and as an attractant for ECB natural enemies. Sentinel ECB egg masses were placed in each subplot to monitor establishment and dispersal of *T. ostrinae* within and between plots. Fruit were harvested at maturity, graded according to USDA standards, inspected for insect damage, and dissected to confirm ECB presence when evidence of entry was suspected, to determine percentage of infested fruits. Percent ECB infested fruit was reduced in plots with wasp releases and in plots with buckwheat inter-planted. The interaction of habitat modification and wasp releases significantly reduced pepper damage as a result of the synergy between tactics. Percentage of *T. ostrinae* parasitized sentinel eggs was significantly higher in wasp release plots compared to non-release plots. *T. ostrinae* releases used in conjunction with habitat modification for ECB control in bell peppers appears to be a promising alternative to traditional insecticide-based strategies for small-acreage and organic farms. This study displays an example system utilizing conservation biological control at a landscape level for pest suppression.

Solyman, B. (2009). Élaboration et mise en oeuvre d'un programme de lutte intégrée à risque réduit contre les lépidoptères ravageurs du maïs à consommer en frais en Ontario et au Québec. O. EarthTramper Consulting Incorporated. PRR07-460.

Lien : <http://www.agr.gc.ca/fr/?id=1299089918299>

Spangler, S. M., D. D. Calvin, J. Russo and J. Schlegel (2009). "Predicting Risk of European Corn Borer Infestation in Sweet Corn Based on Harvest Date." *Horttechnology* 19(1): 173-180.

Infestation of sweet corn (*Zea mays*) at harvest by European corn borer (*Ostrinia nubilalis*) was examined in 16 hybrid/harvest date combinations from 1994 through 1996 in central Pennsylvania. Two general periods of sweet corn ear infestation levels were observed. Infestations, expressed as proportion of ears infested, were 0.11 (11%) or lower in 10 of 11 plots harvested from 21 July to 23 Aug., whereas they were noticeably higher (30%-88%) in September and early October. Infestations expressed as larvae per ear showed the same temporal pattern. A nonlinear (sigmoidal) relationship was found between degree-days from 1 Jan. and proportion of ears infested. The higher infestations were caused by the second-generation larvae of the bivoltine ecotype. Based on these relationships, a risk-prediction system is proposed that anticipates, at planting, harvest infestation by using predicted harvest dates of sweet corn, European corn borer life stages, and infestation levels. Examples are presented for multiple plantings and hybrids for a specific site and a landscape (Pennsylvania). The risk prediction system we propose will allow growers to anticipate the risk of ear infestations at planting time, thus providing predictions that would help with management decisions.

Suverkropp, B. P., F. Bigler and J. C. van Lenteren (2009). "Dispersal behaviour of *Trichogramma brassicae* in maize fields." *Bulletin of Insectology* 62(1): 113-120.

Glue-sprayed maize plants were used to study dispersal behaviour of the egg parasitoid *Trichogramma brassicae* Bezdenko (Hymenoptera Trichogrammatidae) in maize fields. To estimate the distance covered during an initial flight, *T. brassicae* were studied in a field cage with 73 glue-sprayed plants. Most of the parasitoids were found close to the release point, but several reached plants at distances up to 180 cm showing that walking and jumping are not the only mechanisms involved in initial dispersal. Mean distance of recapture from the release point was 60 cm. In a second experiment, glue-sprayed plants were placed in a maize field in a cross-pattern with 1.5 m distance between plants. On plants neighbouring the glue-sprayed plants, egg masses were fixed to measure parasitism. Only 0.7 to 3% of the released parasitoids were recaptured in the field. During the first day there was a sharp gradient with distance in the numbers of parasitoids recaptured, but during the second and third day there was no longer a significant gradient. The

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numbers captured on the second and third day were Much lower than those Captured on the first day. There was little correlation between the number of wasps landing oil a plant and parasitism. In the field, apparently 75% of the wasps had left the area within 7.5 meter of the release point at the end of the first day, and 95% had left this area at the end of the second day. It is concluded that T brassicae disperses in maize fields mainly by short flights.

Tiwari, S., R. R. Youngman, C. A. Laub, C. C. Brewster, T. A. Jordan and C. Teutsch (2009). "European Corn Borer (Lepidoptera: Crambidae) Infestation Level and Plant Growth Stage on Whole-Plant Corn Yield Grown for Silage in Virginia." *Journal of Economic Entomology* 102(6): 2146-2153.

Field experiments were conducted in 2004 and 2005 to determine the effect of different levels of hand-infested third instar European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), on whole-plant yield and plant growth stage in corn, *Zea mays* L., grown for silage. In 2004 and 2005, European corn borer infestation level had a significant negative impact on whole-plant yield (grams of dry matter per plant) with increasing infestation; however, whole-plant yield was not significantly affected by plant growth stage in either year. In 2004, the six larvae per plant treatment caused the greatest percentage of reduction (23.4%) in mean (+/- SEM) whole-plant yield (258.5 +/- 21.0 g dry matter per plant) compared with the *Bacillus thuringiensis* (Bt) Cry1Ab control (337.3 +/- 11.1 g dry matter per plant). In 2005, the five larvae per plant treatment caused the greatest percentage of reduction (8.3%) in mean whole-plant yield (282.3 +/- 10.8 g dry matter per plant) compared with the Bt Cry1Ab control (307.8 +/- 8.3 g dry matter per plant). The relationship between mean whole-plant yield and European corn borer larvae infestation level from the pooled data of both years was described well by using an exponential decay model ($r^2 = 0.84$, $P = 0.0038$). The economic injury level for silage corn was estimated to be approximate to 73% higher than for corn grown for grain based on similar control costs and crop values. In addition, plant growth stage and European corn borer infestation level had no effect on percentage of acid detergent fiber, neutral detergent fiber, and crude protein values in either year of the study.

Tiwari, S., R. R. Youngman, E. E. Lewis and J. D. Eisenback (2009). "European Corn Borer (Lepidoptera: Crambidae) Stalk Tunneling on Root-Knot Nematode (Tylenchida: Heteroderidae) Fitness on Corn." *Journal of Economic Entomology* 102(2): 602-609.

Greenhouse experiments were conducted in 2004-2006 to examine the reciprocal effects of aboveground herbivory by European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), and belowground herbivory by root knot nematode, *Meloidogyne incognita* Chitwood (Tylenchida: Heteroderidae), on one another at three corn, *Zea mays* L., growth stages. Two experiments were conducted to study the effect of aboveground herbivory by *O. nubilalis* on the number of *M. incognita* juvenile penetration/root system and eggs/root system. In the first experiment the *O. nubilalis* infestation level by plant growth stage main effect interaction was not significant for either *M. incognita* juvenile penetration or eggs. The overall effect of stalk tunneling by *O. nubilalis* resulted in 48.9% fewer juvenile penetration and 40% fewer eggs than in the respective controls. In the second experiment, the main effects interaction was significant for juvenile penetration ($P = 0.042$) and eggs ($P = 0.0134$). At the eight- and 10-leaf growth stages, the combined effect of one and three *O. nubilalis* larvae per plant resulted in 41.2 and 44.7% significantly fewer juvenile penetration than in the respective controls. Similarly, the combined effect of stalk tunneling (with the exception of one larvae per plant at the 10-leaf growth stage) at the six-, eight-, and 10-leaf growth stages resulted in 46.3, 53.3, and 55.2% fewer eggs were significantly negatively correlated with *O. nubilalis* tunnel length. In a reciprocal experiment conducted two times, no significant ($P > 0.05$) effect of *M. incognita* inoculation level on stalk tunneling was found in either experiment.

Accinelli, C., H. K. Abbas, R. M. Zablutowicz, S. Maini and A. Vicari (2008). "AGFD 83-Role of *Ostrinia nubilalis* in vectoring *Aspergillus flavus* in a corn field in northern Italy." *Abstracts of Papers of the American Chemical Society* 235.

Al Dabel, F., R. K. Mensah and B. Frerot (2008). "Effects of nC24 and nC27 petroleum spray oils on oviposition and egg survival of *Ostrinia nubilalis* Hubner (Lepidoptera, Pyralidae) and *Trichogramma brassicae* Bezdenko (Hymenoptera, Trichogrammatidae) adults on maize plants." *International Journal of Pest Management* 54(1): 5-11.

The study determined the effectiveness of nC24 and nC27 petroleum spray oils (PSOs) to reduce oviposition of *Ostrinia nubilalis* and survival of *O. nubilalis* eggs and *Trichogramma brassicae* adults. Under choice and no-choice tests, maize treated with 3, 5 and 10% (v/v) of both oils deter *O. nubilalis* oviposition on maize. The study also showed that treatment of 1-3- day-old *O. nubilalis* eggs with 1 and 2% (v/v) nC24 oil caused 6% mortality compared with 99.5%

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when treated with 3, 5 and 10% (v/v) oil. In contrast, treatment with 1-10% (v/v) nC27 oil caused 99% mortality. *Trichogramma brassicae* is a major parasitoid of *O. nubilalis*. The mortality of *T. brassicae* 24 h after exposure to maize sprayed with 2% (v/v) nC24 and nC27 oils was 8.3 and 12.7%, respectively. At 5% (v/v), the mortalities were 24.9 and 23.5%, respectively. Therefore, application of 3% (v/v) PSO may deter *O. nubilalis* egg lay, egg mortality and survival of *T. brassicae* on maize.

Albert, R., G. Maier and K. Dannemann (2008). "Control of the European corn borer and new developments with the use of *Trichogramma brassicae*." *Gesunde Pflanzen* 60(2): 41-54.

The European corn borer *Ostrinia nubilalis* (Huebner) is a well-known and investigated pest of corn and sweet corn particularly in the southwest of Germany since a long time. Nevertheless the pest can still surprise scientists and farmers. The first occurrence of a bivoltine race of the European corn borer in South Badenia in the years 2006 and 2007 is remarkable. The European corn borer had to be controlled in the last year on an area of approx. 60.000 hectares in Germany. An important antagonist of this pest is the parasitoid *Trichogramma brassicae* Bezdenko (Hym., Trichogrammatidae), which is already used for over 30 years on a continuously rising acreage for the control of *Ostrinia nubilalis*. The biology of the pest and its parasitoid are recapitulated particularly with regard to the biological control. The flight activities of the European corn borer are supervised with light traps in Southwest Germany. The data were inserted into a central data base at the LTZ Augustenberg, office Stuttgart (at first in 2007). The data can be used by advisors and farmers. They determinate the optimal time for the introduction of *Trichogramma brassicae* and optimize the application of insecticides. The annual randomized monitoring of the *Trichogramma* quantities and partially also qualities by the former state institute for plant protection and nowadays the LTZ Augustenberg helped to supply the farmers with good *Trichogramma* material. The efficiencies of the *Trichogramma* introduction reach up to over 70%. With the insecticide STEWARD (active ingredient Indoxacarb) similar and partly better efficiencies can be obtained. With the necessity of controlling *Diabrotica virgifera virgifera* with insecticides problems for the use of *Trichogramma* can arise - this will be discussed.

Alves, A. P., W. J. Allgeier and B. D. Siegfried (2008). "Effects of the synergist, S,S,S-tributyl phosphorotrithioate on indoxacarb toxicity and metabolism in the European corn borer, *Ostrinia nubilalis* (Hubner)." *Pesticide Biochemistry and Physiology* 90(1): 26-30.

The toxicity of the oxadiazine insecticide indoxacarb to the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), was evaluated in the presence and absence of S,S,S-tributyl phosphorotrithioate (DEF), an inhibitor of hydrolytic metabolism. Bioassays involving topical application of different concentrations of indoxacarb to third instars; of a susceptible *O. nubilalis* laboratory strain were performed, and in vitro metabolism experiments involving [C-14] indoxacarb were examined to determine the role of hydrolytic metabolism in indoxacarb activation. Indoxacarb toxicity decreased in the presence of DEF indicating antagonism of toxicity. Results of in vivo and in vitro inhibition experiments indicated a reduction of indoxacarb activation and formation of the hydrolytic metabolite. These results are consistent with the proposed mechanism of hydrolytic activation for this compound. (c) 2007 Elsevier Inc. All rights reserved.

Andreadis, S. S., Z. Vryzas, E. Papadopoulou-Mourkidou and M. Savopoulou-Soultani (2008). "Age-dependent changes in tolerance to cold and accumulation of cryoprotectants in overwintering and non-overwintering larvae of European corn borer *Ostrinia nubilalis*." *Physiological Entomology* 33(4): 365-371.

The age-dependent cold hardiness profile of *Ostrinia nubilalis* is compared between nondiapausing and diapausing larvae, as well as with field-collected larvae. The results suggest that both cold tolerance and accumulation of cryoprotectants depends upon the age of *O. nubilalis* larva. Late fifth-instar nondiapausing larvae are more cold tolerant than younger fifth-instars because they show enhanced ability to withstand sub-zero temperatures. No appreciable difference is observed between the experimental groups of diapausing larvae as far as their supercooling ability and tolerance at sub-zero temperatures above the supercooling point. In general, both field-collected and diapausing larvae are more cold tolerant than nondiapausing larvae, indicating a direct link between diapause and cold hardiness. The age of diapausing larvae affects the ability to accumulate glycerol. Glycerol levels of 45-day-old diapausing larvae are significantly higher (2.7-fold) compared with 90-day-old diapausing larvae. Moreover, diapausing larvae display a five- to 13-fold higher glycerol content compared with nondiapausing larvae. There is a trend for an

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age-dependent cold hardiness profile in *O. nubilalis* and further tests that could demonstrate a causal relationship between age and cold tolerance are needed.

Baca, F., S. Gosic-Dondo, Z. Kaitovic, Z. Videnovic, B. Kresovic, D. Glamoclija, A. Datta and S. Knezevic (2008). "Effect of planting dates on the level of European corn borer (*Ostrinia nubilalis* Hbn.) infestation, and crop injury and grain yield of maize (*Zea mays* L.) (vol 53, pg 111, 2008)." *Maydica* 53(3-4): 303-303.

Baca, F., S. Gosic-Dondo, Z. Kaitovic, Z. Videnovic, B. Kresovic and S. Knezevic (2008). "EFFECT OF PLANTING DATES ON THE LEVEL OF EUROPEAN CORN BORER (*Ostrinia nubilalis* Hbn.) INFESTATION, AND CROP INJURY AND GRAIN YIELD OF MAIZE (*Zea mays* L.)" *Maydica* 53(2): 111-115.

Proper planting date is important for maize production. Therefore, field studies were conducted from 1995-2005 to determine the most suitable planting date for six maize hybrids (FAO 300-700 maturity groups) as influenced by infestation level of European corn borer (ECB), *Ostrinia nubilalis* (Hbn). Significant differences in the levels of ECB infestation, level of damage and grain yield were observed between the planting dates, and the years. The total plant infestation by both generations ECB over the planting dates ranged from 47% to 60%. Plant damage rating was on the average of 2.2 and slightly differed across the planting dates. Yield results indicated that the planting period for maize production in the Vojvodina province was from April 15 to May 5, but the Most Suitable date was the beginning of the third week of April.

Blandino, M., A. Reyneri, F. Vanara, M. Pascale, M. Haidukowski and M. Saporiti (2008). "Effect of sowing date and insecticide application against European corn borer (Lepidoptera: Crambidae) on fumonisin contamination in maize kernels." *Crop Protection* 27(11): 1432-1436.

Fusarium verticillioides, a known producer of fumonisins, has been reported to be the most common pathogen of maize causing *Fusarium* ear rot and grain fumonisin contamination. Field tests were carried out in 2004 and 2005 growing seasons in two sites located in the North of Italy to determine the effects of sowing date and insecticide treatment against European corn borer (ECB, *Ostrinia nubilalis* Hubner) on maize susceptibility to *Fusarium* ear rot and fumonisin contamination under natural infection conditions. Two sowing dates (at about 25-30 day intervals) and two insecticide application treatments with lambda-cyhalothrin (at 7 and 14 days after the ECB flight peak) were compared with the untreated control in each year/site. Ears were rated for both incidence and severity of ECB damage and *Fusarium* ear rot at harvest. Harvested kernels were analyzed for fumonisin B-1 (FB1) and B-2 (FB2) contents. Insecticide treatments significantly reduced the ECB infestation compared to the untreated control. The insecticide treatments applied 7 days after the ECB flight peak controlled insect damage significantly better than those applied later. The ECB damage severity was also higher for the later than the earlier sowing date (14%) compared to the earlier one. A significant effect of sowing date and insecticide application on *Fusarium* ear rot was evidenced. For the earlier sowing date treatments, ear rot incidence and severity reductions of 13% and 16%, respectively, compared to those of later sowing dates were noted. Insecticide applications to plants resulted in lower ear rot severity than the untreated control (up to 29%). Maize sowed earlier and treated with insecticide 7 days after the ECB flight peak resulted in a significantly lower grain fumonisin concentration (up to 67%), compared to those of untreated and late sowed maize. In Mediterranean areas, the choice of an early sowing date and appropriate treatments with pyrethroid insecticides against ECB might represent a useful tool to limit raw maize fumonisin concentration to levels below the EU maximum admissible level recently fixed by the Commission. (C) 2008 Elsevier Ltd. All rights reserved.

Blandino, M., M. A. Saladini, A. Reyneri, F. Vanara and A. Alma (2008). "THE INFLUENCE OF SOWING DATE AND INSECTICIDE TREATMENTS ON *OSTRINIA NUBILALIS* (HUBNER) DAMAGE AND FUMONISIN CONTAMINATION IN MAIZE KERNELS." *Maydica* 53(3-4): 199-206.

Fusarium verticillioides, a known producer of fumonisins, has been reported to be the most common pathogen of maize causing *Fusarium* ear rot and grain fumonisin contamination. A field experiment was conducted from 2005 to 2007 in North Italy to determine the effects of sowing date and insecticide treatment against ECB on the susceptibility of maize to *Fusarium* ear rot and to fumonisin contamination in natural infection conditions. Three sowing dates and two insecticide applications were compared for each year. The late sown maize showed significantly higher insect damage to both the plants (stalks) and the ears (kernels and cobs). The ECB damage severity was 23% higher for the

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later sowing date than for the earlier. The insecticide treatment significantly reduced the ECB infestation compared to the untreated control. A significant effect of the sowing date and of the insecticide application on Fusarium ear rot was highlighted. The earlier sowing date reduced the ear rot incidence and severity by 25% and 49%, respectively, compared to the later dates. The insecticide application led to 25% lower ear rot severity than the untreated control. The fumonisin contamination was significantly reduced by an earlier sowing date (62%) and by the treatment against ECB (51%). The plots sown earlier and treated with insecticide resulted in a 79% lower concentration of fumonisins in kernels compared to plots characterized by later sowing and a lack of treatment. In fuperate climates, where ECB attack is consistent, low fumonisin contamination may be enhanced by an early sowing date and a correct insecticide application against 2nd-generation ECB larvae.

Carroll, M. W., J. A. Glaser, R. L. Hellmich, T. E. Hunt, T. W. Sappington, D. Calvin, K. Copenhaver and J. Fridgen (2008). "Use of spectral vegetation indices derived from airborne hyperspectral imagery for detection of European corn borer infestation in Iowa corn plots." *Journal of Economic Entomology* 101(5): 1614-1623.

Eleven spectral vegetation indices that emphasize foliar plant pigments were calculated using airborne hyperspectral imagery and evaluated in 2004 and 2005 for their ability to detect experimental plots of corn manually inoculated with *Ostrinia nubilalis* (Hubner) neonate larvae. Manual inoculations were timed to simulate infestation of corn, *Zea mays* L., by first and second flights of adult *O. nubilalis*. The ability of spectral vegetation indices to detect *O. nubilalis*-inoculated plots improved as the growing season progressed, with multiple spectral vegetation indices able to identify infested plots in late August and early September. Our findings also indicate that for detecting *O. nubilalis*-related plant stress in corn, spectral vegetation indices targeting carotenoid and anthocyanin pigments are not as effective as those targeting chlorophyll. Analysis of image data suggests that feeding and stem boring by *O. nubilalis* larvae may increase the rate of plant senescence causing detectable differences in plant biomass and vigor when compared with control plots. Further, we identified an approximate time frame of 5-6 wk postinoculation, when spectral differences of manually inoculated "second" generation *O. nubilalis* plots seem to peak.

Coates, B. S., D. V. Sumerford, R. L. Hellmich and L. C. Lewis (2008). "Mining an *Ostrinia nubilalis* midgut expressed sequence tag (EST) library for candidate genes and single nucleotide polymorphisms (SNPs)." *Insect Molecular Biology* 17(6): 607-620.

Genes expressed in lepidopteran midgut tissues are involved in digestion and *Bacillus thuringiensis* (Bt) toxin resistance traits. Five hundred and thirty five unique transcripts were annotated from 1745 high quality *O. nubilalis* larval midgut expressed sequence tags (ESTs). Full-length cDNA sequence of 12 putative serine proteinase genes and 3 partial *O. nubilalis* aminopeptidase N protein genes, *apn1*, *apn3*, and *apn4*, were obtained, and genes may have roles in plant feeding and Bt toxin resistance traits of *Ostrinia* larvae. The EST library was not normalized and insert frequencies reflect transcript levels under the initial treatment conditions and redundancy of inserts from highly expressed transcripts allowed prediction of putative single nucleotide polymorphisms (SNPs). Ten di-, tri- or tetranucleotide repeat unit microsatellite loci were identified, and minisatellite repeats were observed within the C-termini of two encoded serine proteinases. Molecular markers showed polymorphism at 28 SNP loci and one microsatellite locus, and Mendelian inheritance indicated that markers were applicable to genome mapping applications. This *O. nubilalis* larval midgut EST collection is a resource for gene discovery, expression information, and allelic variation for use in genetic marker development.

Coates, B. S., D. V. Sumerford and L. C. Lewis (2008). "Segregation of European corn borer, *Ostrinia nubilalis*, aminopeptidase 1, cadherin, and *bre5*-like alleles, from a colony resistant to *Bacillus thuringiensis* Cry1Ab toxins, are not associated with F-2 larval weights when fed a diet containing Cry1Ab." *Journal of Insect Science* 8.

Protein receptors may be required for activated *Bacillus thuringiensis* Cry toxins (Cry1Ab) to bind midgut epithelium prior to pore formation. Single nucleotide polymorphism markers from two *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae) midgut peptide receptors, cadherin (*OnCad*), aminopeptidase N1 (*OnAPN1*), and *OnBre5* (*Onb3GalT5*; a beta-1,3-galactosyltransferase family 5 member) were used to examine segregation in F-2 families derived from paired matings of Cry1Ab-resistant females and Cry1Ab-susceptible males. Genotypic frequencies for these markers did not deviate from Mendelian expectations. Analysis of F-2 larvae indicate the segregation of single nucleotide pores in *OnAPN1*, *OnBre5* (*Onb3GalT5*), and *OnCad* marker loci were independent of the segregation of log(10) weights of larvae feeding on Cry1Ab diet.

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Domingue, M. J., C. J. Musto, C. E. Linn, W. L. Roelofs and T. C. Baker (2008). "Olfactory neuron responsiveness and pheromone blend preference in hybrids between *Ostrinia furnacalis* and *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Journal of Insect Physiology* 54(8): 1261-1270.

The olfactory receptor neuron (ORN) and behavioral responses of hybrids between the Asian corn borer (ACB), *Ostrinia furnacalis*, and the E-strain European corn borer (ECB(E)), *Ostrinia nubilalis* were examined and compared to the parental populations. In hybrids and both parents, the large-spike-size ORN was capable of responding to all four pheromone components of ACB and ECB, despite differences in which compounds elicited the greatest spike frequency in each population. There was a small-spiking ORN more narrowly tuned to the minor pheromone components in both ACB and ECB(E). In hybrids the homologous small-spiking ORN was tuned primarily to the ECB(E) minor pheromone component, with some responsiveness to the ACB minor component. Both species and all the hybrids had an intermediate spike-size ORN tuned primarily to their common behavioral antagonist. Dominance of responsiveness to the ECB(E) versus the ACB minor pheromone component on the small-spiking ORN may explain the greater tendency of hybrids to fly upwind to the ECB(E) pheromone blend than the ACB blend. This finding points toward a distinct evolutionary role for this ORN in allowing a pheromone shift. Published by Elsevier Ltd.

Dorhout, D. L., T. W. Sappington and M. E. Rice (2008). "Evidence for Obligate Migratory Flight Behavior in Young European Corn Borer (Lepidoptera: Crambidae) Females." *Environmental Entomology* 37(5): 1280-1290.

European corn borer, *Ostrinia nubilalis*, flight behavior was examined in laboratory experiments. Adults were each tethered to 1 of 16 round-about flight mills in an environmental chamber, and the data were relayed to a computer. Parameters analyzed included duration, distance, and speed of the longest continuous flight and total flight time during an 8-h night. Comparisons were made between unmated and mated adults of both sexes at different ages up to 5 d after emergence. For unmated females, duration of the longest flight was highest the first night after emergence, declining significantly by 5 d of age. In contrast, duration of the longest flight for males was lowest at 1 d of age, increasing significantly by 3 d of age. Flight speed of females was roughly twice that of males at all ages. Mating did not affect flight behavior of either sex at any age tested, but mated adults could not be tested before 2 d of age because the first night was needed for mating. The pattern of age-specific flight behavior suggests that unmated females engage in obligate migratory flight the first full night after emergence. The median duration of this flight was approximate to 2 h in our experiments, with some adults flying continuously for the full 8 h of darkness. Females of other ages and males of all ages tested were capable of long-duration flights, but they more likely represent foraging flight. These results help explain the high dispersal rate of newly emerged adults from release sites in field experiments.

Engels, H., A. Sinha, I. Schuphan and S. Eber (2008). "Small-scale dispersal of the European corn borer and its relevance for resistance management in Bt maize." *Journal of Applied Entomology* 132(8): 675-680.

The small-scale dispersal of the European corn borer (ECB) was studied in a release-recapture experiment using reared dye-marked adults. Thereby, six light trap cages were set up across two maize fields at 50-m intervals. In total, 736 marked ECBs were released, of which 10.2% were recaptured together with 212 unmarked naturally occurring adults after a period of 48 h. All marked-released individuals left the release point, with a mean dispersal distance of 195 m. Eighty-two per cent of the recaptured ECBs moved to the second maize field across a ditch and associated shrubs. The spatial and temporal patterns of incidence of naturally occurring ECBs in the traps were consistent with those of the marked moths and showed an inhomogeneous distribution. There was a highly significant relationship between male and female densities in the cages. No ECBs were caught during a period of adverse weather conditions. Dispersal distances may be influenced by plant size, weather conditions during the flight, pheromonal patterns in the field and the timing of the flight.

Gereszek, L. J., J. R. Coats and D. C. Beitz (2008). "Effects of dietary conjugated linoleic acid on European corn borer (Lepidoptera : Crambidae) survival, fatty acid profile, and fecundity." *Annals of the Entomological Society of America* 101(2): 430-438.

Conjugated linoleic acid (CLA) is an unusual fatty acid produced by fermentative bacteria in the rumen of ruminant mammals. Positive biological effects, including anticarcinogenic, antiatherogenic, and immune enhancing effects, have been observed in mammals fed CLA-enriched diets. Little is known of the biological effects of dietary CLA on insects, and nothing is known of the dietary CLA effects on the fatty acid profile of an insect. In this study, we examined the

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effects of a CLA or safflower oil-enriched meridic diet at several concentrations on European corn borer, *Ostrinia nubilalis* (Hubner), survival, development, fatty acid profiles, and fecundity. The fatty acid profiles of pupal and adult tissues as well as eggs from adults fed CLA-enriched diets as larvae were studied. Control insects were fed the meridic diet with the solvent carrier added. We hypothesized a CLA-enriched diet, but not a safflower oil-enriched diet, would decrease survival, alter fatty acid profiles, and decrease fecundity. Larvae fed the CLA-enriched diet developed more slowly than did larvae fed the safflower oil-enriched diet or the control diet. Pupal mass was not affected by any of the treatments. Survival was decreased greatly in larvae fed the CLA-enriched diet. Saturated fatty acids increased proportionately, whereas polyunsaturated and monounsaturated fatty acids decreased proportionately in both pupal and adult tissues. Fecundity was not affected by any of the treatments.

Hoshizaki, S., R. Washimori, S. I. Kubota, A. N. Frolov, D. Kageyama, S. Gomboc, S. Ohno, S. Tatsuki and Y. Ishikawa (2008). "Limited variation in mitochondrial DNA of maize-associated *Ostrinia nubilalis* (Lepidoptera: Crambidae) in Russia, Turkey and Slovenia." *European Journal of Entomology* 105(4): 545-552.

A sequence analysis of the mitochondrial cytochrome oxidase subunit II (COII) gene in Russian and Turkish maize-associated populations of *Ostrinia nubilalis* and a Slovenian population of *O. nubilalis* probably infesting maize revealed little diversity. This lack of diversity may have resulted from bottleneck event(s) when the maize-associated population of *O. nubilalis* expanded from small population(s) in association with the cultivation of maize in Europe ca. 500 years ago. In the genealogy of COII genes obtained in the present and previous studies, Eurasian samples were substantially differentiated from North American samples. Since the North American population of *O. nubilalis* came from Europe, our finding suggests that there is geographical differentiation in European maize-associated *O. nubilalis*, and that maize-associated populations of *O. nubilalis* expanded multiple times in Europe. Finally, a phylogenetic analysis of the COII gene did not support that *O. nubilalis* and *O. furnacalis* are the closest relatives within the *O. furnacalis* species group.

Karpati, Z., T. Dekker and B. S. Hansson (2008). "Reversed functional topology in the antennal lobe of the male European corn borer." *Journal of Experimental Biology* 211(17): 2841-2848.

The European corn borer *Ostrinia nubilalis* (Hubner) is a model of evolution of sexual communication in insects. Two pheromone strains produce and respond to opposite ratios of the two pheromone components, Z11 and E11-tetradecenylacetate. The Z-strain uses a ratio of 97:3 of Z11:E11 tetradecenylacetate, whereas the E-strain uses a ratio of 1:99. We studied how the difference in male preference correlates with differences in wiring of olfactory input and output neurons in the antennal lobe (AL). Activity-dependent anterograde staining, intracellular recording and immunocytochemistry were used to establish the structure and function of male olfactory receptor neurons (ORNs) and AL projection neurons (PNs). Physiologically characterized neurons were reconstructed using confocal microscopy of alpha-synapsin stained ALs. The ALs of males and females in both strains had approximately 64 glomeruli. In males the macroglomerular complex (MGC) was morphologically similar in the two strains and consisted of two major compartments, a large, medial compartment folded around a smaller, lateral one. Extensive physiological and morphological analysis revealed that in both strains the major pheromone component-specific ORNs and PNs arborize in the medial MGC glomerulus, whereas those sensitive to the minor pheromone component arborize in the lateral glomerulus. In other words, the two strains have an indistinguishable MGC morphology, but a reversed topology. Apparently, the single-gene-mediated shift that causes a radical change in behavior is located upstream of the antennal lobes, i.e. at the ORN level.

Keszthelyi, S., J. Puskas and L. Nowinszky (2008). "Changing of Flight Phenology and Ecotype Expansion of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in Hungary." *Cereal Research Communications* 36(4): 647-657.

The studies aimed to acquire the widest possible information on the annual flight in Hungary of the European corn borer (ECB), *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae). The investigations used biomathematical (Part 1) and graphical (Part 2) evaluation to document changes in the individual population number. The study was conducted in Hungary using ECB moth capture records from the Plant Protection Information System black light trap system (1991-2004). We have drawn conclusions on the appearance of annual flights and the tendency of alterations in flight direction by means of light trap results in four different areas in Hungary. We calculated the flight peak quotients, the individual population numbers of the second flight peak, the distinctions of individual numbers of two flight peaks in

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this part. As previously published, alterations in flight direction of ECB flights began at different times in Hungary. In the current study, a gradual disappearance of the univoltine ecotype and gradual appearance of the bivoltine ecotype ECB in Hungary is confirmed by the data obtained between 1991-2004. Flight peak quotients and data concerning the second flight peak have confirmed change this process, too: the appearance of a second flight peak in Northwestern Hungary from 1995-1996 (FP = 1.27), the more significant appearance of flights in August in Western Hungary (FP = 1.05) and Northeastern Hungary (FP = 1.45), and a three and four times more individual number of the second flight peak in Southeastern Hungary (FP = 3.44). Flight peak quotients, individual population numbers of the second flight peak, the tendency towards a difference in population number of the two peaks, and size of increase of these values demonstrates the southeastern-northwestern presence of the bivoltine ecotype in Hungary.

Kim, K. S., B. S. Coates, R. L. Hellmich, D. V. Sumerford and T. W. Sappington (2008). "Isolation and characterization of microsatellite loci from the European corn borer, *Ostrinia nubilalis* (Hubner) (Insecta : Lepidoptera : Crambidae)." *Molecular Ecology Resources* 8(2): 409-411.

Few useful microsatellites are available for population studies of the European corn borer, *Ostrinia nubilalis* (Hubner). An enrichment strategy was used to develop microsatellite markers for *O. nubilalis*, and over 500 positive clones were isolated. Seventy-five contained unique microsatellites, 10 of which were polymorphic with discernable polymerase chain reaction products. The 10 loci were surveyed for variability in 72 wild individuals from central Iowa. Five loci showed no deviation from Hardy-Weinberg proportions, and all were successfully cross-amplified in the related Asian corn borer, *Ostrinia furnacalis*. These loci represent a significant addition to microsatellites appropriate for population studies of *O. nubilalis*.

Krumm, J. T., T. E. Hunt, S. R. Skoda, G. L. Hein, D. J. Lee, P. L. Clark and J. E. Foster (2008). "Genetic variability of the European corn borer, *Ostrinia nubilalis*, suggests gene flow between populations in the Midwestern United States." *Journal of Insect Science* 8.

The European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), is a widely distributed and serious economic pest to corn production in the U.S. Genetic variability of *O. nubilalis* was studied in 18 sub-populations in the upper Midwestern United States using amplified fragment length polymorphism. The relatively low G(ST) values indicate that more variation exists within populations than between populations. High gene flow (Nm) values were indicated across the entire *O. nubilalis* population; the lowest degree of gene flow was in the northern samples (Nm = 1.96) and the highest degree of gene flow was in the southern samples (Nm = 2.77). The differences observed in the respective regions (north vs. south) may be explained by the voltinism patterns (univoltine vs. multivoltine, respectively) of *O. nubilalis*: southern multivoltine populations have opportunities for multiple matings for the duration of the year, further mix alleles. AMOVA results also indicated that most of the genetic variation was within sub-populations (approximate to 81% of total variation); less variation (approximate to 13%) was detected among populations within each of the three regions as designated for this study. However, the most striking and unexpected result was the low percentage of variation between all groups (approximate to 6%), further supporting implications of a high degree of gene flow. These results provide support for current requirements of refugia corn planting in Bt-corn management. These results also indicate that if resistance to Bt were to evolve in *O. nubilalis*, quick action would be necessary to deter the rapid spread of the gene for resistance.

Li, J. M., J. P. Yong and H. A. Aisa (2008). "Synthesis of (Z/E)-11-tetradecen-1-ol, a component of *Ostrinia nubilalis* sex pheromone." *Chemistry of Natural Compounds* 44(2): 224-226.

11-Tetradecen-1-ol acetate is a mixture of geometric isomers with the Z/E-conformations in a 94:6 ratio that is used as an attractant to trap corn pests. It has a powerful attractive action similar to that of an isomeric mixture of 11-tetradecenyl acetate with the Z/E-conformation in a 95:5 ratio that was extracted from the peritoneal cavity of male *Ostrinia nubilalis* Hubner in Xinjing (PRC).

Pereira, E. J. G., B. A. Lang, N. P. Storer and B. D. Siegfried (2008). "Selection for Cry1F resistance in the European corn borer and cross-resistance to other Cry toxins." *Entomologia Experimentalis Et Applicata* 126(2): 115-121.

Evolution of resistance by insect pests is the greatest threat to the continued success of *Bacillus thuringiensis* (Bt) toxins used in insecticide formulations or expressed by transgenic crop plants such as Cry1F-expressing maize [(*Zea mays* L.)

(Poaceae)]. A strain of European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), obtained from field collections throughout the central US Corn Belt in 1996 was selected in the laboratory for resistance to Cry1F by exposure to the toxin incorporated into artificial diet. The selected strain developed more than 3000-fold resistance to Cry1F after 35 generations of selection and readily consumed Cry1F expressing maize tissue; yet, it was as susceptible to Cry1Ab and Cry9C as the unselected control strain. Only a low level of cross-resistance (seven-fold) to Cry1Ac was observed. These lacks of cross-resistance between Cry1F and Cry1Ab suggest that maize hybrids expressing these two toxins are likely to be compatible for resistance management of *O. nubilalis*.

Pereira, E. J. G., N. P. Storer and B. D. Siegfried (2008). "Inheritance of Cry1F resistance in laboratory-selected European corn borer and its survival on transgenic corn expressing the Cry1F toxin." *Bulletin of Entomological Research* 98(6): 621-629.

A major assumption of the high-close/refuge strategy proposed for insect resistance management strategies for transgenic crop plants that express toxins from *Bacillus thuringiensis* is that resistance traits that evolve in pest species will be recessive. The inheritance of Cry1F resistance and larval survival on commercially available Cry1F corn hybrids were determined in a laboratory-selected strain of European corn borer, *Ostrinia nubilalis* (Hubner), displaying more than 3000-fold resistance to Cry1F. Concentration-response bioassays of reciprocal parental crosses indicated that the resistance is autosomal and recessive. Bioassays of the backcross of the F₁ generation with the selected strain were consistent with the hypothesis that a single locus, or a set of tightly linked loci, is responsible for the resistance. Greenhouse experiments with Cry1F-expressing corn hybrids indicated that some resistant larvae survived the high dose of toxin delivered by Cry1F-expressing plants although F₁ progeny of susceptible by resistant crosses had fitness close to zero. These results provide the first direct evidence that the high dose/refuge strategy currently in place to manage resistance in Cry1F-expressing corn is appropriate.

Saladini, M. A., M. Blandino, A. Reyneri and A. Alma (2008). "Impact of insecticide treatments on *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) and their influence on the mycotoxin contamination of maize kernels." *Pest Management Science* 64(11): 1170-1178.

BACKGROUND: European corn borer (ECB), *Ostrinia nubilalis* (Hubner), is the main maize pest in Central and Southern Europe and promotes the infection of maize with *Fusarium* spp., which produce mycotoxins. The objective of this study was to determine the effect of insecticide treatments on ECB damage, *Fusarium* infection and mycotoxin contamination. The field experiments were performed from 2000 to 2006 in three locations in north-western Italy. At harvest, ears were rated for the incidence and severity of ECB damage and *Fusarium* ear rot symptoms, and the harvested kernels were analysed for fumonisins and zearalenone. **RESULTS:** In all the years except 2003, the chemical treatment had a significant effect on ECB incidence and severity. The ear damage was reduced, on average, by 44.1%. *Fusarium* ear rot and fumonisin contamination were affected by ECB control. The occurrence of the mycotoxin was significantly reduced, on average by 68%. The differences between the treatments were less clear in the year with highest ECB pressure. No significant difference was observed between the different insecticide classes. No relations were detected between the ECB activity and the occurrence of zearalenone. **CONCLUSION:** This research indicates that the production of kernels with low fumonisin content may be enhanced by an insecticide treatment against the second ECB generation. (c) 2008 Society of Chemical Industry

Sole, J., A. Sans, M. Riba, E. Rosa, M. P. Bosch, M. Barrot, J. Palencia, J. Castella and A. Guerrero (2008). "Reduction of damage by the Mediterranean corn borer, *Sesamia nonagrioides*, and the European corn borer, *Ostrinia nubilalis*, in maize fields by a trifluoromethyl ketone pheromone analog." *Entomologia Experimentalis Et Applicata* 126(1): 28-39.

Large-scale field experiments on the Mediterranean corn borer, *Sesamia nonagrioides* Lefebvre (Lepidoptera: Noctuidae), were carried out in 2004-2006 on maize [*Zea mays* L. (Poaceae)] fields using (Z)-11-hexadecenyl trifluoromethyl ketone, an antagonist analog of the pheromone of this species, to evaluate a possible reduction of damage caused by this pest. The effect of the treatments on the European corn borer, *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae), a sympatric species, was also determined. Evaluation of the success of the experiments was assessed by counting (i) the number of males caught by pheromone traps in treated and untreated fields, (ii) the number of plants attacked by both insects in both plots, and (iii) the number of larvae present in infested plants in both fields. Effectiveness of the treatment was high for the second generation of the Mediterranean corn borer, the most harmful to the crop (86-90% reduction in the number of plants attacked and 67-98% reduction in the number of larvae

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per plant in treated fields in comparison to untreated fields), and moderate for the third generation (reduction of 41-71% and 33-77%, respectively). Treatments were also effective for the second generation of the European corn borer (61-75% reduction in the number of plants attacked, 58-78% reduction in the number of larvae found per plant) as well as for the third generation (69-97% and 70-98% reduction, respectively). By plotting the amount of the antagonist remaining on the dispensers after 40-45 days of exposure with time, the mean release rate of the compound was calculated to be 2.2%/day in 2004, 1.95%/day in 2005, and 2.1%/day in 2006, with 26% of the initial compound remaining after 20 days of experimentation. The emission rate appears to cover the flight of the most damaging second generation of both insects. Prospects of using trifluoromethyl ketones as new potential agents for pest control are also outlined.

Sole, J., A. Sans, M. Riba, G. Rosell, E. Rosa, L. Munoz, M. P. Bosch and A. Guerrero (2008). "Differential activity of non-fluorinated and fluorinated analogues of the European corn borer pheromone." *Chemoecology* 18(2): 99-108.

The differing antagonist activity of (Z)-13-hexadecen-2-one (Z11 - 14 :MK, 1) and its 1,1,1-trifluoro derivative (Z11 -14 :TFMK, 2), two closely related analogues of the European corn borer pheromone *Ostrinia nubilalis* (Z strain), and their rationale is reported. Both chemicals exhibited some electrophysiological activity, and topical application of 10 pg of pheromone analogue on male antennae was sufficient to induce significantly lower depolarization responses to the pheromone versus untreated insects. In a wind tunnel, the number of European corn borer males attracted to sources containing mixtures of 1 + pheromone in ratios \leq N 1 :1 was significantly lower than the number attracted to a source containing pheromone alone. Source contact behaviour was dramatically impaired when the 1 + pheromone blend reached a ratio of 10 :1, in which only 2% of males displayed source contact in the presence of antagonist. When compound 1 was present at the source, males usually flew upwind with occasional downwind reversals; when compound 2 was present at the lure, males performed wider crosswind reversals, with little progress toward the source. In the field, traps baited with mixtures of both compounds with the pheromone in ratios of 5 :1 and 10 :1 elicited a significantly decreased number of male catches. In esterase inhibition assays, compound 2 was a potent inhibitor (IC(50) = 70 nM), whereas the non-fluorinated compound 1 was not. The different activity of both compounds is presumed to be due to different mechanisms of action; considerations for using methyl ketone analogues as new behavioural antagonists of the pheromone are outlined.

Suverkropp, B. P., A. Dutton, F. Bigler and J. C. van Lenteren (2008). "Oviposition behaviour and egg distribution of the European corn borer, *Ostrinia nubilalis*, on maize, and its effect on host finding by *Trichogramma* egg parasitoids." *Bulletin of Insectology* 61(2): 303-312.

Oviposition behaviour and egg distribution of *Ostrinia nubilalis* is reviewed based on published information and new research. The position of egg masses of *O. nubilalis* on maize plants and leaves were sampled in the field. Most egg masses were found on the lower leaf side, on the middle part of the leaf or close to the stern, and close to the mid-rib. Direct observations of oviposition behaviour were made in laboratory and field cages. *O. nubilalis* moved very little on the plants and only 10 % of the females that landed on the plants oviposited. The number of actual ovipositions was quite low compared to the number of landings, with females walking only a few centimetres if at all. Shed scales of adult moths were not abundant near egg masses with only 37% of egg masses associated with scales and 45% with only a few scales. Many scales were found on other places of the plants. At the leaf and plant level, scales might serve as a useful host-cue to *Trichogramma brassicae*, all egg parasitoid of *O. nubilalis*. However, scales are not an indicator for the presence of egg masses in their immediate vicinity.

Tate, C. D., R. L. Hellmich and L. C. Lewis (2008). "Evaluating popcorn as a potential refuge, of *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Environmental Entomology* 37(2): 615-623.

Popcorn was evaluated in a series of experiments conducted over four growing seasons for its potential as a refuge for European corn borer, *Ostrinia nubilalis* (Hubner). Objectives of these studies were to determine whether more larvae were produced in popcorn than in field corn and to determine how popcorn influenced female oviposition and larval distribution in neighboring field corn. Two varieties of popcorn (M140, 105d and M3374Y, 118d), one mixture of popcorn (50% 105d and 50% 118d), and field corn (DK580,108d) were evaluated. Number of egg masses, eggs per egg mass, and larvae were significantly higher in popcorn compared with field corn. Moth oviposition and larval distribution were evaluated using 105d popcorn embedded in several cornfields across Iowa. The row of field corn adjacent to

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popcorn had significantly more larvae compared with background field corn. In larger field experiments, *O. nubilalis* larval survival after overwintering was significantly different, with 2.2-18.7 times more *O. nubilalis* larvae surviving in popcorn than field corn. The potential use of popcorn as an *O. nubilalis* refuge for genetically engineered corn is considered.

Tyutyunov, Y., E. Zhadanovskaya, D. Bourguet and R. Arditi (2008). "Landscape refuges delay resistance of the European corn borer to Bt-maize: A demo-genetic dynamic model." *Theoretical Population Biology* 74(1): 138-146.

We constructed a reaction-diffusion model of the development of resistance to transgenic insecticidal Bt crops in pest populations. Kostitzin's demo-genetic model describes local interactions between three competing pest genotypes with alleles conferring resistance or susceptibility to transgenic plants, the spatial spread of insects being modelled by diffusion. This new approach makes it possible to combine a spatial demographic model of population dynamics with classical genetic theory. We used this model to examine the effects of pest dispersal and of the size and shape of the refuge on the efficiency of the "high-dose/refuge" strategy, which was designed to prevent the development of resistance in populations of insect pests, such as the European corn borer, *Ostrinia nubilalis* Hubner (Lepidoptera, Crambidae). We found that, with realistic combinations of refuge size and pest dispersal, the development of resistance could be considerably delayed. With a small to medium-sized farming area, contiguous refuge plots are more efficient than a larger number of smaller refuge patches. We also show that the formal coupling of classical Fisher-Haldane-Wright population genetics equations with diffusion terms inaccurately describes the development of resistance in a spatially heterogeneous pest population, notably overestimating the speed with which Bt resistance is selected in populations of pests targeted by Bt crops. (C) 2008 Elsevier Inc. All rights reserved.

Ziems, J. R., W. W. Hoback, L. G. Higley, T. E. Hunt, O. A. Fernandes, C. Bastos and A. D. Bueno (2008). "Second generation European corn borer injury and Irish potato physiology, yield, and quality." *Agronomy Journal* 100(3): 720-725.

European corn borer (ECB) [*Ostrinia nubilalis* (Hubner)] (Lepidoptera: Crambidae) is known to infest Irish potato (*Solanum tuberosum* L.) but only causes economic damage during the first generation in East Coast potato producing areas. However, in Nebraska, second generation ECB infest potato plants during the bulking period and may reduce yield and/or potato quality. Experiments were conducted in 2001, 2002, and 2003 to examine physiological and yield effects of second generation ECB injury to potato in Nebraska. Pike, Atlantic, and three Frito Lay proprietary varieties (FL1867, FL1879, and FL1833) were used. Experimental plots were infested with four ECB egg masses per plant to simulate ECB infestation by second-generation larvae; controls received no egg masses. Photosynthetic rates, tuber weights, tuber size grades, solids, and fry quality were measured. Potato plants with ECB infestation had significantly reduced photosynthetic rates on ECB-infested stems and on uninfested stems on the same plant when larvae were in the fifth instar. When insects were in the fourth instar, photosynthetic rates were reduced only on ECB-infested stems. In 2001, ECB infestation reduced the average mass of large tubers and increased the amount of small tubers in FL1867 and FL1879. In 2002, significant yield reductions were not observed. Across both years, ECB-infested plots produced fewer large (65- to 100-mm diam.) tubers than control plots. Other tuber properties and chip qualities were unaffected. This study indicates that second generation ECB infestation of approximately 30% infested plants results in economic loss for some chipping varieties and affects tuber bulking. In contrast to east coast growers, Midwest potato farmers must be concerned with second generation ECB.

Baca, F., S. Gotic-Dondo, Z. Kaitovic and D. Hadzistevic (2007). "European corn borer (*Ostrinia nubilalis* Hbn) population fluctuation at Zemun Polje between 1986 and 2005." *Maydica* 52(3): 325-328.

The European corn borer (ECB) (*Ostrinia nubilalis* Hbn) is one of the most important pests of maize in Serbia. Therefore, it has been and continues to be an attractive subject of research. The flight of ECB adults has been monitored by light traps at the Maize Research Institute in Zemun Polje, Serbia since 1966. Significant qualitative changes in the ECB voltinism occurred during the last three decades of the 20th century. ECB used to be extremely univoltine with 80-90% moths of the first generation, but lately it has become predominately bivoltine. During these 20 years of monitoring, a total of 52,450 specimens were captured (32,382 females and 20,068 males) and their population varied between 351 moths per year recorded in 2001 and 8,347 recorded in 1987. Ratio between the first and the second generation has been changed so that the larger number is the second generation: on the average 1:5.94 (first: second generation), and ranged between 1:0.34 recorded in 2004 and 1: 21.6 recorded in 1987.

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Bailey, R. I., D. Bourguet, A. H. Le Pallec and S. Ponsard (2007). "Dispersal propensity and settling preferences of European corn borers in maize field borders." *Journal of Applied Ecology* 44(2): 385-394.

Bacillus thuringiensis (Bt) crops kill pest larvae but have led to resistance evolution in several target pests. The high dose-refuge (HDR) strategy aimed at delaying Bt resistance evolution depends on dispersal patterns of target pests. Examination of adult dispersal of the European corn borer *Ostrinia nubilalis* (ECB), the main target of Bt maize, can help to improve resistance management. Estimated recapture rates over 20 mark-release-recapture sessions in herbaceous field borders, where ECB adults rest during the day and mate at night, were used to examine the influence of sex, release period and site on ECB dispersal. Data from an additional 30 sessions were used to test the influence of night temperature, humidity, dew index and wind speed. Average recaptures within 50 m of release were lower 12 h after night (7.7%) than 12 h after day (34.5%) releases, did not differ between sexes, and decreased during nights with higher temperatures and lower wind speed. Local habitat had a major influence on dispersal. The number of unmarked adults caught initially in a given section of field border was strongly correlated with those subsequently captured in the same section, suggesting that moths flying in from the surroundings consistently settle in the same preferred spots. Moreover, recapture rates of marked adults were positively correlated with the prior density of unmarked adults in the release section. The spatial distribution of recaptured moths around the release point suggests that they moved on a very local scale, while those not recaptured probably left the area by a different, long-range type of dispersal. Synthesis and applications. A proportion of European corn borer adults typically remained within a few metres of their initial location for at least 12 h. This should favour non-random mating early in the flight season when nights are cold, population mixture is low and most individuals are unmated. Non-random mating can accelerate the evolution of resistance, but this effect may be offset by non-random oviposition. Our findings suggest that the intensity and direction of dispersal could be manipulated by field border management. Our data on the range and prevalence of short-range dispersal and the factors influencing this process, support the view that resistance evolution is multifactorial. Our results can be used to parameterize multifactorial models from which specific management recommendations can be formulated.

Belloncik, S., O. Petcharawan, M. Couillard, G. Charpentier, B. Larue, H. Guardado, S. Chareonsak and S. Imanishi (2007). "Development and characterization of a continuous cell line, AFKM-On-H, from hemocytes of the European corn borer *Ostrinia nubilalis* (Hubner) (Lepidoptera, Pyralidae)." *In Vitro Cellular & Developmental Biology-Animal* 43(7): 245-254.

The corn borer, *Ostrinia nubilalis*, is a very important pest in different countries, and the in vitro system of the insect could be a useful tool for isolation and characterization of the pathogens and physiological responses of the insect. In this context, a cell line was derived from the hemocytes of the European corn borer and was named AFKM-On-H for, respectively, *O. nubilalis*, Armand Frappier, King Mongkut Institutes, and Hemocytes. This cell line was initiated and maintained in Ex-Cell 400 medium supplemented with 10% heat-inactivated fetal bovine serum. The cells, mostly spherical in shape, not firmly attached to the plastic culture flasks, were passaged up to 200 times by repeated gentle pipetting of the cells. The doubling times at the 80th and 125th passages at 28 degrees C and at the 122th and 169th passages at 25 degrees C were 40, 29, 35, and 34 h, respectively. The AFKM-On-H cell line was further characterized by the morphology, karyotype, random amplified polymorphic DNA analysis, and isozyme profiles. Susceptibility of the cell line to cytoplasmic polyhedrosis viruses (CPV) *Euxoa scandens* (EsCPV), *Dendrolimus punctatus* (DpCPV), and *Choristoneura fumiferana* (CfCPV); nuclear polyhedrosis viruses [*Autographa californica* (AcMNPV) wild type and recombinant, *Antheraea yammamai* (AnyNPV)]; and *Chilo iridescent virus* was demonstrated. Relative sensitivities of the cell line to *Bacillus thuringiensis* and *Metarhizium anisopliae* toxins and effects of the molting hormone 20-hydroxyecdysone on this new hemocyte cell line were characterized.

Boisclair, J. and F. Fournier (2007). Validation d'un stade phénologique optimal pour débiter et minimiser les interventions contre la pyrale du maïs dans la culture du maïs sucré frais I. d. r. e. d. e. agroenvironnement. IRDA-1-SPP-04-006: 9.
Lien : http://www.agrireseau.qc.ca/references/6/Strat_phyto/V11_RapportFinal006.pdf

Boiteau, G. and C. Noronha (2007). "Topical, residual and ovicidal contact toxicity of three reduced-risk insecticides against the European corn borer, *Ostrinia nubilalis* (Lepidoptera : Crambidae), on potato." *Pest Management Science* 63(12): 1230-1238.

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BACKGROUND: The goal of the research was to gather efficacy data required to introduce reduced-risk insecticides in sustainable control programs for European corn borer, *Ostrinia nubilalis* Hubner, on potato. **RESULTS:** Laboratory tests confirmed that sprays of indoxacarb and novaluron at recommended field rates are as effective as spinosad against neonate larvae of *O. nubilalis*. However, there is evidence that higher rates would enhance the inhibition of chitin synthesis by novaluron. The three insecticides showed ovicidal activity when applied to *O. nubilalis* egg masses 2 days prior to black head stage. The ovicidal activity of spinosad and novaluron was almost twice that of indoxacarb. At the recommended field rates, the residues of the three insecticides displayed contact toxicity to *O. nubilalis* larvae. Spinosad residues 16 h old or less provided the highest immediate (24 h after exposure) contact mortality, followed by indoxacarb and then by novaluron. Also, residues of spinosad had faster contact efficacy than indoxacarb, which had faster efficacy than novaluron. **CONCLUSION:** Spinosad, indoxacarb and novaluron have ovicidal properties, which could enhance *O. nubilalis* management programs. However, the contact residual toxicity is limited in duration and would likely only play a minor role in *O. nubilalis* control. Copyright (C) 2007 Crown in the right of Canada. Published by John Wiley & Sons, Ltd.

Calas, D., A. Berthier and F. Marion-Poll (2007). "Do european corn borer females detect and avoid laying eggs in the presence of 20-hydroxyecdysone?" *Journal of Chemical Ecology* 33(7): 1393-1404.

European corn borer larvae detect and avoid feeding in the presence of phytoecdysteroids (PEs) such as 20-hydroxyecdysone (20E). Therefore, we hypothesized that females would have taste receptors similar to larvae and avoid laying eggs in the presence of 20E. We found female-specific taste sensilla on the tarsi that respond to 20E at concentrations as low as 10^{-6} M, a threshold comparable to that of larvae. However, in choice tests, females laid a similar number of eggs on 20E-treated and on nontreated artificial substrates (filter paper, glass, and nylon), although they spent significantly more time in behavioral sequences related to substrate assessment when 20E was present. In contrast, when given a choice between maize plants (eight leaves) sprayed with 20E or only the solvent, females laid 70% fewer eggs on the treated than on control plants. These observations suggest that other chemical cues of plant origin must be present at the same time as 20E for females to modify their oviposition behavior.

Calcagno, V., Y. Thomas and D. Bourguet (2007). "Sympatric host races of the European corn borer: adaptation to host plants and hybrid performance." *Journal of Evolutionary Biology* 20(5): 1720-1729.

The European corn borer (ECB), *Ostrinia nubilalis*, is a major pest of maize crops. In Europe, two sympatric host races are found: one feeds on maize (*Zea mays*) and the other mainly on mugwort (*Artemisia vulgaris*). The two host races are genetically differentiated, seldom crossing in the laboratory or in the field, and females preferentially lay eggs on their native host species. We conducted two independent experiments, in field and greenhouse conditions, to determine whether the two host races are locally adapted to their host species. The effect of larval density and the performance of hybrids were also investigated. Despite some differences in overall larval feeding performance, both experiments revealed consistent patterns of local adaptation for survival and for larval weight in males. In females the same trend was observed but with weaker statistical support. F1 hybrids did not seem to be disadvantaged compared with the two parental races. Overall, our results showed that both host races are physiologically adapted to their native host. The fitness trade-off between the two host plants provides a potential driving force for ecological speciation in this species.

Coates, B. S., D. V. Sumerford, R. L. Hellmich and L. C. Lewis (2007). "A beta-1,3-galactosyltransferase and brainiac/bre5 homolog expressed in the midgut did not contribute to a Cry1Ab toxin resistance trait in *Ostrinia nubilalis*." *Insect Biochemistry and Molecular Biology* 37(4): 346-355.

Post-translational glycosylation of midgut epithelial protein and lipid receptors may be required prior to binding of activated *Bacillus thuringiensis* (Bt) Cry toxins. A 931 bp cDNA encoding a putative 297-residue beta-1,3-galactosyltransferase (beta 3GAT5) was cloned from larval *Ostrinia nubilalis* midgut tissue, and showed homology to *Drosophila* brainiac (brn) and *Caenorhabditis elegans* bre5 proteins. Single nucleotide polymorphisms (SNPs) were detected in coding and promoter regions of *O. nubilalis* beta 3GalT5 (Onb3GalT5), of which 3 of 31 CDs SNPs were non-synonymous. SNPs within HaeIII and MspI recognition sites were confirmed by PCR-RFLP, and are Mendelian inherited. Analysis of F-2 pedigrees suggested an Onb3GalT5 SNP C660 fixed within a Cry1Ab-resistant colony was not correlated with Cry1Ab resistance traits, as measured by higher larval *O. nubilalis* weights when fed toxin-containing diet. (c) 2007 Elsevier Ltd. All rights reserved.

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Dalecky, A., D. Bourguet and S. Ponsard (2007). "Does the European corn borer disperse enough for a sustainable control of resistance to Bt maize via the High Dose/Refuge strategy?" *Cahiers Agricultures* 16(3): 171-176.

The use of transgenic crops producing toxins from the bacterium *Bacillus thuringiensis*- or Bt crops - is associated with the risk that the targeted pests become resistant to these toxins. To reduce this risk, the US government required the implementation of a strategy named High Dose/Refuge (HDR). This strategy is based on maintaining Bt toxin-free plants or crops - referred to as, refuges, - to preserve a pool of susceptible insects in the vicinity of Bt fields. Among other factors, its efficiency relies on a high gene flow between these susceptible individuals and any resistant individuals selected in Bt fields. For several pests targeted by these toxins, this strategy was nevertheless implemented when little was in fact known, as to the life history traits likely to influence the intensity of the gene flow. Part of this gap has been filled since then: we summarize here the recent advances on the European corn borer (ECB), one of the main targets of insecticidal Bt maize. Although this moth pest is highly polyphagous, its other host plants - whether wild or cultivated - do not provide a sufficient source of susceptible individuals to efficiently prevent toxin resistance from developing. Moreover, a fraction of the ECB reproduce in close vicinity of their place of emergence, so that refuges situated a few hundred meters from Bt maize fields - the maximal distance currently required is 800 meters - may not warrant a sufficient intermixing between susceptible and resistant individuals. In crop rotation situations, this intermixing could however be facilitated through a contrasted management of herbaceous maize field borders. Although 10 years after the beginning of Bt maize cultivation no resistance has yet broken out, our data suggests that it is illusory to aim at a universally suitable strategy, and that the HDR strategy - as currently implemented - may not necessarily be optimal.

Domingue, M. J., C. J. Musto, C. E. Linn, W. L. Roelofs and T. C. Baker (2007). "Altered olfactory receptor neuron responsiveness in rare *Ostrinia nubilalis* males attracted to the *O. furnacalis* pheromone blend." *Journal of Insect Physiology* 53(10): 1063-1071.

Three percent of E-strain *Ostrinia nubilalis* males fly upwind in response to the *Ostrinia furnacalis* pheromone blend [a 40:60 ratio of (E)-12-tetradecenyl acetate to (Z)-12-tetradecenyl acetate (E12-14:OAc to Z12-14:OAc)], in addition to their own pheromone blend [a 99:1 ratio of (E)-11-tetradecenyl acetate to (Z)-11-tetradecenyl acetate (E 11-14:OAc to Z 11-14:OAc)]. We assessed the olfactory receptor neuron (ORN) responses of these behaviorally "rare" males versus those of normal males. For the three ORNs housed within each sensillum, we tested responsiveness to Z12-14:OAc, E12-14:OAc, Z11-14:OAc, E11-14:OAc, and the behavioral antagonist (Z)-9-tetradecenyl acetate (Z9-14:OAc). Z11-14:OAc, E11-14:OAc, and Z9-14:OAc stimulated ORNs exhibiting distinct small, large, and medium spike sizes, respectively. For rare and normal males, both Z12-14:OAc and E12-14:OAc usually elicited responses from the largest-spiking ORN. In many ORNs of normal males, Z12-14:OAc or E12-14:OAc stimulated the smaller-spiking ORN that is responsive to Z 11-14:OAc. In rare males, detectable ORN responses from the smaller-spiking ORN in response to Z12- and E12-14:OAc were virtually non-existent. These differences in ORN tuning in rare males will tend to create an ORN firing ratio between the large- and small-spiking ORNs in response to the *O. furnacalis* blend that is similar to that elicited by the *O. nubilalis* blend. (C) 2007 Elsevier Ltd. All rights reserved.

Eizaguirre, M., R. Albajes, C. Lopez, A. Sans and C. Gemeno (2007). "Inhibition of pheromone response in *Sesamia nonagrioides* by the pheromone of the sympatric corn borer, *Ostrinia nubilalis*." *Pest Management Science* 63(6): 608-614.

Sesamia nonagrioides Lef. and *Ostrinia nubilalis* (Hubn.) are two corn borers present in the Mediterranean area that share a similar feeding habitat. The female sex pheromones of the two species consist of (Z)-11-hexadecenyl acetate, (Z)-11-hexadecen-1-ol, (Z)-11-hexadecenal and dodecyl acetate (77:8:10:5 w/w) and (Z)-11-tetradecenyl acetate and (E)-11-tetradecenyl acetate (97:3 w/w) respectively. Although the pheromones share no common components, previous work had shown the inhibition of the response by *O. nubilalis* males to their own pheromone owing to the presence of *S. nonagrioides* pheromone. In this study, the pheromone of *O. nubilalis* and its two components separately were shown to inhibit the attraction of *S. nonagrioides* males to the synthetic female pheromone in both laboratory wind-tunnel bioassay and field trapping studies. In the wind tunnel, the number of contacts of *S. nonagrioides* males with the source were significantly ($P < 0.05$) reduced by the single pheromone components of *O. nubilalis*. In the field, the addition of 1% of *O. nubilalis* pheromone significantly ($P < 0.05$) reduced the catches of *S. nonagrioides* males. The components of both pheromones also elicited electroantennographic responses from antennae of male *S. nonagrioides*.

moths. The ecological consequences and the possibilities of applying this cross-inhibition for mating disruption techniques are discussed. (c) 2007 Society of Chemical Industry.

Eltahlawy, H. S., J. S. Buckner and S. P. Foster (2007). "Regulation of pheromone biosynthesis in the "Z strain" of the European corn borer, *Ostrinia nubilalis*." Archives of Insect Biochemistry and Physiology 65(1): 29-38.

The regulation of pheromone biosynthesis by the neuropeptide PBAN in the Z strain of the European corn borer, *Ostrinia nubilalis*, was investigated using labeled intermediates. Injection of radiolabeled acetate showed PBAN did not influence the de novo synthesis of saturated fatty acids in the gland. When deuterium-labeled myristic acid was topically applied to the gland, females injected with PBAN produced more labeled pheromone than did control females, indicating that PBAN controls one of the later steps of pheromone biosynthesis. Although more myristic acid was Delta 11-desaturated in the gland in the presence of PBAN, this was counterbalanced by less Delta 11-desaturation of palmitic acid, indicating that desaturase activity did not change overall. This change in flux of myristic acid through to pheromone was shown to be caused by increased reduction of fatty acid pheromone precursors occurring in the presence of PBAN.

Gardner, J., M. P. Hoffmann, S. A. Cheever, A. J. Seaman, P. Westgate and R. V. Hazzard (2007). "Large-scale releases of *Trichogramma ostrinae* to suppress *Ostrinia nubilalis* in commercially grown processing and fresh market sweet corn." Journal of Applied Entomology 131(6): 432-440.

We evaluated the egg parasitoid *Trichogramma ostrinae* (Pang et Chen) (Hym.: Trichogrammatidae) for control of European corn borer [Lep.:Crambidae: *Ostrinia nubilalis* (Hubner)] in fields of commercial processing sweet corn in New York in 2002 and 2003. We made inoculative releases of 75 000 *T. ostrinae*/ha when corn was at mid-whorl and regional *O. nubilalis* activity had begun. Each release field was paired with a similar non-release control. The incidence of egg mass parasitism, number of stalk tunnels, incidence of ear damage and effect on insecticide spray decisions were evaluated. Parasitism of cumulative number of *O. nubilalis* egg masses was 51.3 +/- 7.2% and 43.5 +/- 5.7% (mean +/- SEM) in release fields in 2002 and 2003 respectively. The incidence of ear damage by *O. nubilalis* was not affected by *T. ostrinae* in either year of the study. There was no difference in stalk damage between release fields and control fields in either 2002 or 2003. However, individual comparisons between paired release and control fields showed reduced stalk tunnelling in 10 of 19 fields, but ear damage was reduced in only two of 19 fields. Neither the number of actual insecticide sprays nor the number of decisions to spray based on sequential sampling were affected significantly by releasing *T. ostrinae*. In a separate but related study, where releases were conducted in commercial fresh market sweet corn and used higher rates of release, *T. ostrinae* had no effect on the number of insecticidal sprays. In an additional experiment using small plots of sweet corn, ear damage was similar whether plots were treated with *T. Ostrinae* or with insecticide. Additional research should focus on improving the timing, frequency and rate of releases.

Jovanovic-Galovic, A., D. P. Blagojevic, G. Grubor-Lajsic, M. R. Worland and M. B. Spasic (2007). "Antioxidant Defense in mitochondria during diapause and postdiapause development of European corn borer (*Ostrinia nubilalis*, Hubn.)." Archives of Insect Biochemistry and Physiology 64(3): 111-119.

Antioxidant enzymes (CAT, catalase; GPx, selenium nondependent glutathione peroxidase; GST, glutathione-S-transferase; GR, glutathione reductase; DHAR, dehydroascorbate reductase) were determined in the mitochondria of diapausing and non-diapausing larvae and pupae of both diapausing and non-diapausing larvae of the European corn borer (*Ostrinia nubilalis*, Hubn., Lepidoptera: Pyralidae). CAT, GST, and DHAR activity in mitochondria of diapausing larvae were reduced compared to non-diapausing larvae. Pupae of diapaused-larvae possessed lower GST, but higher DHAR activities compared to pupae of non-diapaused individuals. Comparison between larvae and pupae revealed lower GPx activity in the mitochondria of pupae. CAT activity in the mitochondria of pupae was higher compared to diapausing larvae, but lower than in non-diapausing ones. Correlation and canonical discriminant analyses revealed different antioxidant enzyme compositions for a particular stage and developmental pattern. Our results show that antioxidant enzymes have a similar role in the regulation of energetics in mitochondria as that in diapause and metamorphosis.

Krakowsky, M. D., M. Lee and J. B. Holland (2007). "Genotypic correlation and multivariate QTL analyses for cell wall components and resistance to stalk tunneling by the European corn borer in maize." Crop Science 47(2): 485-490.

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Correlations between concentrations of cell wall components (CWCs) in the leaf sheath and stalk and resistance to stalk tunneling by the European corn borer (ECB) [*Ostrinia nubilalis* (Hubner)] have been reported in some maize (*Zea mays* L.) populations. Evaluations of resistance to ECB stalk tunneling (ECB-ST) and concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) have been performed on recombinant inbred lines (RILs) developed from the cross of maize inbred lines B73 (susceptible to ECB-ST, low to moderate CWC concentrations) and DE811 (resistant to ECB-ST, high CWC concentrations). The objective of this study was to estimate genotypic correlations between ECB-ST and CWC concentrations and compare locations and effects of quantitative trait loci (QTL) for those traits. Genotypic correlations between ECB-ST and CWCs were not significant, but clustering of QTL for ECB-ST and CWCs was observed. Negative genotypic correlations between ECB-ST and CWC concentrations were observed at some loci, and resistance to ECB-ST may be associated with a subset of the QTL observed for CWCs and ADF in particular. Resistance to ECB-ST may also be associated with starch concentration in the stalk, which could explain the detection of resistance alleles contributed by B73. Examination of temporal differences in CWC and starch concentrations, and marker-assisted transfer of select alleles, could provide more information on mechanisms of resistance to ECB-ST.

Laurent, P. and B. Frerot (2007). "Monitoring of European corn borer with pheromone-baited traps: Review of trapping system basics and remaining problems." *Journal of Economic Entomology* 100(6): 1797-1807.

Since the identification of female European corn borer, *Ostrinia nubilalis* (Hubner) pheromone, pheromone-baited traps have been regarded as a promising tool to monitor populations of this pest. This article reviews the literature produced on this topic since the 1970s. Its aim is to provide extension entomologists and other researchers with all the necessary information to establish an efficient trapping procedure for this moth. The different pheromone races of the European corn borer are described, and research results relating to the optimization of pheromone blend, pheromone bait, trap design, and trap placement are summarized followed by a state-of-the-art summary of data comparing blacklight trap and pheromone-baited trap techniques to monitor European corn borer flight. Finally, we identify the information required to definitively validate/invalidate the pheromone-baited traps as an efficient decision support tool in European corn borer control.

Li, H. R., L. L. Buschman, F. N. Huang, K. Y. Zhu, B. Bonning and B. Oppert (2007). "DiPel-Selected *Ostrinia nubilalis* larvae are not resistant to transgenic corn expressing *Bacillus thuringiensis* Cry1Ab." *Journal of Economic Entomology* 100(6): 1862-1870.

The survival of KS-SC DiPel-resistant and -susceptible European corn borer, *Ostrinia nubilalis* (Hubner), was evaluated on different tissues from corn, *Zea mays* L., hybrids, including a nontransgenic and two transgenic corn plants (events MON810 and Bt11) expressing high doses of *Bacillus thuringiensis* (Bt) Cry1Ab. The survival of Bt-resistant and -susceptible third instars was similar after a 5-d exposure to transgenic plant tissues. Survivors eventually died when returned to Bt corn tissues, but many were able to continue development when transferred to non-Bt corn tissues. Survival of resistant and susceptible larvae also was evaluated in bioassays with dilutions of leaf extracts from the three corn hybrids incorporated in an artificial diet. In these assays, survival was significantly higher for resistant *O. nubilalis* neonates at three of the five dilutions compared with the susceptible strain, but the resistance ratio was only 2.2- and 2.4-fold for MON810 and Bt11, respectively. The data demonstrate that Bt-resistant and unselected control *O. nubilalis* larvae were similar in susceptibility to MON810 and Bt11 event corn hybrids. Although we were unable to evaluate the Cry1Ab protein that larvae were exposed to in the transgenic tissue because of company restrictions, Cry1Ab protoxin produced in *Escherichia coli* was incubated with extracts from non-Bt corn leaves to simulate the in planta effect on the transgenic protein. Cry1Ab protoxin was hydrolyzed rapidly by enzymes in the corn extract into peptide fragments with molecular masses ranging from 132 to 74 kDa, and eventually 58 kDa. Overall, these data suggest that plant enzymes hydrolyze transgenic toxin to one that is functionally activated. Therefore, resistant insect populations with reduced proteinase activity do not seem to pose a threat to the efficacy of commercial MON810 and Bt11 corn hybrids.

Linn, C. E., M. J. Domingue, C. J. Musto, T. C. Baker and W. L. Roelofs (2007). "Support for (Z)-11-hexadecanal as a pheromone antagonist in *Ostrinia nubilalis*: Flight tunnel and single sensillum studies with a New York population." *Journal of Chemical Ecology* 33(5): 909-921.

The flight-tunnel response of male Z-strain European corn borer moths (ECB), *Ostrinia nubilalis*, from a population in New York State (USA), was significantly antagonized by addition of 1% (Z)-11-hexadecanal (Z11-16:Ald) to their sex

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pheromone (a 97:3 mix of (Z)- and (E)-11-tetradecenyl acetate [Z/E11-14:OAc]). The level of antagonism was equivalent to that observed for the previously identified ECB antagonist, (Z)-9-tetradecenyl acetate (Z9-14:OAc), and supports a recent report showing that Z11-16:Ald, a minor pheromone component of the Noctuid moth, *Sesamia nonagrioides*, caused antagonism of ECB pheromone communication in sympatric populations in the Iberian Peninsula. Single sensillum recordings from ECB antennae, which included cross-adaptation experiments, showed that the same olfactory receptor neuron processing Z9-14:OAc inputs was responsible for detecting Z11-16:Ald, and that this neuron was not responsive to two other aldehydes, (Z)-9-tetradecanal (Z9-14:Ald) and (Z)-9-hexadecanal (Z9-16:Ald), found in other moth sex pheromones. Our results show that the antagonism is not confined to one geographic region, is specific for Z11-16:Ald, and that antagonist pathways might have the potential for processing a number of structurally similar compounds.

Linn, C. E., C. J. Musto and W. L. Roelofs (2007). "More rare males in *Ostrinia*: Response of asian corn borer moths to the sex pheromone of the european corn borer." *Journal of Chemical Ecology* 33(1): 199-212.

A previous flight tunnel study showed that 3-5% of European corn borer (ECB) moths, *Ostrinia nubilalis* (Z/E11-14:OAc), could fly upwind and make contact with sources releasing the sex pheromone of the related Asian corn borer (ACB), *Ostrinia furnacalis* (2:1 Z/E12-14:OAc). In this study, we show that rare males (3-4%) are also present in South Korean ACB that respond to the sex pheromone blends of the ECB UZ (97:3 Z/E11-14:OAc) and BE (1:99 Z/E11-14:OAc) pheromone races. We also show that the upwind flight response of a significant proportion of male ACB was antagonized by the addition of 1% Z9-14:OAc to the ACB blend, a compound that also antagonizes the upwind flight of ECB males. Male ACB flight behavior was not, however, affected by adding either of the ECB blends to the ACB blend, or by the addition of 50% 14:OAc, a compound identified from female pheromone glands of ACB and a number of other *Ostrinia* species. Additional flight tunnel tests with ACB to study the comparative aspects of ECB and ACB pheromone response specificity showed that male ACB exhibited maximal levels of upwind flight and source contact with doses of pheromone (30 and 100 μ g on rubber septum sources) that also elicited maximal levels in the two ECB pheromone races. The maximal level of source contact for ACB (66%) was lower than observed with the UZ race of ECB to its pheromone blend (> 95%), but comparable to those for the BE race of ECB (65-70%). Male ACB also flew upwind in high proportions to a broader range of ratios of Z/E12-14:OAc (80:20 to 20:80) than was previously observed for either of the ECB races.

Malausa, T., L. Leniaud, J. F. Martin, P. Audiot, D. Bourguet, S. Ponsard, S. F. Lee, R. G. Harrison and E. Dopman (2007). "Molecular differentiation at nuclear loci in French host races of the European corn borer (*Ostrinia nubilalis*)." *Genetics* 176(4): 2343-2355.

French populations of the European corn borer consist of two sympatric and genetically differentiated host races. As such, they are well suited to study processes that could be involved in sympatric speciation, but the initial conditions of host-race divergence need to be elucidated. Gene genealogies can provide insight into the processes involved in speciation. We used DNA sequences of four nuclear genes to (1) document the genetic structure of the two French host races previously delineated with allozyme markers, (2) find genes directly or indirectly involved in reproductive isolation between host races, and (3) estimate the time since divergence of the two taxa and see whether this estimate is compatible with this divergence being the result of a host shift onto maize after its introduction into Europe similar to 500 years ago. Gene genealogies revealed extensive shared polymorphism, but confirmed the previously observed genetic differentiation between the two host races. Significant departures from the predictions of neutral molecular evolution models were detected at three loci but were apparently unrelated to reproductive isolation between host races. Estimates of time since divergence between French host races varied from similar to 75,000 to similar to 150,000 years, suggesting that the two taxa diverged recently but probably long before the introduction of maize into Europe.

Malvar, R. A., A. Butron, A. Alvarez, G. Padilla, M. E. Cartea, P. Revilla and A. Ordas (2007). "Yield performance of the European Union Maize Landrace Core Collection under multiple corn borer infestations." *Crop Protection* 26(5): 775-781.

In Europe, corn borer attack is the main biotic stressor for the maize (*Zea mays* L.) crop. European corn borer (*Ostrinia nubilalis* Hbn.) is the most important maize pest in central and north Europe, while pink stem borer (*Sesamia nonagrioides* Lef.) is predominant in warmer areas of southern Europe. The objective of this study was the evaluation of the European Maize Union Landrace Core Collection (EUMLCC) for yield under infestation with European corn borer (*O. nubilalis*) and pink stem borer (*S. nonagrioides*). Eighty-five landraces from Germany, Spain, France, Greece, Italy, and

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Portugal were evaluated, under corn borer infestation, for yield, grain moisture, and days to flowering at two locations in Spain. Landraces were evaluated separately in four trials that corresponded to four maturity groups. In each maturity group, there were significant differences among landraces for yield of infested plants. Extra-early landraces, ESP0090214, FRA0410010, and ESP0070339; early landraces, FRA0410022, and ESP1985022; midseason landraces, PRT00100392 and ESP11981047; and late landraces, PRT00100569 and PRT00100530, were promising sources of high-yielding maize under corn borer infestation and showed relative earliness within their maturity groups. (c) 2006 Elsevier Ltd. All rights reserved.

Mao, J. Q., A. J. Burt, A. I. Ramputh, J. Simmonds, L. Cass, K. Hubbard, S. Miller, I. Altosaar and J. T. Arnason (2007). "Diverted secondary metabolism and improved resistance to European corn borer (*Ostrinia nubilalis*) in maize (*Zea mays* L.) transformed with wheat oxalate oxidase." *Journal of Agricultural and Food Chemistry* 55(7): 2582-2589.

An alteration in the secondary metabolism of maize (*Zea mays* L.) genetically modified with the wheat oxalate oxidase (OxO) gene was observed using HPLC and fluorescence microscopy. Phenolic concentrations in the OxO lines were significantly increased, but DIMBOA synthesis was reduced due to a diversion in the shikimate pathway leading to phenolic and hydroxamic acids. Ferulic acid exhibited the largest increase and accounted for 80.4% of the total soluble phenolics. Transcription of a 13-lipoxygenase gene, coding for a key enzyme involved in the regulation of secondary metabolism, was substantially higher in the OxO line than in the null line. To test whether the high levels of soluble phenolic acids, in particular ferulic acid, contributed to the insect resistance in the OxO maize, ferulic acid was administered in meridic diets to European corn borer (ECB). A significant negative correlation between ferulic acid concentration and ECB larval growth rate was found. Field testing during 2001 showed that OxO maize was more resistant to ECB, with leaf consumption and stalk-tunneling damage significantly reduced by 28-34 and 37-39%, respectively, on all of the OxO lines tested and confirming published 2000 findings.

Oztemiz, S. and S. Kornosor (2007). "The effects of different irrigation systems on the inundative release of *Trichogramma evanescens* westwood (Hymenoptera : trichogrammatidae) against *Ostrinia nubilalis* hubner (Lepidoptera : pyralidae) in the second crop maize." *Turkish Journal of Agriculture and Forestry* 31(1): 23-30.

This study was conducted to determine the effects of different irrigation systems on the inundative release of the egg parasitoid *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae) against *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae) in the second crop maize in the Cukurova region of Turkey in 1999 and 2000. *O. nubilalis*, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) and *T. evanescens* were reared in a climatic room under constant temperature of 25 +/- 1 degrees C, relative humidity of 65 +/- 10%, and an appropriate light regime (16:8 LD). *Trichogramma evanescens* was applied twice at a rate of 75,000 parasitoid ha(-1) at 10-day intervals at the beginning of the oviposition period of the third generation of *O. nubilalis* in the second crop maize. Irrigation was an important factor for the effectiveness of *T. evanescens* and significant differences between the 2 irrigation systems tested were observed. The efficiency of *T. evanescens* was higher under flood irrigation than sprinkler irrigation conditions. Egg parasitism was 81.0% and 84.3% with flood irrigation, and 66.3% and 69.2% with sprinkler irrigation in 1999 and 2000, respectively. The reduction rate of infested plants with *O. nubilalis* was 80.0% and 88.3% with flood irrigation, and 60.7% and 68.9% with sprinkler irrigation in 1999 and 2000, respectively. Yield increased approximately 1500-2000 kg ha(-1) under flood irrigation as compared to sprinkler irrigation.

Reardon, B. J. and T. W. Sappington (2007). "Effect of age and mating status on adult European corn borer (Lepidoptera : Crambidae) dispersal from small-grain aggregation plots." *Journal of Economic Entomology* 100(4): 1116-1123.

The European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), is often controlled with genetically modified corn, *Zea mays* L., hybrids (*Bacillus thuringiensis* [Bt] corn) in the United States. If Bt-resistant insects are detected in the field, mitigation-remediation tactics must be implemented to sustain the efficacy of insecticidal, transgenic corn. Mass releasing laboratory-reared, susceptible adults near aggregation sites to mate with locally emerging resistant adults is a possible remediation tactic, but it is imperative that the former remain in or near the release site long enough to mate. Understanding adult dispersal behavior relative to the timing of mating is important, because it directly affects patterns of gene flow and the rate at which Bt resistance moves through a population. Previous work shows that newly eclosed adults do not remain in proximity to their natal field. However, moth age, reproductive development, or mating status may influence the propensity to disperse. The objectives of this study were

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to determine the effect of adult age (0-3, 4-6, and 7-10 d old) and mating status on dispersal of adults released in small-grain aggregation plots. Less than 1% of the marked adults released in the aggregation plots remained after one night. More males than females were recovered. Age influenced dispersal, with mostly 4-6-d old adults being recovered. Conversely, mating status did not affect the number of adults recovered. Given the paucity of marked adult moths recovered near their release sites, mass releases of adults may not be a viable tactic to combat the spread of resistance to Bt corn.

Reardon, K. T., R. L. Hellmich, D. V. Sumerford, L. C. Lewis, B. J. Reardon and D. D. Calvin (2007). "Influence of plant severing on movement of *Ostrinia nubilalis* larvae in *Zea mays* hybrid seed production fields." *Journal of Economic Entomology* 100(4): 1129-1135.

Genetically engineered corn hybrids that contain a cry gene from the bacterium *Bacillus thuringiensis* Berliner (Bt) are gaining popularity for controlling the corn pest *Ostrinia nubilalis* (Hübner). Continuous use of Bt corn, however, could select for *O. nubilalis* that are resistant to this corn. Monitoring for insect resistance is important, because it could help maintain the Bt technology. A possible monitoring method is to collect larval insects in commercial drying bins after harvest from Bt seed production fields. A drawback to this method is that these collections may be contaminated by insects that moved as later instars from severed non-Bt male rows into the adjacent Bt female rows. These larvae have little to no exposure to Bt toxin, resulting in possible "false positives." The objectives of this study were to first find which combination of planting and severing dates produces the least number of larvae that move from non-Bt male plants to Bt female plants and to assess *O. nubilalis* larval movement from severed non-Bt male rows to Bt female rows. Field studies in 2002 and 2003 were designed to simulate a hybrid seed production field. Results suggest that movement of *O. nubilalis* larvae from male corn is minimized when corn is planted early and male plants are severed by 2 wk post-anthesis. This reduces the likelihood of false positives by reducing the number of susceptible larvae moving between Bt and non-Bt plants. Also, larvae moved to all four female rows that were adjacent to the severed rows, but there were significantly more larvae found in the closest row compared with the other three. These results could be used to develop a monitoring program to find *O. nubilalis* larvae with resistance to Bt corn in field populations of *O. nubilalis*.

Sass, M., M. Schorling, M. Gossmann and C. Buttner (2007). "Varieties and infestation of *Fusarium* spp. in Bt maize and conventional maize in the European corn borer infested area Oderbruch region (Germany)." *Gesunde Pflanzen* 59(3): 119-125.

The European corn borer (*Ostrinia nubilalis*) is one of the most important pests of maize (*Zea mays*). Injuries to the plants caused by the larvae of the European corn borer may represent entrance gates for fungal-spores. The cultivation of *Bacillus thuringiensis* maize (Bt-maize) is one possibility to reduce infestation by the European corn borer. The aim of the present project was to determine and to compare the number of species and the frequency of *Fusarium* spp. infestation in Bt-maize (cry1Ab) and conventional maize. In 2003, we analysed the *Fusarium* spp. infestation of samples of chaffed Bt-maize and its isogenic variety on two experimental fields in the Oderbruch region (Germany), an European corn borer infested area. The conventional variety on the first of the experimental fields (previous crop wheat and forking cultivation) showed a small infestation (16%) of *Ostrinia nubilalis* while in the conventional variety on the second field (previous crop maize and not forking cultivation) the infestation of the European corn borer was almost three times higher (47%). In the conventional variety on both of the experimental fields we found a high *Fusarium* spp. infestation (70%). Especially species of the section *Liseola* dominates, among them: *F. subglutinans*, *F. proliferatum* und *F. verticillioides*. The *Fusarium* infestation in the samples of Bt-maize from the field with previous crop wheat and forking cultivation was just as high as in the conventional variety (70%). The infestation of *Fusarium* spp. in the samples of Bt-maize from the field with previous crop maize and forking cultivation was more than 20% lower.

Stamps, W. T., T. V. Dailey and N. M. Gruenhagen (2007). "Infestation of European corn borer, *Ostrinia nubilalis*, in Midwestern USA fields with herbaceous borders." *Agriculture Ecosystems & Environment* 121(4): 430-434.

Three years (2000-2002) of field studies were conducted in mid-Missouri, USA, to assess the impact of various compositions of herbaceous field borders on populations of the European corn borer, *Ostrinia nubilalis*. Border treatments of: (1) a mixture of warm-season grasses and legumes, (2) a mixture of cool-season grasses and legumes, (3) tall fescue alone, and (4) a corn border control were planted around plots of field corn. Percent stalks infested with European corn borer and number and length of larval tunnels in stalks were analyzed. Warm-season vegetation-

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bordered corn had consistently lower percent stalks infested than corn bordered by cool-season vegetation, tall fescue or a corn control. The results indicate that the adoption of field border programs such as CP33 will have little or no impact on European corn borer management. (c) 2007 Elsevier B.V. All rights reserved.

Stanger, T. F. and J. G. Lauer (2007). "Corn stalk response to plant population and the Bt-European corn borer trait." *Agronomy Journal* 99(3): 657-664.

Current research indicates that plant populations should increase above the current Wisconsin recommendation of 74100 plants ha⁻¹ for higher corn (*Zea mays* L.) grain yields. However, stalk lodging is a major constraint to increasing plant populations. One option growers have is using Bt (*Bacillus thuringiensis*) hybrids, which are known to lodge less. A new method for assessing stalk lodging risk is needed. The objectives of this study were to (i) assess rind strength of corn hybrids with or without the Bt trait to increasing plant populations at natural levels of European Corn Borer [ECB, *Ostrinia nubilalis* (Hubner)], and (ii) determine the potential of rind strength measurements for predicting stalk lodging. In 2003 and 2004, rind penetrometer resistance (RPR) was used to measure rind strength for four Bt and five non-Bt hybrids with plant populations ranging from 64220 to 123500 plants ha⁻¹ at 10 locations in Wisconsin. Stalk lodging increased from 6 to 18% as plant population increased, and only at one location, Arlington, did Bt hybrids lodge significantly less (20 vs. 42%) than non-Bt hybrids. The RPR of both Bt and non-Bt hybrids decreased from 3.9 to 3.7 load-kg plant⁻¹ with increasing plant population. Plants with rind strength measurements < 3.9 load-kg plant⁻¹ taken at physiological maturity showed more lodging. Thus, such measurements appear to be a good indicator of stalk lodging potential in a high plant population situation. This new method has potential to help growers prepare for grain harvest by identifying fields with plants having average RPR below a 3.9 load-kg plant⁻¹ threshold, and adjusting harvest schedules of suspect fields earlier to avoid yield losses caused by stalk lodging. Further research using more hybrids across a range of environmental conditions and plant populations will be necessary to fully understand the importance of this tool and its potential importance in understanding and identifying high lodging potential environments.

Trnka, M., F. Muska, D. Semeradova, M. Dubrovsky, E. Kocmankova and Z. Zalud (2007). "European Corn Borer life stage model: Regional estimates of pest development and spatial distribution under present and future climate." *Ecological Modelling* 207(2-4): 61-84.

Predicting the potential distribution of agricultural pests, both indigenous and introduced, plays a key role in determining the impact of global change on agricultural, horticultural and forestry ecosystems. This study investigates changes in the climatic niche of one of the most important agricultural pests, the European Corn Borer (*Ostrinia nubilalis*, Hubner), using the multi-generational phenology model ECAMON. The model enables us to predict the development of the European Corn Borer (ECB), to estimate the risk of its establishing a permanent population, and to give an indication of climate-related stress factors affecting the species. The evaluation of ECAMON demonstrated that it provides accurate predictions of the onset and duration of the key phenological stages over a broad range of sites. It explains over 70% of the variation in the timing of key developmental stages based only on daily weather data. ECAMON simulations correctly predicted the presence/absence of the ECB over the study region during the 1961-1990 reference period. It also helped to explain the sudden increase in the maize infestation over the territory of the Czech Republic during the unusually warm period of 1991-2000. The ECAMON results demonstrated that the effect of climate will be significant and complex. According to our estimates, the extent of the climate niche will expand within the next 20-30 years to cover almost the entire area suitable for agriculture by 2040-2075. The establishment of a bivoltine population is not imminent within the next decade, but it is likely to take place during the period of 2025-2050. The timing and extent of these changes will be affected not only by changes in the means of key meteorological parameters, but also in their variability. These shifts will be clearly accompanied by an earlier onset of key developmental stages of the pest. The study demonstrated that the level of uncertainty caused both by emission scenarios and by differences in global circulation models (GCMs) are of the same order of magnitude. Thus, only the combination of a wide range of emission scenarios and GCMs can provide insight into the potential effect of climate change on any particular species. Under future climate conditions, grain maize is expected to partly replace traditional cereals (e.g. winter wheat, rye, etc.); thus the establishment of a national or international monitoring scheme is desirable, and an ECAMON-like tool might serve as the basic modeling platform for such an effort. (C) 2007 Elsevier B.V. All rights reserved.

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Tyutyunov, Y. V., E. A. Zhadanovskaya, R. Arditi and A. B. Medvinsky (2007). "Spatial model of development of resistance to transgenic insecticidal crop in a pest as applied to the European corn borer." *Biofizika* 52(1): 95-113.

A mathematical model of the development of resistance to transgenic Bt-crop in insect-pest populations as applied to the European corn borer has been constructed. The model represents a system of differential equations in special derivatives of the reaction-diffusion type. Local interactions of three competing pest genotypes formed by the allele of Bt-resistance and allele of susceptibility, are described by the same relations as in the Kostitsyn model, and the spread of insects is modelled as diffusion. The model was used to estimate the influence of the pest on the efficiency of the < < high dose-refuge > > strategy, which is intended for the suppression of development of Bt-resistance in pest populations. It was shown that formal integration of the Fisher-Haldane-Wright model and the diffusion term cannot adequately describe the development of Bt-resistance in a spatially heterogeneous pest population. A further development of the model is discussed.

Alves, A. P., T. A. Spencer, B. E. Tabashnik and B. D. Siegfried (2006). "Inheritance of resistance to the Cry1Ab *Bacillus thuringiensis* toxin in *Ostrinia nubilalis* (Lepidoptera : crambidae)." *Journal of Economic Entomology* 99(2): 494-501.

Laboratory selection with Cry1Ab, the predominant *Bacillus thuringiensis* (Bt) toxin in transgenic corn, *Zea mays* L., produced > 1000-fold resistance in two laboratory strains of European corn borer, *Ostrinia nubilalis* (Hübner). We tested the offspring of various crosses to determine the mode of inheritance of resistance to Cry1Ab. Patterns of inheritance of resistance were similar in the two resistant strains. The progeny of reciprocal F-1 crosses (resistant male X susceptible female and vice versa) responded alike in bioassays, indicating autosomal inheritance. The median lethal concentrations (LC50 values) of F-1 were intermediate between the resistant and susceptible parents, indicating approximately additive inheritance. However, the dominance of resistance increased as the concentration of Cry1Ab decreased. Analysis of progeny from backcrosses (F-1 X susceptible strain) suggests that resistance was controlled by more than one locus. In particular, the fit of observed to expected mortality improved as the number of putative loci increased from 1 to 10. The polygenic nature of resistance in these two laboratory strains suggests that major genes for resistance to Cry1Ab were not common in the founding populations of *O. nubilalis*. A low initial frequency of major genes for Cry1Ab resistance might be an important factor in delaying evolution of resistance to Bt corn in this pest.

Bengtsson, M., Z. Karpati, G. Szocs, H. Reuveny, Z. H. Yang and P. Witzgall (2006). "Flight tunnel responses of Z strain European corn borer females to corn and hemp plants." *Environmental Entomology* 35(5): 1238-1243.

European corn borer females *Ostrinia nubilalis* Hübner (Lepidoptera, Pyralidae) exhibited upwind flight to three main host plants, corn *Zea mays*, hemp *Cannabis sativa* and hop *Humulus lupulus*, in a laboratory wind tunnel. Within a 15-min experimental period, 22.9% to 24.3% mated females flew toward and landed on a single potted corn plant. A potted hemp plant attracted 25.7% females. In a choice test, significantly more females landed on a hemp plant than on an adjacent corn plant. In contrast, paprika *Capsicum annum* did not elicit attraction. Headspace collections from corn, hemp, and hop contained 18 compounds which consistently elicited a response from female antennae. Four of these, (Z)-3-hexenyl acetate, beta-caryophyllene, (E)-beta-farnesene, and (E,E)-alpha-farnesene co-occurred in three host plants studied. A 4-component blend of these compounds did not attract female moths in the wind tunnel. Availability of a wind tunnel bioassay is, however, a step toward the identification of plant volatiles guiding long-range attraction of gravid corn borer females.

Cardinal, A. J., M. Lee, W. D. Guthrie, J. Bing, D. F. Austin, L. R. Veldboom and M. L. Senior (2006). "Mapping of factors for resistance to leaf-blade feeding by European corn borer (*Ostrinia nubilalis*) in maize." *Maydica* 51(1): 93-102.

The European corn borer (ECB) *Ostrinia nubilalis* Hübner is an important pest of maize in the U.S. Breeding for resistance to leaf-feeding by ECB can be more efficient if the genetic basis for resistance is better understood. The objectives of this study were (i) to locate and characterize the genetic factors controlling resistance to leaf blade feeding by ECB larvae in temperate lines and (ii) to compare the locations of the quantitative trait loci (QTLs) detected in the F-2:3 and F-6:8 generations of the same maize population derived from the cross of inbred lines Mo17 and H99. One hundred and fifty F-2:3 lines and the parents and 185 F6:8 lines and the parents were grown in replicated trials in 1989 and 1995, respectively. Plots were infested with ECB larvae and visual leaf blade feeding ratings were obtained for each plot. Lines were genotyped with RFLP and SSR loci and a linkage map was developed. QTL analysis was performed

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with composite interval mapping. The heritability of family means was 0.77 in the F-2:3 generation and 0.91 in the F-6:8 generation. The QTLs explained around 50% of the phenotypic variance in both generations. Five QTL were detected in each generation. A QTL on linkage group 4 near *umc123* and a QTL on linkage group 7 near *umc110* were detected in both generations. Significant epistatic interactions among QTL were detected in both generations. Several loci that showed significant interactions did not have significant main effects, indicating that important epistatic interactions will be missed if only interactions between QTLs with significant main effects are tested. Marker-assisted selection will be most efficient when main effects and interaction effects of QTL are included in the selection criteria.

Coates, B. S., R. L. Hellmich and L. C. Lewis (2006). "Sequence variation in trypsin- and chymotrypsin-like cDNAs from the midgut of *Ostrinia nubilalis*: methods for allelic differentiation of candidate *Bacillus thuringiensis* resistance genes." *Insect Molecular Biology* 15(1): 13-24.

Midgut expressed alkaline serine proteases of *Lepidoptera* function in conversion of *Bacillus thuringiensis* (Bt) protoxin to active toxin, and reduced level of transcript T23 is associated with *Ostrinia nubilalis* resistance to Dipel(R) Bt formulations. Three groups of trypsin- (*OnT25*, *OnT23*, and *OnT3*) and two chymotrypsin-like (*OnC1* and *OnC2*) cDNAs were isolated from *O. nubilalis* midgut tissue. Intraspecific groupings are based on cDNA similarity and peptide phylogeny. Derived serine proteases showed a catalytic triad (His, Asp, and Ser; except transcript *OnT23a*), three substrate specificity-determining residues, and three paired disulphide bonds. RT-PCR indicated all transcripts are expressed in the midgut. Mendelian-inherited genomic markers for loci *OnT23*, *OnT3* and *OnC1* will be useful for association of alleles with bioassayed Bt toxin resistance phenotypes.

Dalecky, A., S. M. Bogdanowicz, E. B. Dopman, D. Bourguet and R. G. Harrison (2006). "Two multiplex sets of eight and five microsatellite markers for the European corn borer, *Ostrinia nubilalis* Hubner (*Lepidoptera* : *Crambidae*)." *Molecular Ecology Notes* 6(3): 945-947.

Primer sequence and polymorphism data are presented for 13 microsatellite loci isolated from the European corn borer moth, *Ostrinia nubilalis*, as part of a project to construct a linkage map for the two pheromone strains. Experimental conditions are described for polymerase chain reaction (PCR) multiplexing, which allows genotyping in two electrophoresis runs of eight and five markers each. In a sample of 27 individuals coming from one European locality, the number of alleles per locus ranged from one to 12, and gene diversity from 0 to 0.859. Seven loci showed a deficit of heterozygotes. Eleven loci cross-amplify in the related *Ostrinia furnacalis*.

Dalecky, A., S. Ponsard, R. I. Bailey, C. Pelissier and D. Bourguet (2006). "Resistance evolution to Bt crops: Predispersal mating of European corn borers." *Plos Biology* 4(6): 1048-1057.

Over the past decade, the high-dose refuge (HDR) strategy, aimed at delaying the evolution of pest resistance to *Bacillus thuringiensis* (Bt) toxins produced by transgenic crops, became mandatory in the United States and is being discussed for Europe. However, precopulatory dispersal and the mating rate between resident and immigrant individuals, two features influencing the efficiency of this strategy, have seldom been quantified in pests targeted by these toxins. We combined mark-recapture and biogeochemical marking over three breeding seasons to quantify these features directly in natural populations of *Ostrinia nubilalis*, a major lepidopteran corn pest. At the local scale, resident females mated regardless of males having dispersed beforehand or not, as assumed in the HDR strategy. Accordingly, 0-67% of resident females mating before dispersal did so with resident males, this percentage depending on the local proportion of resident males (0% to 67.2%). However, resident males rarely mated with immigrant females (which mostly arrived mated), the fraction of females mating before dispersal was variable and sometimes substantial (4.8% to 56.8%), and there was no evidence for male pre-mating dispersal being higher. Hence, *O.nubilalis* probably mates at a more restricted spatial scale than previously assumed, a feature that may decrease the efficiency of the HDR strategy under certain circumstances, depending for example on crop rotation practices.

Dekker, T., Z. Karpati and B. S. Hansson (2006). "Reversed innervation of pheromone specific antennal lobe neurons in the European corn borer (*Ostrinia nubilalis*)." *Chemical Senses* 31(8): E77-E77.

Domingue, M. J., W. L. Roelofs, C. E. Linn and T. C. Baker (2006). "Effects of egg-to-adult development time and adult age on olfactory neuron response to semiochemicals in European corn borers." *Journal of Insect Physiology* 52(9): 975-983.

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We used the cut-sensillum technique to assess the effect of both adult age and egg-to-adult development time on olfactory neuron responses of Z strain moths of the European corn borer, *Ostrinia nubilalis*. Compounds tested included the pheromone components, (Z)-11-tetradecenyl acetate and (E)-11-tetradecenyl acetate, the behavioral antagonist, (Z)-9-tetradecenyl acetate, and components of the *O. furnicalis* (Asian corn borer) sex pheromone, (Z)-12-tetradecenyl acetate and (E)-12-tetradecenyl acetate. The proportion of moths having neurons responding to the two *O. nubilalis* sex pheromone components and antagonist increased with longer development time and age. The spike frequency of neurons responding to (E)-11-tetradecenyl acetate and the antagonist increased with longer development time. Fourteen of 45 moths with neurons sensitive to either of the *O. nubilalis* pheromone components responded to (Z)-12-tetradecenyl acetate or (E)-12-tetradecenyl acetate. The likelihood of (Z)-12-tetradecenyl acetate stimulating a neuron similar in spike shape and waveform to that responding to (E)-11-tetradecenyl acetate increased with development time. (c) 2006 Elsevier Ltd. All rights reserved.

Gemeno, C., A. Sans, C. Lopez, R. Albajes and M. Eizaguirre (2006). "Pheromone antagonism in the European corn borer moth *Ostrinia nubilalis*." *Journal of Chemical Ecology* 32(5): 1071-1084.

Mixing the sex pheromones of the Mediterranean corn borer, *Sesamia nonagrioides*, and the European corn borer, *Ostrinia nubilalis*, results in significantly lower captures of *O. nubilalis* when compared to traps loaded with its pheromone alone. Rubber septa loaded with a constant concentration of the pheromone of *O. nubilalis* and different percentages of the *S. nonagrioides* pheromone (from 1 to 100%) causes dose-dependent antagonism in the field. Electroantennograms of *O. nubilalis* males showed high antennal responses to its own pheromone components, followed by smaller responses to the major, [(Z)-11-hexadecenyl acetate (Z11-16:Ac)], and two minor components [dodecyl acetate (12:Ac) and (Z)-11-hexadecenal (Z11-16:Ald)] of the *S. nonagrioides* pheromone. There was almost no response to the *S. nonagrioides* minor component (Z)-11-hexadecenol (Z11-16:OH). Field tests that used traps baited with the *O. nubilalis* pheromone plus individual components of *S. nonagrioides* showed that Z11-16:Ald causes the antagonism. Adding 1% Z11-16:Ald to the pheromone of *O. nubilalis* reduced oriented flight and pheromone source contact in the wind tunnel by 26% and 83%, respectively, and trap captures in the field by 90%. The other three pheromone components of *S. nonagrioides* inhibited pheromone source contact but not oriented flight of *O. nubilalis* males and did not inhibit capture in the field. Cross-adaptation electroantennogram suggests that Z11-16:Ald stimulates a different odor receptor neuron than the pheromone components of *O. nubilalis*. We conclude that Z11-16:Ald is a potent antagonist of the behavioral response of *O. nubilalis*.

Hoffmann, M. P., S. A. Pitcher, S. A. Cheever, J. Gardner, J. E. Losey, T. P. Kuhar, C. A. Laub and R. R. Youngman (2006). "Efficacy of inoculative releases of *Trichogramma ostrinae* (Hymenoptera : Trichogrammatidae) against European corn borer *Ostrinia nubilalis* (Lepidoptera : Crambidae) in field corn." *Biological Control* 36(3): 345-349.

We evaluated the egg parasitoid *Trichogramma ostrinae* (Hymenoptera: Trichogrammatidae) to control European corn borer [Lepidoptera: Crambidae: *Ostrinia nubilalis* (Hubner)] in field corn in 2001 and 2002. Inoculative releases of 75,000 *T. ostrinae*/ha occurred in New York and Virginia in 5-10 cornfields per state when corn was at mid-whorl. Incidence of egg mass parasitism, number of stalk tunnels, incidence of ear damage, and whole-plant yield were evaluated. Parasitism of European corn borer egg masses ranged from 0 to 75% in release plots and was greater in release plots than in control plots. Individual comparisons between paired release and control plots showed no reductions in either stalk or ear damage. However, when data were combined across both years and fields, stalk and ear damage were significantly reduced in New York. In Virginia, no significant differences were detected using data obtained from one year. There were no differences in yield between release and control plots. Low densities of European corn borer.. drought conditions in 1 year, and a larger plant canopy in field corn are possible reasons why *T. ostrinae* releases provided less control than has been observed in previous trials in sweet corn. Additional research focused on improved timing and frequency and number of releases is warranted. (c) 2005 Elsevier Inc. All rights reserved.

Huang, F. N., B. R. Leonard and R. H. Gable (2006). "Comparative susceptibility of European corn borer, southwestern corn borer, and sugarcane borer (Lepidoptera : Crambidae) to Cry1Ab protein in a commercial *Bacillus thuringiensis* corn hybrid." *Journal of Economic Entomology* 99(1): 194-202.

One field strain each of the European corn borer, *Ostrinia nubilalis* (Hubner); southwestern corn borer, *Diatraea grandiosella* Dyar; and sugarcane borer, *Diatraea saccharalis* (F.); were collected from cornfields in northeastern

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Louisiana. Susceptibilities of the field strain and a corresponding laboratory strain of the three borer species to Cry1Ab protein in DK69-70 *Bacillus thuringiensis* (Bt) corn hybrid were determined by exposing neonates to intact leaf tissues from whorl stage plants or by feeding neonates or third instars on a meridic diet treated with different concentrations of Cry1Ab protein extracted from Bt corn leaves. Mortality and growth of larvae were evaluated after 2 and 4 d posttreatment in the bioassays by using intact leaf tissues or after 7 d in the bioassays by using diet incorporating Cry1Ab protein. *D. saccharalis* was the least susceptible species to Cry1Ab protein among the three species, followed by *D. grandiosella*, whereas *O. nubilalis* was most susceptible. The 2-d mortality of *D. saccharalis* neonates on intact Bt leaf tissues was lower than that of *O. nubilalis* and *D. grandiosella*. All neonates of *O. nubilalis* were killed on the diet treated with Cry1Ab protein at 0.5 and 1 mg/kg. The mortality of *D. grandiosella* was > 75% at 1 mg/kg, but it was < 6% for *D. saccharalis* at 1 mg/kg. The LC50 values of *D. saccharalis* were 3- and 11-fold higher than those of *D. grandiosella* and *O. nubilalis*, respectively. The LC90 values of *D. saccharalis* were 8- and 32-fold higher than those of *D. grandiosella* and *O. nubilalis*, respectively. Larval growth of the three species on Cry1Ab-treated diet was inhibited, but the inhibition was greater for *O. nubilalis* and *D. grandiosella* than for *D. saccharalis*. The lower susceptibility of *D. saccharalis* to Cry1Ab protein suggests that it is necessary to verify if a high-dose Bt corn for *O. nubilalis* and *D. grandiosella* is also a high dose for *D. saccharalis*.

Keszthelyi, S., L. Nowinszky and J. Puskas (2006). "Spreading examination of European corn borer (*Ostrinia nubilalis* Hbn.) flight types in the background of Peczey's climate districts." *Cereal Research Communications* 34(4): 1283-1290.

European corn borer (ECB) flight and ecotype spread examinations were made in Hungary with the help of catching results of 44 agricultural Jermy light traps (2004). We wondered about alteration of flight types spread borderline as a function of global climate change. Catching data were evaluated by simple mathematical proportional numbers. Catching results originating from different points of the country were compared with Walter-Lieth climate diagram (2004) and Peczey's Hungarian climate districts. Latter was to reveal correlations of flight types and different climatic districts. The previously published flight alteration tendency of ECB (Keszthelyi 2003, 2004b) continued in 2004. Generation quotients proved this process too. Average generation quotient of populations in South-eastern Hungary was 6, and the top of the same rate in this district was 10,84. The earlier observed „one peak flight" type was replaced by „two peaks flight" type in North-western Hungary (average generation quotient of this district: 2,5). The IRIN (relative individual number per one day) shows regressive tendency from South-eastern Hungary to North-western Hungary (1RIN of 1.district: 6,99; 1RIN of 4.district: 4,69; 1RIN of 10.district: 2,78), but unequivocal conclusions cannot be drawn from these values for places of ecotypes. There is no unambiguous connection between Peczey's Hungarian climate districts and spread of ECB flight types as proved by the statistical examinations.

Leonardi, M. G., S. Caccia, J. Gonzalez-Cabrera, J. Ferre and B. Giordana (2006). "Leucine transport is affected by *Bacillus thuringiensis* Cry1 toxins in brush border membrane vesicles from *Ostrinia nubilalis* Hb (Lepidoptera : Pyralidae) and *Sesamia nonagrioides* Lefebvre (Lepidoptera : Noctuidae) midgut." *Journal of Membrane Biology* 214(3): 157-164.

The pore-forming activity of Cry1Ab, Cry1Fa and Cry1Ca toxins and their interaction with leucine transport mediated by the K⁺/leucine cotransporter were studied in brush border membrane vesicles (BBMVs) isolated from the midgut of *Ostrinia nubilalis* and *Sesamia nonagrioides*. In both species, as in other Lepidoptera, leucine uptake by BBMVs can take place in the absence of cations, but it can also be driven by a K⁺ gradient. Experiments with the voltage-sensitive fluorescent dye 3,3'-diethylthiobarbiturate iodide proved that Cry1Ab, a *Bacillus thuringiensis* toxin active in vivo, enhanced the membrane permeability to potassium in *O. nubilalis* BBMVs. This result is in agreement with similar effects observed in *S. nonagrioides* BBMV incubated with various Cry1 toxins active in vivo. The effect of the above toxins was tested on the initial rate of 0.1 mM leucine influx. Instead of an increase in leucine influx, a reduction was observed with the Cry1 toxins active in vivo. Cry1Ab and Cry1Fa, but not the inactive toxin Cry1Da, inhibited in a dose-dependent manner leucine uptake both in the absence and in the presence of a K⁺ gradient, a clear indication that their effect is independent of the channel formed by the toxins and that this effect is exerted directly on the amino acid transport system.

Lewis, L. C., D. V. Sumerford, L. A. Bing and R. D. Gunnarson (2006). "Dynamics of *Nosema pyrausta* in natural populations of the European corn borer, *Ostrinia nubilalis*: A six-year study." *Biocontrol* 51(5): 627-642.

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Nosema pyrausta (Paillot) (Microsporidia: Nosematidae) is an obligatory intracellular parasite of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae). This pathogen is maintained in natural populations of *O. nubilalis* by both horizontal and vertical transmission. The impact of *N. pyrausta* on fecundity of adults and survival of larvae has been well documented in laboratory and field research. In an extensive study covering a 6 year period at one site, we described the effect of *N. pyrausta* within *O. nubilalis* populations in a continuous corn following corn ecosystem. We documented the presence of the pathogen through all life stages of *O. nubilalis* (egg, larva, pupa, adult), by collecting throughout the crop season and examining each insect stage in the laboratory for the frequency of infection with *N. pyrausta*. The percentage of infection with *N. pyrausta* and magnitude of the *O. nubilalis* population fluctuated throughout generation 1 and generation 2. Both horizontal and vertical transmission played a role in maintaining *N. pyrausta* in the population in both generations. There were strong correlations between percentage adults with *N. pyrausta* and percentage larvae with *N. pyrausta*, and between percentage eggs with *N. pyrausta* and percentage larvae with *N. pyrausta*. There was a weak correlation between percentage adults with *N. pyrausta* and percentage eggs with *N. pyrausta*. The percentage of insects infected with *N. pyrausta* was always lowest in the egg.

Marion-Poll, F. (2006). "Habituation to ecdysone in their diet in *Ostrinia nubilalis* larvae." *Chemical Senses* 31(8): E84-E84.

Musser, F. R., J. P. Nyrop and A. M. Shelton (2006). "Integrating biological and chemical controls in decision making: European corn borer (Lepidoptera : Crambidae) control in sweet corn as an example." *Journal of Economic Entomology* 99(5): 1538-1549.

As growers switch to transgenic crops and selective insecticides that are less toxic to natural enemies, natural enemies can become more important in agricultural pest management. Current decision-making guides are generally based on pest abundance and do not address pest and natural enemy toxicity differences among insecticides or the impact of natural enemies on pest survival. A refined approach to making pest management decisions is to include the impact of natural enemies and insecticides, thereby better integrating biological and chemical control. The result of this integration is a dynamic threshold that varies for each product and the level of biological control expected. To demonstrate the significance of conserved biological control in commercial production, a decision-making guide was developed that evaluates control options for European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), in sweet corn, *Zea mays* L., where the primary natural enemies are generalist predators. Management options are lambda-cyhalothrin (broad-spectrum insecticide), spinosad (selective insecticide), *Trichogramma ostrinae* (Peng & Chen) (Hymenoptera: Trichogrammatidae) (parasitoid), and *Bacillus thuringiensis* (Bt) sweet corn (transgenic variety). The key factors influencing thresholds for all treatments are the intended market, predator populations, and the presence of alternative foods for the predators. Treatment cost is the primary factor separating the threshold for each treatment within a common scenario, with the lowest cost treatment having the lowest pest threshold. However, when the impact of a treatment on natural enemies is projected over the 3-wk control period, the impact of the treatment on predators becomes the key factor in determining the threshold, so the lowest thresholds are for broad-spectrum treatments, whereas selective products can have thresholds > 6 times higher by the third week. This decision guide can serve as a framework to help focus future integrated pest management research and to aid in the selection of pest management tools.

Onstad, D. W. and L. L. Buschman (2006). "Evaluation of oviposition deterrence in management of resistance to transgenic corn by European corn borer (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 99(6): 2100-2109.

We modified an existing model for European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), population dynamics and genetics to evaluate the effectiveness of oviposition deterrence in transgenic fields for resistance management. We simulated two types of deterrence: one type has females reducing their oviposition because of lost opportunities to lay eggs (eggs lost), and the other type has the deterred females moving to the refuge to lay eggs. Oviposition deterrence was clearly effective in extending the time to resistance to transgenic corn (R allele) in the European corn borer, particularly when 80% or more of the eggs were deterred from being oviposited on the transgenic plants. With 90% of eggs deterred, the time required to reach 50% R-allele frequency increases 3.7- to 5.5-fold compared with the no-deterrence scenario. The time to 50% R-allele frequency was similar for the two types of simulated deterrence, but the densities of the European corn borer were 100-fold higher when the deterred females oviposited in the refuge. The Y allele for insensitivity or resistance to deterrence never reached 50% within the 50-yr time line for these simulations except when the R allele was dominant and the Y allele was not recessive. The time to 50% Y-allele frequency was 33 and 26 yr when the Y allele was additive or dominant, respectively, when 50% of the

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eggs were deterred, but the time decreased to 18 and 16 yr when 90% of the eggs were deterred. The effectiveness of oviposition deterrence on time to resistance to transgenic insecticidal plants was not changed much when we altered our assumptions about behavior in a sensitivity analysis.

Pelozuelo, L. and B. Frerot (2006). "Behaviour of male European corn borer, *Ostrinia nubilalis* Hubner (Lep.: Crambidae) towards pheromone-baited delta traps, bucket traps and wire mesh cone traps." *Journal of Applied Entomology* 130(4): 230-237.

Pheromone-baited traps are used to monitor the flight of European corn borer (ECB; *Ostrinia nubilalis*). Traps of various designs are available: bucket traps, delta sticky traps and wire mesh cone traps. However, these traps are not all equally efficient and little is known about the reasons for this difference in efficiency. We investigated the behaviour of ECB males towards bucket traps and delta traps by means of observation in a wind tunnel. We also carried out observations and capture trials with delta traps and wire mesh cone traps in field conditions. Our laboratory studies showed that ECB males were not optimally attracted and were poorly captured by a pheromone baited bucket trap. Furthermore, they were shown to readily enter delta traps in the wind tunnel but were caught after more than three passages through this trap. Field studies showed that wire mesh cone traps captured approximately six times more ECB males than delta traps. Observation of the behaviour of ECB males showed that this difference was due to more efficient moth capture rather than greater attraction of the moth. In total, 31.5% of the 219 males observed close to wire mesh cone traps were caught, vs. 2.5% of the 520 males observed close to delta traps. This greater efficiency is due to a better capture rate of the attracted males by wire mesh cone traps than by delta traps.

Prasifka, J. R., D. V. Sumerford, R. L. Hellmich, L. C. Lewis and D. D. Calvin (2006). "Sampling European corn borer (Lepidoptera : Crambidae) larvae from seed corn drying bins for Bt resistance monitoring." *Southwestern Entomologist* 31(4): 269-279.

Monitoring for resistance to *Bacillus thuringiensis* Berliner (Bt) toxins in transgenic crops is challenging, in part because alleles conferring resistance appear to be rare. Consequently, several complementary methods are used to identify, collect and test putatively resistant individuals. A series of experiments conducted at commercial seed production facilities explored an alternative sampling method. Larvae of the European corn borer, *Ostrinia nubilalis* Hubner, were collected from bins containing Bt hybrid seed corn and their inbred progeny (both F-2 and backcross-F-2 larvae) were tested for resistance to the Bt toxin Cry1Ab. Marked, laboratory-reared *O. nubilalis* larvae also were placed beneath drying corn ears to evaluate potential contamination of samples by larvae developing on non-Bt corn. Both feral and laboratory-reared larvae were used to examine the causes and levels of mortality of larvae in drying bins. Screening of larvae on diet containing Cry1Ab failed to provide evidence of resistance, although insufficient inbred lines survived to make conclusions about the presence of resistance alleles in larvae originally collected beneath Bt corn. Both larvae from previously dried non-Bt corn and *O. nubilalis* moving between adjacent bins are potential sources of contamination of larvae collected beneath drying Bt corn. Exposure to conditions inside seed corn drying bins for 3 d significantly increased *O. nubilalis* mortality. Larvae collected beneath seed corn also showed infection by the pathogens *Nosema pyrausta* (Paillot) and *Beauveria bassiana* (Balsamo) Vuillemin, with significant mortality apparently caused by *B. bassiana*. While contamination and mortality may limit the application of sampling beneath drying bins, several modifications could improve the potential utility of the technique.

Reardon, B. J., D. V. Sumerford and T. W. Sappington (2006). "Impact of trap design, windbreaks, and weather on captures of European corn borer (Lepidoptera : Crambidae) in pheromone-baited traps." *Journal of Economic Entomology* 99(6): 2002-2009.

Pheromone-baited traps are often used in ecological studies of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae). However, differences in trap captures may be confounded by trap design, trap location relative to a windbreak, and changes in local weather. The objectives of this experiment were, first, to examine differences in *O. nubilalis* adult (moth) captures among the Intercept wing trap, the Intercept bucket/funnel UNI trap, and the Hartstack wire-mesh, 75-cm-diameter cone trap (large metal cone trap) as well as among three cone trap designs. Second, we examined the influence of the location of the large metal cone trap relative to a windbreak on the number of moths captured. Third, we examined the relationship between nightly mean air temperature, relative humidity, wind speed, precipitation, and the number of moths captured in large metal cone traps. The number of moths captured was significantly influenced by trap design, with large metal cone traps capturing the most moths. Wing and bucket traps were ineffective. Differences among trap captures were significant among trap locations relative to a windbreak. Under strong (> 14 kph) or moderate (7 < 14 kph) wind speeds, traps located leeward of the windbreak

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captured the most moths, but when wind speeds were light (< 7 kph), traps not associated with windbreaks captured the most moths. The multiple regression model fitted to the relationship between number of moths captured per Julian date and nightly weather patterns was significant. Nightly mean air temperature was the most influential parameter in the model, and its relationship with moth capture was positive.

Reardon, B. J., D. V. Sumerford and T. W. Sappington (2006). "Dispersal of newly eclosed European corn borer adults (Lepidoptera : Crambidae) from corn into small-grain aggregation plots." *Journal of Economic Entomology* 99(5): 1641-1650.

Genetically modified, insecticidal *Bacillus thuringiensis* (Bt) corn, *Zea mays* L., hybrids are used throughout the Corn Belt for European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), control. To slow development of Bt corn resistance, the Environmental Protection Agency requires growers to plant a refuge. Determining the appropriate distance between a refuge and Bt corn, and development of mitigation-remediation strategies such as mass releases of susceptible moths, requires an understanding of adult dispersal and mating behavior. However, much remains unknown about these behaviors. Because mating often occurs in grass near cornfields where adult *O. nubilalis* aggregate, we planted small-grain plots as aggregation sites in an attempt to retain mass-released adults. The objectives of this study were to examine influences of pheromone lure, plant density, and plant species on distributions of feral and newly emerged, laboratory-reared *O. nubilalis* among small-grain aggregation plots. Feral adults were collected in aggregation plots in relative abundance, indicating that small-grain plots were acceptable aggregation sites. In contrast, newly emerged adults that were released weekly as dye-marked pupae were rarely found in aggregation plots, with approximate to 150 -1,500-fold fewer adults captured than expected if all released adults had occupied the plots for ≥ 1 d. The majority of newly emerged adults did not colonize the aggregation plots, suggesting that recently eclosed adults leave their natal field and do not colonize the first aggregation sites encountered. Plant species significantly influenced adult distributions among aggregation plots. Mass releases of laboratory-reared pupae in the field may not be a viable remediation tactic because almost all of the newly emerged adults dispersed beyond 300 m of the release point.

Saeglitz, C., D. Bartsch, S. Eber, A. Gathmann, K. U. Priesnitz and I. Schuphan (2006). "Monitoring the Cry1Ab susceptibility of European corn borer in Germany." *Journal of Economic Entomology* 99(5): 1768-1773.

The European corn borer, *Ostrinia nubilalis* (Hubner), is one of the most important insect pests in corn, *Zea mays* L. Transgenic corn cultivars expressing *Bacillus thuringiensis* (Bt) toxin provide a promising crop protection strategy against European corn borer; however, management is needed to avoid resistance development of the target pest species. The aim of this work was to establish the baseline susceptibility of different European corn borer populations in Germany to be able to forecast a possible development of resistance at an early stage. To standardize test procedures for future resistance management, the efficiency of Cry1Ab toxins from different suppliers and different production was assessed. Furthermore, two different test methods, surface treatment and the incorporation method, were compared with regard to their practicability and efficiency. Neither method provided significant differences in the baseline susceptibility of populations from different German regions. Overall, the data suggested little differentiation among German populations in terms of their susceptibility to Bt toxin and their genetic background. Future monitoring could therefore use a single European corn borer population as a representative for southwestern Germany. However, toxins from different suppliers and different production batches produced a vast range of LC50 values. Changes because of different toxin batches may be mistaken as a change in baseline susceptibility or even as the start of a resistance development. Thus, it is important throughout insect resistance management that the same toxin batches will be available for baseline susceptibility bioassays and for future tests.

Siqueira, H. A. A., J. Gonzalez-Cabrera, J. Ferre, R. Flannagan and B. D. Siegfried (2006). "Analyses of Cry1Ab binding in resistant and susceptible strains of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera : Crambidae)." *Applied and Environmental Microbiology* 72(8): 5318-5324.

Cry1Ab toxin analysis was performed to determine whether resistance in laboratory-selected *Ostrinia nubilalis* strains is associated with target site alteration. Brush border membrane vesicles were prepared using dissected midguts from late instars of susceptible and resistant strains (Europe-R and RSTT) of *O. nubilalis*. Immunoblot analysis indicated that three different proteins bound to Cry1Ab toxin and were recognized by an anticadherin serum. In a comparison of resistant and susceptible strains, reduced Cry1Ab binding was apparent for all three bands corresponding to cadherin-

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like proteins in the Europe-R strain, while reduced binding was apparent in only one band for the RSTT strain. Real-time analysis of Cry1Ab binding to gut receptors using surface plasmon resonance suggested slight differences in affinity in both resistant strains. Additional binding analysis was conducted using I-125-labeled Cry1Ab, Cry1Ac, and Cry1Ac. Slight differences were again observed between the resistant and susceptible strains for Cry1Ab binding. However, when binding of I-125-labeled Cry1Aa was tested, a 10-fold reduction in the concentration of binding sites was observed in the Europe-R strain. Expression of the *O. nubilalis* cadherin gene was similar in both the resistant and susceptible strains and did not account for differences in binding. In combination, the results of the present work suggest that differences in susceptibility to CryIA toxins in the Europe-R strain of *O. nubilalis* are associated with altered receptor binding, although the precise nature of this mechanism is still uncertain.

Stodola, T. J., D. A. Andow, A. R. Hyden, J. L. Hinton, J. J. Roark, L. L. Buschman, P. Porter and G. B. Cronholm (2006). "Frequency of resistance to *Bacillus thuringiensis* toxin Cry1Ab in southern United States corn belt population of European corn borer (*Lepidoptera* : *Crambidae*)." *Journal of Economic Entomology* 99(2): 502-507.

The high-dose refuge resistance management strategy is the main approach used to delay resistance in targeted pests to *Bacillus thuringiensis* (Bt) toxins in transgenic crops. We used an F-2 screen to test a critical assumption of the high-dose refuge strategy, which is that resistance allele (R) frequencies are initially rare ($< 10^{-3}$) in *Ostrinia nubilalis* (Hubner) (*Lepidoptera*: *Crambidae*) from the southern Corn Belt. We expanded the methodological scope of the F₂ screen so that both males and females may be used to initiate a screen and determined how the results from both sexes may be combined. In total, 62 female and 131 male *O. nubilalis* lines from Kansas and 39 female and four male lines from Texas were screened. No major resistance alleles were found and estimated R frequency for the southern Corn Belt was updated to between 0 and 0.0044 with 95% credibility. The experiment-wise detection probability was 98.7%. These results suggest the frequency of resistance alleles is low enough that the high-dose refuge resistance management strategy may be effective for delaying resistance evolution in *O. nubilalis* to Bt corn in the southern Corn Belt.

Tate, C. D., R. L. Hellmich and L. C. Lewis (2006). "Evaluation of *Ostrinia nubilalis* (*Lepidoptera* : *Crambidae*) neonate preferences for corn and weeds in corn." *Journal of Economic Entomology* 99(6): 1987-1993.

Choice tests were conducted to determine feeding preferences of European corn borer, *Ostrinia nubilalis* (Hubner) (*Lepidoptera*: *Crambidae*), neonates for 15 species of plants. Percentage of neonates accepting (found on) each leaf disc after 24 h was measured using choice tests. Initially, nine species of plants were evaluated. The following year, 10 plant species were evaluated during *O. nubilalis* first generation and 11 species during the second generation. Pennsylvania smartweed, *Polygonum pennsylvanicum* (L.), had the highest percentage of neonates accepting leaf discs in both years. Other plants with high acceptance rates included swamp smartweed, *Polygonum amphibium* L.; velvetleaf, *Abutilon theophrasti* Medicus; cocklebur, *Xanthium strumarium* L.; and yellow foxtail, *Setaria glauca* (L.). Corn, *Zea mays* L., consistently had low percentages of neonates accepting leaf discs along with common waterhemp, *Amaranthus rudis* Sauer. Implications these results may have on *O. nubilalis* host plant selection in central Iowa's corn dominated landscape are considered.

Agusti, N., D. Bourguet, T. Spataro, M. Delos, N. Eychenne, L. Folcher and R. Arditi (2005). "Detection, identification and geographical distribution of European corn borer larval parasitoids using molecular markers." *Molecular Ecology* 14(10): 3267-3274.

Biological control requires specific tools for the accurate detection and identification of natural enemies, and to detect unusual variations in their density, which may follow changes in agricultural practices. Here we have developed specific molecular markers to detect *Lydella thompsoni* (Herting) and *Pseudoperichaeta nigrolineata* (Walker) (*Diptera*: *Tachinidae*) within the European corn borer, *Ostrinia nubilalis* (Hubner) (*Lepidoptera*: *Crambidae*). Primers amplifying fragments of the mitochondrial COI gene were designed following alignment of comparable sequences for a range of parasitoid and host species. Each of the primer pairs proved to be species specific to a tachinid species, amplifying DNA fragments of 191 and 91 bp in length for *L. thompsoni* and *P. nigrolineata*, respectively. This DNA-based technique allowed molecular evaluation of parasitism in *O. nubilalis* natural populations. In order to study the geographical distribution of both species in France, *O. nubilalis* diapausing larvae in maize stalks were collected from 12 locations over the whole country. The molecular evaluation of parasitism was compared with the traditional method of

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maintaining *O. nubilalis* populations in controlled conditions before breaking off the diapause. The percentage parasitism found in both species of tachinids was higher - approximately three times - using the molecular method, suggesting an underestimation by the traditional rearing protocol. Tachinid parasitism on *O. nubilalis* was not significantly different between geographical areas (south, central and north France) for both species. This study shows that molecular methods are very promising for the correct detection and identification of tachinid parasitoids in natural field populations.

Alma, A., F. Lessio, A. Reyneri and M. Blandino (2005). "Relationships between *Ostrinia nubilalis* (Lepidoptera : Crambidae) feeding activity, crop technique and mycotoxin contamination of corn kernel in northwestern Italy." *International Journal of Pest Management* 51(3): 165-173.

The relationships between the feeding activity of *Ostrinia nubilalis* (Hubner), crop technique (i.e., planting date, nitrogen fertilization, irrigation, and use of deltamethrin), and mycotoxin contamination of kernels were studied in Italian corn crop systems. Field sampling was conducted to determine the incidence of first- and second-generation larvae for each crop technique. At harvest, kernel contamination by fumonisins and zearalenon was measured and related to the number and position of tunnels on corn ears. The number of corn plants injured from second-generation larvae was partially reduced by using deltamethrin (-35%) and by bringing forward planting (-12%), whereas differences in nitrogen and water supply had little effect. The abundance of the first generation was, on average, low. The amount of fumonisin was generally one scale point higher in injured ears, and was positively related to ear tunnelling: tunnels in the apex seem to increase the amount of contamination. No links were detected between *O. nubilalis* presence and zearalenon contamination.

Bethenod, M. T., Y. Thomas, F. Rousset, B. Frerot, L. Pelozuelo, G. Genestier and D. Bourguet (2005). "Genetic isolation between two sympatric host plant races of the European corn borer, *Ostrinia nubilalis* Hubner. II: assortative mating and host-plant preferences for oviposition." *Heredity* 94(2): 264-270.

The European corn borer, *Ostrinia nubilalis* Hubner, colonized maize (*Zea mays* L.) after its introduction into Europe about 500 years ago and is now considered one of the main pests of this crop. In northern France, two sympatric host races have been described: one feeding on maize and the other on mugwort (*Artemisia vulgaris* L.) and hop (*Humulus lupulus* L.). In a previous study, we showed that mating between the two races may be impeded by differences in the timing of moth emergence and in the composition of the sex pheromone produced by the females. In this study, we further investigated the genetic isolation of these two races using strains from the maize (Z strain) and mugwort (E strain) races selected for diagnostic alleles at two allozyme loci. In a cage containing maize and mugwort plants and located in natural conditions, mating between individuals of the same strain occurred more often than mating between males and females of the E and Z strains. In particular, we obtained no evidence for crosses between Z females and E males. We also found that females of the Z strain laid their eggs almost exclusively on maize, whereas females of the E strain laid their eggs preferentially, but not exclusively, on mugwort. These results suggest that the genetic differentiation between the two host races may also be favored by host-plant preference, one of the first steps toward sympatric speciation.

Coates, B. S., R. L. Hellmich and L. C. Lewis (2005). "Two differentially expressed ommochrome-binding protein-like genes (obp1 and obp2) in larval fat body of the European corn borer, *Ostrinia nubilalis*." *Journal of Insect Science* 5.

Ommochrome-binding proteins function in coloration and detoxification pathways by transporting tryptophan metabolites, and increase in hemolymph concentration prior to diapause. Two ommochrome-binding protein genes from the European corn borer *Ostrinia nubilalis* (Hubner) (Onobp1 and Onobp2; GenBank accession nos. AY819651 to AY819655 and AY862870) were isolated. Relatedness to OBP-encoding genes was suggested by peptide similarity, phylogenetic reconstruction, and expression data. 21 single nucleotide polymorphisms between obp1 and 23 polymorphisms between obp2 alleles were identified, and resultant genomic markers were inherited in a Mendelian fashion. RT-PCR showed fat body specific Onobp1 and Onobp2 transcription. The Onobp1 transcript was RT-PCR amplified from fat body of 5(th) instars, whereas Onobp2 was expressed in fat body of 4(th) and 5(th) instars, and peaked in 5(th) instar wandering and 1 week old diapausing larvae. Expression suggests gene duplicates are maintained by change in temporal expression. The significance of Onobp1 and 2 gene products to *O. nubilalis* diapause physiology requires additional investigation.

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Coates, B. S., R. L. Hellmich and L. C. Lewis (2005). "Polymorphic CA/GT and GA/CT microsatellite loci for *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Molecular Ecology Notes* 5(1): 10-12.

Ten polymorphic dinucleotide (CA/GT and GA/CT) microsatellite loci suitable for population genetic screening were characterized from enriched partial *Ostrinia nubilalis* genomic libraries. Sequence from 126 enriched small insert genomic library clones identified 25 CA/GT and 58 GA/CT loci that were unique. Perfect repeats tended to be short ($n = 10-12$). Ten microsatellites, PCR amplified from a Crawfordsville Iowa population showed a mean of 10 alleles per locus (range six to 20), and six of 10 loci showed heterozygote deficiency. Amplification of eight loci was observed in the sister species *O. furnicalis*.

Coates, B. S., D. V. Sumerford, R. L. Hellmich and L. C. Lewis (2005). "Sequence variation in the cadherin gene of *Ostrinia nubilalis*: a tool for field monitoring." *Insect Biochemistry and Molecular Biology* 35(2): 129-139.

Toxin-binding proteins of insect midgut epithelial cells are associated with insect resistance to *Bacillus thuringiensis* (Bt) Cry toxins. A 5378 nt cDNA encoding a 1717 amino acid putative midgut cadherin-like glycoprotein and candidate CryIAb toxin-binding protein was characterized from *Ostrinia nubilalis*. Intraspecific alignment of partial *O. nubilalis* cadherin gene sequences identified variance within proposed CryIA toxin binding region 2 (TBR2), (1328)IPLQTSILVVT[I/V] N-1340, and flanking CryIA toxin binding region 1 (TBR1). (DIEIEIDTNN871)-D-861. DNA sequence and PCR-RFLP detected single nucleotide polymorphism between cadherin alleles. and pedigree analysis demonstrated Mendelian inheritance. A population sample from Mead, Nebraska showed allelic polymorphism. These assays may be useful for linkage mapping and field surveillance of wild Populations and of *O. nubilalis*. Published by Elsevier Ltd.

Dillehay, B. L., D. D. Calvin, G. W. Roth, J. A. Hyde, G. A. Kuldau, R. J. Kratochvil, J. M. Russo and D. G. Voight (2005). "Verification of a European corn borer (Lepidoptera : Crambidae) loss equation in the major corn production region of the northeastern United States." *Journal of Economic Entomology* 98(1): 103-112.

Field studies in Pennsylvania and Maryland were conducted during 2000, 2001, and 2002 to test the applicability of published yield loss relationships developed in central Pennsylvania for European corn borer, *Ostrinia nubilalis* (Hubner), management in warmer, longer season corn, *Zea mays* L., grain production regions of the northeastern United States. Both isoline hybrids and non-Bt lead hybrids were compared against *Bacillus thuringiensis* (Bt) hybrids to measure effects of the pest on yield. The European corn borer economic analysis model was used to make site-specific predictions of loss per European corn borer larva for comparison with measured yield loss per larva. Although the model did not predict loss per larva at a field level, it did predict loss at a regional level. The model predicted an overall percentage of yield loss per larva of 2.69 +/- 0.12% over the region, which was similar to the measured yield loss per larva of 2.66 +/- 0.59% for isoline hybrids and 3.08 +/- 0.51% for lead hybrids. The model, on average, provided a good prediction of percentage of yield loss per larva within the climatic zones of 1100-1700 degree-days (DD) (base threshold 12.5 degreesC). Our results suggest that the yield loss relationship developed in Central Pennsylvania, when matched to the timing of third instar second generation European corn borer stalk tunneling is adequate for major corn grain production zones of the northeast United States.

Dopman, E. B., L. Perez, S. M. Bogdanowicz and R. G. Harrison (2005). "Consequences of reproductive barriers for genealogical discordance in the European corn borer." *Proceedings of the National Academy of Sciences of the United States of America* 102(41): 14706-14711.

Speciation involves the origin of trait differences that limit or prevent gene exchange and ultimately results in daughter populations that form monophyletic or exclusive genetic groups. However, for recently diverged populations or species between which reproductive isolation is often incomplete, gene genealogies will be discordant, and most regions of the genome will display nonexclusive genealogical patterns. In these situations, genome regions for which one or both species are exclusive groups may mark the footprint of recent selective sweeps. Alternatively, such regions may include or be closely linked to "speciation genes," genes involved in reproductive isolation. Therefore, comparisons of gene genealogies allow inferences about the genetic architectures of both reproductive isolation and adaptation. Contrasting genealogical relationships in sexually isolated pheromone strains of the European corn borer moth (*Ostrinia nubilalis*) demonstrate the relevance of this approach. Genealogies for five gene regions are discordant, and only one molecular

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marker, the sex-linked gene *Tpi*, has evidence for pheromone strain exclusivity. *Tpi* maps to a position on the sex chromosome that is indistinguishable from a major factor (*Pdd*) affecting differences in postdiapause development time. The major factor (*Resp*) determining male behavioral response to pheromone is also sex-linked, but maps 20-30 cM away. Exclusivity at *Tpi* may be a consequence of these linkage relationships because evidence from phenotypic variation in natural populations implicates both *Pdd* and *Resp* as candidates for genes involved in recent sweeps and/or reproductive isolation between strains.

Flannagan, R. D., C. G. Yu, J. P. Mathis, T. E. Meyer, X. M. Shi, H. A. A. Siqueira and B. D. Siegfried (2005). "Identification, cloning and expression of a Cry1Ab cadherin receptor from European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera : Crambidae)." *Insect Biochemistry and Molecular Biology* 35(1): 33-40.

Transgenic corn expressing the Cry1Ab toxin from *Bacillus thuringiensis* is highly toxic to European corn borer, *Ostrinia nubilalis*, larvae. A putative Cry1Ab receptor (*OnBt-R-1*) molecule was cloned and sequenced from a cDNA library prepared from midgut tissue of *O. nubilalis* larvae. The 5.6 Kb gene is homologous with a number of cadherin genes identified as Cry1 binding proteins in other lepidopterans. Brush border membrane vesicles were prepared using dissected midguts from late instars. A 220-kDa protein was identified as a cadherin-like molecule, which bound to Cry1Ab toxin and cross-reacted with an anti-cadherin serum developed from recombinant expression of a partial *O. nubilalis* cadherin peptide. Two additional proteins of smaller size cross-reacted with the anti-cadherin serum indicating that Cry1Ab binds to multiple receptors or to different forms of the same protein. *Spodoptera frugiperda* (SF9) cells transfected with the *OnBt-R-1* gene were shown to express the receptor molecule which caused functional susceptibility to Cry1Ab at concentrations as low as 0.1 µg/ml. These results in combination suggest strongly that a cadherin-like protein acts as receptor and is involved with Cry1Ab toxicity in *O. nubilalis*. (C) 2004 Elsevier Ltd. All rights reserved.

Fu, X. Y., M. Fukuzawa, J. Tabata, S. Tatsuki and Y. Ishikawa (2005). "Sex pheromone biosynthesis in *Ostrinia zaguliaevi*, a congener of the European corn borer moth *O. nubilalis*." *Insect Biochemistry and Molecular Biology* 35(6): 621-626.

In order to clarify the biochemical basis to the divergence of sex pheromones in the genus *Ostrinia* (Lepidoptera: Crambidae), the pheromone biosynthetic pathway in *O. zaguliaevi*, a close relative of the European corn borer *O. nubilalis*, was investigated. Deuterium-labeled hexadecanoic or tetradecanoic acids were topically applied to the surface of the pheromone gland, and the incorporation of the label into pheromone components and their putative precursors was determined. It was suggested that the two components shared by *O. zaguliaevi* and *O. nubilalis*, (E)-11- and (Z)-11-tetradecenyl acetates, are biosynthesized from hexadecanoic acid through one round of chain shortening, Delta 11 desaturation, reduction, and acetylation. An additional component specifically found in *O. zaguliaevi*, (Z)-9-tetradecenyl acetate, is likely to be produced by Delta 11 desaturation of hexadecanoic acid, one round of chain shortening, reduction, and acetylation. Non-production of (Z)-9-tetradecenyl acetate in *O. nubilalis* was suggested to be due to the blockage of chain shortening from (Z)-11-hexadecenoate to (Z)-9-tetradecenoate. (c) 2005 Elsevier Ltd. All rights reserved.

Gathmann, A. and I. Rothmeier (2005). "Dispersal of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in southern Rhineland - Results of the infestation assessment 2002 and 2003." *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection* 112(2): 200-203.

The distribution of the European Corn Borer (ECB, *Ostrinia nubilalis* Hbn.) was described in detail in the Rhineland between Aachen and Cologne since 2000. The distribution limit moved about 12 km northwards in 2001. The assessment of ECB was continued in 2002 and 2003. In the first year of the study, we could observe again a northwards distribution up to 13 km. In 2003, the distribution limit did not change between Aachen and Cologne probably caused through extreme hot and dry weather conditions during summer. Additionally the distribution was also observed in the Bergischen Hohen for the first time in 2002. There ECB spread continuously north- and eastwards in 2003.

Huang, F. N., L. L. Buschman and R. A. Higgins (2005). "Larval survival and development of susceptible and resistant *Ostrinia nubilalis* (Lepidoptera : Pyralidae)." *Agricultural and Forest Entomology* 7(1): 45-52.

1 Larval survival and development of Dipel-susceptible and -resistant strains of European corn borer, *Ostrinia nubilalis* (Hubner), were assayed using diets incorporating low doses of a commercial formulation of *Bacillus thuringiensis* var.

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kurstaki Berliner (Dipel ES). 2 Larval mortality, growth and development, pupation rate and pupal weight were not significantly different between Dipel-susceptible and -resistant strains when larvae were reared on a nontoxic control diet. 3 Larval mortality of Dipel-resistant larvae did not significantly change as Dipel concentration increased at the tested concentrations, whereas mortality of Dipel-susceptible larvae increased dramatically as Dipel concentration increased. 4 Larval development was significantly delayed when larvae were fed diets containing low doses of Dipel. 5 Pupation rate and pupal body weight declined as Dipel concentration increased but it decreased faster for the susceptible strain than for the resistant strain.

Kaster, L. V. and M. E. Gray (2005). "EUROPEAN CORN BORERS AND WESTERN CORN ROOTWORMS: OLD AND NEW INVASIVE MAIZE PESTS CHALLENGE FARMERS ON EUROPEAN AND NORTH AMERICAN CONTINENTS." *Maydica* 50(3-4): 235-245.

Since the early 1990s, Maize producers in Europe and North America have shared management challenges with two formidable insect foes: the European corn borer (*Ostrinia nubilalis* Hubner) and the western Corn rootworm (*Diabrotica virgifera virgifera* LeConte). Although considerable progress has been made in the management of European corn borer via the use of commercially available maize hybrids that offer some degree of conventional host plant resistance, the deployment of resistant (antibiosis) alleles in maize for corn rootworm has been disappointing. Producers in the United States have relied largely upon crop rotation and the prophylactic use of soil insecticides in an effort to prevent economic losses caused by corn rootworm larvae. In some areas of the western Corn Belt, an over reliance on insecticides to suppress egg laying by corn rootworm adults has led to the development of insecticide resistance to methylparathion and carbaryl. Since the mid-1990s, the non-diversified agroecosystem of the US eastern Corn Belt has led to the development of a variant western corn rootworm that is able to circumvent the cultural management tactic of rotating maize and soybean. The integration of many management strategies (IPM) is critical in prolonging the usefulness of individual control tactics for both of these important insect pests of maize. The receptiveness to transgenic hybrids by producers on each continent remains strikingly different. Although we believe transgenic hybrids offer producers yet another management tool to deploy within an IPM framework for European corn borers and western corn rootworms, they should not be viewed as the ultimate solution for either species. Like all insects, these two pests are versatile and will adapt to my technology if it is abused.

Keszthelyi, S. and Z. Acs (2005). "Comparison on DNA patterns of different ecotypes of European corn borer (*Ostrinia nubilalis* Hubner) in Hungary." *Acta Biologica Hungarica* 56(1-2): 75-81.

For a molecular genetic study on Hungarian populations of European corn borer L-5 stage larvae were collected from 14 places of three different regions of the country (uni- and bivoltine ecotypes). Additionally, the study included larvae from Egypt, too (multivoltine ecotype). Molecular examinations of European corn borer larvae using the study of mitochondrial cytochrome b (cyt b) revealed that by single strand conformation polymorphism (SSCP) the populations found in Hungary represented the same haplotype. Even the Egyptian sample showed no genetic divergence. Some minor deviations were found in the case of a sample from Szekutas, but that did not prove the genetic divergence of the bivoltine ecotype either, since the other samples of South-East Hungary did not display this kind of genetic variation. On the basis of our investigations it can be said that the univoltine and bivoltine generations, have uniform genetic complements.

Lewis, L. C., R. D. Gunnarson and J. C. Robbins (2005). "Trichogramma brassicae and SLAM (R), an integrated approach to managing European corn borer and corn rootworms." *Biocontrol* 50(5): 729-737.

European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae); western corn rootworm (WCRW), *Diabrotica virgifera virgifera* LeConte; and northern corn rootworm (NCRW), *Diabrotica barberi* (Smith & Lawrence) (Coleoptera: Chrysomelidae) are important pests of corn, *Zea mays* L., that occur simultaneously in the US Corn Belt. Area-wide management strategies for northern and western corn rootworm in Iowa, Kansas, South Dakota, Illinois, and Indiana, and for the Mexican strain in Texas, use SLAM(R), which contains cucurbitacin, a feeding stimulant, and a small amount of the insecticide carbaryl. This management strategy is environmentally sound because it introduces a substantially lesser amount of chemical insecticide into the environment than prophylactic soil insecticide applications for WCRW management. To develop a management program for both corn pests, the compatibility of SLAM(R) to control CRW, along with a biological agent to manage European corn borer, was investigated. Laboratory studies were conducted using the egg parasitoid *Trichogramma brassicae* (Bezdenko) (Hymenoptera: Trichogrammatidae). In experiments in

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which SLAM(R) and *T. brassicae* were evaluated as components of a management system, SLAM(R) did not affect parasitism or parasitoid emergence rates. *Trichogramma brassicae* displayed vigorous biotic fitness, emergence rates, sex ratios, and fecundity over the duration of the study. Data collected under these laboratory conditions indicated that SLAM(R) had no adverse effect on the quality of *T. brassicae*, indicated by its ability to reproduce in the filial generation.

Li, H. R., B. Oppert, R. A. Higgins, F. N. Huang, L. L. Buschman, J. R. Gao and K. Y. Zhu (2005). "Characterization of cDNAs encoding three trypsin-like proteinases and mRNA quantitative analysis in Bt-resistant and -susceptible strains of *Ostrinia nubilalis*." *Insect Biochemistry and Molecular Biology* 35(8): 847-860.

Our previous studies suggested that *Bacillus thuringiensis* (Bt) resistance in a Dipel-resistant strain of *Ostrinia nubilalis* was primarily due to reduced trypsin-like proteinase activity. In this study, we demonstrated a 254-fold resistance to Cry1Ab protoxin but only 12-fold to trypsin-activated Cry1Ab toxin in the Dipel-resistant strain. Significantly higher resistance to Cry1Ab protoxin than to trypsin-activated Cry1Ab toxin further supports the hypothesis that reduced trypsin-like proteinase activity leading to reduced activation of the Bt protoxin is a major resistance mechanism in the Dipel-resistant strain. To understand the molecular basis of reduced proteinase activity, three cDNAs, OnT2, OnT23, and OnT25, encoding full-length trypsin-like proteinases, were sequenced in Bt-resistant and -susceptible *O. nubilalis* larvae. Although a number of nucleotide differences were found in sequences from the Bt-resistant and -susceptible strains, the differences were not consistent with reduced trypsin-like activity in the Bt-resistant strain. However, the mRNA levels of OnT23 in the resistant strain were 2.7- and 3.8-fold lower than those of the susceptible strain as determined by northern blotting and real-time quantitative PCR, respectively. Thus, reduced trypsin-like activity may be attributed to reduced expression of OnT23 in Bt-resistant *O. nubilalis*. Our study provides new insights into Bt resistance management strategies, as resistance mediated by reduced Bt protoxin activation would be ineffective if resistant insects ingest a fully activated form of Cry1Ab toxin, either in spray formulations or transgenic Bt crops. (c) 2005 Elsevier Ltd. All rights reserved.

Li, H. R., B. Oppert, R. A. Higgins, F. N. Huang, L. L. Buschman and K. Y. Zhu (2005). "Susceptibility of Dipel-resistant and -susceptible *Ostrinia nubilalis* (Lepidoptera : Crambidae) to individual *Bacillus thuringiensis* protoxins." *Journal of Economic Entomology* 98(4): 1333-1340.

Dipel-resistant and -susceptible strains of *Ostrinia nubilalis* (Hubner) were evaluated for larval mortality and growth inhibition when fed diets containing individual *Bacillus thuringiensis* protoxins. Resistance ratios for four of the protoxins in Dipel (Cry1Aa, Cry1Ab, Cry1Ac, and Cry2Aa) were 170-, 205-, 524, and > 640-fold, respectively, considerably higher than the 47-fold resistance to Dipel. The Dipel-resistant strain was 36-fold resistant to Cry1Ba, a protoxin not present in Dipel. Another non-Dipel protoxin, Cry1Ca, did not cause significant mortality for either resistant or susceptible larvae with doses as high as 1.0 mg/ml. In an evaluation of larval growth inhibition, resistance to Cry1Aa, Cry1Ab, Cry1Ac, and Cry1Ba was significant at concentrations of 0.054 and 0.162 $\mu\text{g/ml}$. However, growth inhibition with Cry2Aa was not significant at either dose. These data provide information on the spectrum of resistance and cross-resistance to individual Cry protoxins in this strain.

Ma, B. L., K. Subedi, L. Evenson and G. Stewart (2005). "Evaluation of detection methods for genetically modified traits in corn genotypes resistant to European corn borer and herbicides." *Journal of Environmental Science and Health Part B-Pesticides Food Contaminants and Agricultural Wastes* 40(4): 633-644.

Detection of genetically modified (GM) traits in corn (*Zea mays* L.) is urgently needed for preservation of genetic identity and marketing GM products. A laboratory study was conducted to evaluate the efficiency, accuracy, and reliability of different analytical methods to detect GM traits in corn. Samples with known fractions of GM concentrations (*Bacillus thuringiensis* [Bt], Liberty Link [LL] and stacked [Bt/LL] genes) from commercial seed companies and those derived from yellow kernels in a white corn ear, outcrossed by pollen of neighboring Bt hybrid, were tested by lateral flow quick test kits and by enzyme-linked immunosorbent assay (ELISA)-based test strips purchased from different companies. Liberty Link hybrids are resistant to glufosinate (Liberty or Basta) herbicides, whereas Bt corn is developed for the control of European corn borer (*Ostrinia nubilalis*). Selected samples of GM concentrations were also tested in a commercial laboratory using DNA-based polymerase chain reaction (PCR) test. The results demonstrated that qualitative lateral flow quick tests could detect samples containing 1% or higher Bt and 2% or higher LL concentrations within the recommended time limit of the test. Faint test lines for samples containing 0.5 to 1% Bt or 1

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to 2% LL concentrations appeared if samples remained in the test cup overnight. ELISA test strips detected the Bt content semiquantitatively in the range of 0.5 to 2.0%. Grain samples derived from non-Bt corn outcrossed by neighboring Bt pollen had usually lower GM concentrations than commercial GM seed samples. Both ELISA- and DNA-based PCR tests distinguished samples with GM concentrations between 0.1 to 0.5%, but the precision of quantification at this range was very low and results were highly inconsistent.

Malausa, T., M. T. Bethenod, A. Bontemps, D. Bourguet, J. M. Cornuet and S. Ponsard (2005). "Assortative mating in sympatric host races of the European corn borer." *Science* 308(5719): 258-260.

Although a growing body of work supports the plausibility of sympatric speciation in animals, the practical difficulties of directly quantifying reproductive isolation between diverging taxa remain an obstacle to analyzing this process. We used a combination of genetic and biogeochemical markers to produce a direct field estimate of assortative mating in phytophagous insect populations. We show that individuals of the same insect species, the European corn borer *Ostrinia nubilalis*, that develop on different host plants can display almost absolute reproductive isolation—the proportion of assortative mating was >95%—even in the absence of temporal or spatial isolation.

Mensah, R. K., B. Frerot and F. Al Dabel (2005). "Effects of petroleum spray oils on oviposition behaviour and larval survival of *Helicoverpa armigera* Hubner (Lepidoptera : Noctuidae) and *Ostrinia nubilalis* Hubner (Lepidoptera : Pyralidae)." *International Journal of Pest Management* 51(2): 111-119.

We determined the effects of petroleum spray oil (PSO) (Caltex Canopy(R)) on oviposition responses of *Helicoverpa armigera* Hubner and *Ostrinia nubilalis* Hubner adults, and larval survival of the pest moths on cotton and maize plants in the laboratory. Application of 2% (v/v) of the PSO deterred *H. armigera* oviposition. Increasing the rate from 2 to 5% (v/v) did not significantly reduce the number of eggs laid by *H. armigera* on the treated plants. In contrast, the minimum rate at which the oil could deter oviposition of *O. nubilalis* on maize plants was 5% (v/v). Increasing the rate from 5 to 10% (v/v) did not significantly reduce the number of eggs laid per plant. However, a reduction in the rate of the PSO from 5 to 3% (v/v) resulted in a 73.9% increase in oviposition activity on the maize plants. In wind tunnel bioassay tests, all mated *H. armigera* females tested could detect and settle on plants treated with water but with plants treated with PSO at various times, only 50% of tested females settled on the plants 4 - 5 days after treatment (DAT) and none on the plants 0 - 2 DAT. A solid phase micro-extraction (SPME) test to determine the effect of the PSO on volatiles released by the cotton plants showed that the quantity of volatiles released by the cotton plants treated with PSO was lower than for water treated plants. This indicates that the PSO sprays may be suppressing or masking the leaf surface volatiles of the cotton plants, thereby deterring oviposition of *H. armigera*. Larval survival data show that PSO sprays can cause direct mortality of first, second and third instar *O. nubilalis* larvae. PSOs may have the potential to be integrated into pest management programme targeting *H. armigera* and *O. nubilalis* on cotton and maize crops, respectively.

Musser, F. R. and A. M. Shelton (2005). "The influence of post-exposure temperature on the toxicity of insecticides to *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Pest Management Science* 61(5): 508-510.

The influence of post-treatment temperature on the toxicities of two pyrethroids (lambda-cyhalothrin and bifenthrin), a carbamate (methomyl) and a spinosyn (spinosad) to *Ostrinia nubilalis* (Hubner) larvae was evaluated in laboratory assays. From 24 to 35 degrees C, the toxicities of the pyrethroids decreased 9.5- and 13.6-fold while spinosad toxicity decreased 3.8-fold. The toxicity of methomyl did not change significantly. The results demonstrate that the most effective insecticide against a pest may vary with environmental conditions. In situations where comparable products from multiple insecticide classes are available, temperature should be included as a factor in the decision-making process. (c) 2005 Society of Chemical Industry.

Papst, C., H. F. Utz, A. E. Melchinger, J. Eder, T. Magg, D. Klein and M. Bohn (2005). "Mycotoxins produced by *Fusarium* spp. in isogenic Bt vs. non-Bt maize hybrids under European corn borer pressure." *Agronomy Journal* 97(1): 219-224.

Stalk and ear rots caused by *Fusarium* subspecies are often related to mycotoxin accumulation in maize (*Zea mays* L.) kernels. Various mycotoxicoses in livestock and humans are triggered by the consumption of these toxins. The European corn borer (*Ostrinia nubilalis* hubner) reportedly promotes the infection by *Fusarium* spp. The objectives of our study were to (i) evaluate the concentration of deoxinivalenol (DON), 3-acetyl-deoxynivalenol (3-A-DON), 15-

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acetyl-deoxynivalenol (15-A-DON), fumonisin (FUM), fusarenon-X (FUS-X), moniliformin (MON), and nivalenol (NIV) in kernels; (ii) determine the level of European corn borer (ECB) resistance; and (iii) investigate the association between the concentration of mycotoxins and ECB resistance. The study used early maturing European Bt (*Bacillus thuringiensis*) cultivars, their isogenic counterparts, and commercial hybrids. The field experiments were conducted at three locations in Germany. The mycotoxins most prevalent were DON, FUM, and MON. Plots infested by and protected from ECB differed significantly for DON and FUM concentrations. In addition, significant differences were found for concentrations of FUM between isogenic Bt and non-Bt hybrids. The two Bt events - Bt176 and Mon810 - were also significantly different for FUM concentrations. Not all mycotoxins were related to ECB damage. Insect management and, therefore, the use of Bt cultivars may be a short-term solution to minimize toxins in kernels.

Quinton, S. E., G. C. Brown, R. T. Bessin and D. W. Johnson (2005). "European corn borer (Lepidoptera : Crambidae) effects on qualitative traits of high oil content corn grown in Kentucky." *Journal of Economic Entomology* 98(2): 395-401.

The European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), is one of the most important pests of corn, *Zea mays* L., because it consistently causes high loss of yield. A study was conducted in 2000-2002 at field sites in central and western Kentucky to investigate whether infestation by *O. nubilalis* differentially affects the production of high-oil corn compared with traditional field corn. Statistical differences in grain weight and percentage of oil content between the five infestation levels were significant at both locations and for all years. Average grain yield was reduced by 0.40% and average oil concentration by 0.011% for each 1% of damaged plants, and there was a strong correlation (0.76) between leaf damage ratings (i.e., Guthrie scale) and yield reduction. In general, corn planted at the early planting date tended to have a higher yield (grain weight) and oil content.

Qureshi, J. A., L. L. Buschman, J. E. Throne and S. B. Ramaswamy (2005). "Adult dispersal of *Ostrinia nubilalis* Hubner (Lepidoptera : Crambidae) and its implications for resistance management in Bt-maize." *Journal of Applied Entomology* 129(6): 281-292.

Dispersal of European corn borer, *Ostrinia nubilalis* Hubner was examined by release and recapture of the dye marked adults and by capture of the feral adults in and around the large 50 ha center pivot irrigated fields of *Bacillus thuringiensis* (Bt) maize. Pheromone and black light traps were used to catch the adults. In 1999, 15 094 marked males and 7993 marked females were released, and in 2001, 13 942 marked males and 9977 marked females were released. In 1999, maximum mean recapture beyond the release point was 1.95 and 1.67% for males and females, but in 2001, the recapture rate was 9.97 and 4.37% for males and females. Few males (3.8%) and females (2.07%) were recaptured in neighbourhood maize fields. An exponential decay function explained recapture of marked adults across the dispersal distance. More than 90% of marked adults were recaptured within 300 m of the release point. Large numbers of feral adults were captured throughout the study fields. Feral adult dispersal could be fitted to a linear model. Virgin females (20% marked and 8% feral) were captured throughout the study fields. The recapture of marked insects suggests that the dispersal was limited. However, capture of feral adults throughout Bt-maize fields indicate that the actual dispersal may be more extensive than indicated by recapture of marked adults. Potential refuge sources for the feral adults were 587-1387 m from the edge of the study fields. It is not clear if the dispersal recorded in this study is extensive enough to support the current resistance management strategy for corn borers. There appears to be some dispersal of corn borers from the non-transgenic 'refuge' fields into the transgenic fields that allows some genetic mixing of the two populations.

Riba, M., A. Sans, J. Sole, L. Munoz, M. P. Bosch, G. Rosell and A. Guerrero (2005). "Antagonism of pheromone response of *Ostrinia nubilalis* males and implications on behavior in the laboratory and in the field." *Journal of Agricultural and Food Chemistry* 53(4): 1158-1165.

The antagonistic effect on the pheromone response and catabolism of male European corn borers, *Ostrinia nubilalis*, by several trifluoromethyl ketones is reported. (Z)-11-Tetradecenyl trifluoromethyl ketone (Z11-14:TFMK), the most closely related analogue of the main component of the pheromone, elicits a remarkable disruptive effect on close approach and source contact of males flying to a source baited with mixtures of the pheromone and the antagonist in 5:1 and 10:1 ratios. In this experiment, the male displayed an erratic flight track with frequent counter turns and intersections with the plume. In the field, the TFMK significantly lowered the number of males caught when mixed with the pheromone in a 10:1 ratio in comparison with the natural attractant. The compound was also a good inhibitor of the antennal esterase of the insect with a IC50 value of 0.28 µM. The homologous (Z)-10-tridecenyl trifluoromethyl

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ketone, with one carbon less in the chain, also elicited an antagonistic effect in the wind tunnel, but in the field, the results were not conclusive. The effect induced was lower than the one displayed by Z11-14:TFMK including the activity as the esterase inhibitor (IC50 value of 7.55 µM). The saturated tetradecyl trifluoromethyl ketone, tetradecyltrifluoropyruvamide, and (Z)-11-2-thiatetradecenyl trifluoromethyl ketone resulted completely inactive. The results obtained in conjunction to the previously shown low toxicity to mice by related trifluoromethyl ketones provide new important data for the putative utilization of these chemicals as new pest control agents.

Sappington, T. W. (2005). "First-flight adult European corn borer (Lepidoptera : Crambidae) distribution in roadside vegetation relative to cropping patterns and corn phenology." *Environmental Entomology* 34(6): 1541-1548.

The European corn borer, *Ostrinia nubilalis* (Hubner), is a serious pest of commercial maize throughout the U.S. Corn Belt. Adults in the central and eastern Corn Belt aggregate in grassy areas around and within the cornfield where they spend the daylight hours resting and where mating activity occurs at night. Mated females leave the aggregation sites at night to oviposit in cornfields, thus using the grass as a staging area. Flush samples were taken in borrow ditches in central Iowa during the first (spring) flight of moths in 2003 and 2004 to determine if cropping patterns and crop phenology influence moth distribution across the landscape. Significantly more moths were present in ditches with an adjacent cornfield on at least one side of the road than in those with no corn on either side. In contrast, effects of corn stubble from the previous year's crop, tillage, and corn phenology were weak or not detectable. Evidence suggests that some moths emerging from corn stubble may aggregate in adjacent grass but that they redistribute themselves in the landscape within a short time. Thus, the presence or absence of adjacent corn was the overwhelming factor affecting spatial distribution of first-flight European corn borer moths among grassy roadside ditches.

Sked, S. L. and D. D. Calvin (2005). "Temporal synchrony between *Macrocentrus cingulum* (Hymenoptera : Braconidae) with its preferred host, *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Environmental Entomology* 34(2): 344-352.

The seasonal occurrences of *Macrocentrus cingulum* Brischke and its host, *Ostrinia nubilalis* Hubner, were studied. Overwintering fifth-instar *O. nubilalis* were collected from the field in 1997, 1998, 2001, and 2002 and reared under controlled laboratory conditions to determine pupation and adult eclosion periods for *M. cingulum* and *O. nubilalis*. In addition, pheromone and yellow sticky traps were established in the field in 2001 and 2002 to monitor adult activity of *O. nubilalis* and *M. cingulum*. Mathematical equations were constructed based on the laboratory and field data. The equations confirmed the temporal co-occurrence of *M. cingulum* and *O. nubilalis* adults. However, third- and fourth-instar *O. nubilalis*, the preferred host stages of *M. cingulum*, occur later in the growing season. The timing of *M. cingulum*, adult life expectancy and the occurrences of its preferred host stages in the field were predicted using the equations, published degree-day requirements for *O. nubilalis* and information from the literature on adult *M. cingulum* longevity. When the predicted period of *M. cingulum* adult activity was compared with the predicted timing of third- and fourth-instar *O. nubilalis*, *M. cingulum* adult presence was synchronized with preferred host stages.

Solter, L. F., J. V. Maddox and C. R. Vossbrinck (2005). "Physiological host specificity: A model using the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera : Crambidae) and microsporidia of row crop and other stalk-boring hosts." *Journal of Invertebrate Pathology* 90(2): 127-130.

We investigated vertical and horizontal transmission as means by which entomopathogenic microsporidia may be isolated in their hosts. *Ostrinia nubilalis* larvae were challenged with microsporidia isolated from other stalk-boring and row crop Lepidoptera and were susceptible to seven species. Two species were horizontally transmitted. A *Nosema* sp. from *Eoreuma loftini* was transmitted among *O. nubilalis* larvae but not among larvae of the *E. loftini* host. This species was also vertically transmitted to the offspring of infected *O. nubilalis* females. An rDNA sequence showed the *E. loftini* isolate to be *Nosema pyrausta*, a naturally occurring species in *O. nubilalis*. Our results suggest that both horizontal and vertical transmission provide physiological barriers to host switching in the microsporidia, thus restricting the natural host range. (c) 2005 Elsevier Inc. All rights reserved.

Sorenson, C. E., G. G. Kennedy, C. Schal and J. F. Walgenbach (2005). "Geographical variation in pheromone response of the European corn borer, *Ostrinia nubilalis* (Lepidoptera : Crambidae), in North Carolina: A 20-Y perspective." *Environmental Entomology* 34(5): 1057-1062.

Pheromone traps were used to assess the distribution of two pheromone races of European corn borer, *Ostrinia nubilalis* (Hubner), in North Carolina, approximate to 10 and 20 yr after previous, similar assessments. In the previous studies, moths responding to a 9Z: 3E isomeric blend (Z blend) of 11-tetradecenyl acetate predominated in the far western parts of the state, whereas moths responding to a 3Z: 97E blend (E blend) prevailed in the east, with a substantial zone of overlap occurring in the eastern Piedmont. There was evidence that the E responsive population had expanded westward between 1978 and 1988. In this study, the distribution of the two races seemed to remain essentially unchanged from that observed in the late 1980s, and no evidence of a continued westward expansion of E responsive moths was detected.

Wilson, T. A., M. E. Rice, J. J. Tollefson and C. D. Pilcher (2005). "Transgenic corn for control of the European corn borer and corn rootworms: a survey of Midwestern farmers' practices and perceptions." *Journal of Economic Entomology* 98(2): 237-247.

In 2001, a self-administered questionnaire was sent to 1000 corn, *Zea mays* L., farmers in each of five states (Illinois, Indiana, Iowa, Minnesota, and Nebraska) to evaluate their perceptions of transgenic corn designed to control the European corn borer, *Ostrinia nubilalis* (Hubner), and corn rootworms, *Diabrotica* spp. Respondents returned 1,313 surveys (26.2%). Farmers with small acreages planted a greater portion of their corn (54.5%) with transgenic corn for control of European corn borer than farmers with large farms (39.2%). The majority (75.2%) of farmers use crop rotation to control the corn rootworm. Nine insecticides comprised 92.2% of the commercial soil insecticides used for control of corn rootworm larvae. More than one-third of the farmers in Illinois (33.5%) and Indiana (39.4%) treated first-year corn for corn rootworm, primarily due to western corn rootworm egg laying in soybean, *Glycine max* (L.). When asked whether they would plant transgenic corn protected against the corn rootworm, 35.0% of farmers responded they would, whereas 40.5% said they were unsure. The two greatest farmer concerns about transgenic corn were the ability to sell harvested grain (59.3%) and additional technology fees (54.8%). Respondents indicated that less farmer exposure to insecticide (69.9%) and less insecticide in the environment (68.5%) were the primary benefits of transgenic corn. Farmers who had no concerns about transgenic corn for rootworm control were more likely to purchase the product (46.8%). The most common refuge-planting options farmers favored were adjacent fields (30.9%) and split fields (29.9%). Farmers (21.1%) observed a yield increase (23.7 bu/ha [9.6 bu/acre]) when using transgenic corn for European corn borer control compared with nontransgenic corn. These data can help in understanding farmers' knowledge and concerns regarding transgenic corn. This information maybe of value to guide researchers, extension specialists, and policy makers in designing insect resistance management and integrated pest management programs.

Barlow, V. M. and T. P. Kuhar (2004). "Within-plant distribution of European corn borer, *Ostrinia nubilalis* Hubner, egg masses on bell pepper." *Journal of Entomological Science* 39(4): 670-672.

Bontemps, A., D. Bourguet, L. Pelozuelo, M. T. Bethenod and S. Ponsard (2004). "Managing the evolution of *Bacillus thuringiensis* resistance in natural populations of the European corn borer, *Ostrinia nubilalis*: host plant, host race and pherotype of adult males at aggregation sites." *Proceedings of the Royal Society B-Biological Sciences* 271(1553): 2179-2185.

The European corn borer (ECB) consists of at least two, genetically differentiated host races: one feeding on maize, the other feeding on mugwort and hop. It is unclear to what extent individuals feeding on these, or other host plants, contribute to natural ECB populations. The mechanisms underlying the genetic differentiation between both races are not well understood; they may include sexual attraction via different pheromone blends (E or Z) and differences in the location of mating sites. We caught adult males with traps baited with the E or the Z blend at hop, maize, and 'mixed' sites. We determined their probable host race by allozyme-based genetic assignment, and the photosynthetic type of their host plant by stable carbon isotope analysis. Most individuals caught in Z traps had emerged from a C-4-type plant and belonged to the maize race, whereas most individuals caught in E traps had emerged from C-3-type plants and were but weakly differentiated from the hop-mugwort race, suggesting a strong, though not absolute, correspondence between host plant, host race and pherotype. We also found that although spatial segregation may contribute to genetic isolation between host races, moths of both host races may be present at a given location. Regarding the management of *Bacillus thuringiensis* (Bt) maize, our results indicate that, at least at the present study sites, it is unlikely that any wild or cultivated C-3-type plant species could be a source of susceptible individuals that would mate randomly with Bt-resistant Z-C-4 moths emerging from Bt-maize fields.

Bourguet, D. (2004). "Resistance to *Bacillus thuringiensis* toxins in the European corn borer: what chance for Bt maize?" *Physiological Entomology* 29(3): 251-256.

Coates, B. S., D. V. Sumerford and R. L. Hellmich (2004). "Geographic and voltinism differentiation among North American *Ostrinia nubilalis* (European corn borer) mitochondrial cytochrome c oxidase haplotypes." *Journal of Insect Science* 4.

DNA sequence of European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), mitochondrial cytochrome c oxidase I (cox1) and II (cox2) genes were characterized and used for population genetic analysis. Twenty-six point mutations were identified from a 2,156 bp DNA sequence alignment. The frequency of polymorphic cox1 DdeI and HaeIII, and cox2 Sau3AI and MspI restriction sites were determined from 1,414 individuals by polymerase chain reaction restriction fragment length polymorphism. Ten haplotypes were observed. A single haplotype was present among 90% of individuals examined, and a HaeIII haplotype was not present in samples from the Atlantic coast. Significant genetic differentiation existed between Atlantic coast and midwestern United States samples, and between sympatric uni- and bivoltine ecotypes. These genetic markers identify regional and ecotype differences in the North American *O. nubilalis* population.

De Nardo, E. A. B. and K. R. Hopper (2004). "Using the literature to evaluate parasitoid host ranges: a case study of *Macrocentrus grandii* (Hymenoptera : Braconidae) introduced into North America to control *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Biological Control* 31(3): 280-295.

We propose a method for using the literature to evaluate host ranges of parasitoids that are candidates for biological control introductions. Data on the parasitoids that attack a given host species can be used as negative evidence concerning the candidate whose host range is being evaluated. By compiling studies for a variety of host species, one can delineate those taxa unlikely to be attacked by the candidate. Using a retrospective case study of a parasitoid introduced into North America, we describe (1) this approach to using the literature to evaluate host range and (2) how well predictions based on such an evaluation match actual host range. Based on the host range of *Macrocentrus grandii* in Eurasia as reported in the literature, we predicted that the species in the genus *Ostrinia* are the most likely hosts. Of native North American species, *Ostrinia obumbratalis* is the only non-target species likely to be attacked by *M. grandii*. The predicted host range for North America matched the actual host range found in the field. This suggests that a careful literature review could be used as an important source of data on host range of parasitoid species proposed for introduction into a new environment. Published by Elsevier Inc.

Dopman, E. B., S. M. Bogdanowicz and R. G. Harrison (2004). "Genetic mapping of sexual isolation between E and Z pheromone strains of the European corn borer (*Ostrinia nubilalis*)." *Genetics* 167(1): 301-309.

The E and Z pheromone strains of the European corn borer (ECB) provide an exceptional model system for examining the genetic basis of sexual isolation. Differences at two major genes account for variation in female pheromone production and male behavioral response, components of the pheromone communication system known to be important for mate recognition and mate choice. Strains of ECB are morphologically indistinguishable, and surveys of allozyme and DNA sequence variation have revealed significant allele frequency differences at only a single sex-linked locus, *Tpi*. Here we present a detailed genetic linkage map of ECB using AFLP and microsatellite markers and map the factors responsible for pheromone production (*Pher*) and male response (*Resp*). Our map covers 1697 cM and identifies all 31 linkage groups in ECB. Both *Resp* and *Tpi* map to the Z (sex) chromosome, but the distance between these markers (>20 cM) argues against the hypothesis that patterns of variation at *Tpi* are explained by tight linkage to this "speciation gene." However, we show, through analysis of marker density, that *Tpi* is located in a region of low recombination and suggest that a second Z-linked reproductive barrier could be responsible for the origin and/or persistence of differentiation at *Tpi*.

Farinos, G. P., M. de la Poza, P. Hernandez-Crespo, F. Ortego and P. Castanera (2004). "Resistance monitoring of field populations of the corn borers *Sesamia nonagrioides* and *Ostrinia nubilalis* after 5 years of Bt maize cultivation in Spain." *Entomologia Experimentalis Et Applicata* 110(1): 23-30.

Approximately 22 000 hectares (5% of the total maize growing area) of transgenic maize expressing the Cry1Ab toxin from *Bacillus thuringiensis* (Bt maize) have been planted annually in Spain since 1998. Changes in the susceptibility to Cry1Ab of Spanish populations of the Mediterranean corn borer (MCB), *Sesamia nonagrioides* (Lefebvre) (Lepidoptera:

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Noctuidae), and the European corn borer (ECB), *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), were assessed by annual monitoring on Bt maize fields. No increase in resistance was detected in the MCB populations from Ebro, Albacete, and Badajoz, nor in the ECB populations from Ebro and Badajoz during the period 1999-2002. The susceptibility of the MCB population from Madrid fluctuated from year to year, but a gradual trend towards higher levels of tolerance was not observed. Laboratory selection assays for eight generations yielded selected strains of MCB and ECB that were 21- and 10-fold significantly more tolerant to Cry1Ab than the corresponding unselected strains, respectively. Nevertheless, none of the field-collected or laboratory-selected larvae were able to survive on Bt maize. Considering these data, no consistent shifts in susceptibility were found for Spanish populations of MCB nor ECB after 5 years of Bt maize cultivation, but systematic field monitoring needs to be continued.

Foster, S. P. (2004). "Fatty acid and sex pheromone changes and the role of glandular lipids in the Z-strain of the European corn borer, *Ostrinia nubilalis* (Hubner)." *Archives of Insect Biochemistry and Physiology* 56(2): 73-83.

Lipids in the sex pheromone gland of females of the Z-strain of *Ostrinia nubilalis* were analyzed for fatty acyl pheromone analogs (FAPAs) and other potential biosynthetic intermediates. More than 80% of the FAPAs were found in the triacylglycerols (TGs), with smaller amounts found in the phosphatidyl cholines, ethanolamines, and serines. Analysis of the TGs by lipase revealed that the two FAPAs were distributed fairly evenly among all three stereospecific positions. Comparison of changes in titers of key glandular fatty acids with those of pheromone components, with respect to photoperiodic time and age of females, showed that both FAPA and pheromone titers exhibited a cyclical pattern with peaks in the scotophase and valleys in the photophase. However, whereas pheromone titer tended to peak in the first half of the scotophase, FAPA titer peaked at the end of the scotophase. Significantly, the titer of the FAPA of the minor component, (E)-11-tetradecenyl acetate (3% of pheromone), was always much greater than the titer of the FAPA of the major component, (Z)-11-tetradecenyl acetate (97%), of the pheromone. Titer of myristate, an intermediate in pheromone biosynthesis, was also higher during the scotophase than the photophase. However, myristate titer showed a pronounced dip in the middle of the scotophase. These data suggest two roles for glandular lipids in sex pheromone biosynthesis in *O. nubilalis*. Firstly, they remove excess FAPA of the minor component so the fatty acid reductase system is not presented with a high ratio of this isomer (which would otherwise result from the reductase's own selectivity), which could cause changes in the final pheromone ratio. Secondly, hydrolysis of the large amounts of stored saturated fatty acids from the TGs may provide substrate for pheromone biosynthesis. (C) 2004 Wiley-Liss, Inc.

Frantz, J. D., J. Gardner, M. P. Hoffmann and M. M. Jahn (2004). "Greenhouse evaluation of *Capsicum* accessions for resistance to European corn borer (*Ostrinia nubilalis*)." *Hortscience* 39(6): 1336-1338.

A replicated greenhouse evaluation of a range of commercial and noncommercial (*Capsicum* spp.) accessions for resistance to European corn borer (ECB) [*Ostrinia nubilalis* (Hubner)] was conducted. Percentage of fruit damaged was observed among 29 accessions four weeks after plants were artificially infested with ECB egg masses. Small-fruited peppers generally showed lower levels of damage, while large-fruited peppers were the most susceptible. Genotypes with elongate fruit were less damaged than those with bell-shaped fruit. Resistance to fruit damage was also associated with increasing pungency level, with two notable exceptions. The pungent genotype 'Large Red Thick Cayenne' was significantly more susceptible than many of the other pungent accessions tested. The relative susceptibility of this accession may be related to large fruit size. The nonpungent pepper 'Corno di Toro' showed significantly lower percent fruit damage than other nonpungent peppers including 'Banana Supreme' with roughly similar fruit size, ranking amidst highly pungent peppers such as 'Red Scotch Bonnet'. These results confirm that resistance to ECB can be identified in nonpungent *Capsicum* genotypes and demonstrate that pungency is not always correlated with ECB damage. Reported sources of aphid resistance or tolerance showed good levels of ECB resistance, but interpretation of these results was confounded by the presence of pungency.

Fu, X., J. Tabata, Y. Huang, T. Takahashi, S. Ohno, H. Honda, S. Tatsuki and Y. Ishikawa (2004). "Female sex pheromone of *Ostrinia orientalis* - throwing a light on the relationship between *O. orientalis* and the European corn borer, *O. nubilalis*." *Chemoecology* 14(3-4): 175-180.

The sex pheromone of *Ostrinia orientalis* (Lepidoptera: Crambidae) was analyzed by gas chromatography-electroantennographic detection (GC-EAD), GC-mass spectrometry and a series of bioassays. Three EAD-active compounds were detected in the female sex pheromone gland extract, and identified as tetradecyl acetate (14:OAc),

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(Z)-11-tetradecenyl acetate (Z11-14:OAc) and (E)-11-tetradecenyl acetate (E11-14:OAc). The titers (ratio) of 14:OAc, Z11-14:OAc and E11-14:OAc in 3-day-old virgin females were 0.49 ng (10), 4.86 ng (98) and 0.10 ng (2), respectively. In a wind-tunnel bioassay, the 98:2 blend of Z11- and E11-14:OAc, but not Z11-14:OAc alone, elicited the same male behavioral responses as virgin females and crude gland extracts. 14:OAc was inactive by itself, and did not show any synergistic effect on the binary blend. Field trapping experiments also confirmed the attractiveness of the binary blend to *O. orientalis* males. Based on these results, we concluded that the sex pheromone of *O. orientalis* is a 98:2 mixture of Z11-14:OAc and E11-14:OAc. This sex pheromone is very similar to that of the Z-type European corn borer, *O. nubilalis*. The present finding raises the question of whether *O. orientalis*, which is indistinguishable from *O. nubilalis* based on external morphology, is a biologically distinct species independent from *O. nubilalis*.

Jovanovic-Galovic, A., D. P. Blagojevic, G. Grubor-Lajsic, R. Worland and M. B. Spasic (2004). "Role of antioxidant defense during different stages of preadult life cycle in European corn borer (*Ostrinia nubilalis*, Hubn.): Diapause and metamorphosis." *Archives of Insect Biochemistry and Physiology* 55(2): 79-89.

Antioxidant enzymes, total glutathione (GSH), and ascorbic acid (ASA) were determined in whole body homogenates of nondiapausing larvae, diapausing larvae during the diapausing period (October, December, and February), and in pupae emerged from both diapausing and nondiapausing larvae of the European corn borer (*Ostrinia nubilalis*, Hubn., Lepidoptera: Pyralidae). The activities of catalase, selenium nondependent glutathione peroxidase (GPx), and glutathione-S-transferase (GST), as well as the content of GSH and ASA, were found to vary throughout the larval diapause. Compared to diapausing larvae, nondiapausing larvae were higher in levels of catalase, GPx, GST, and dehydroascorbate reductase (DHAR) activity. GSH content was also increased. However, nondiapausing larvae contained less ASA than diapausing ones. Pupae had higher GPx and GST activity and an increased ASA content compared to larvae. The pupae emerged from nondiapausing larvae had higher GST, glutathione reductase (GR), and DHAR activities, but lower GPx activity and ASA content than those emerged from diapausing larvae. Correlation analysis revealed differences in the way the antioxidant level is equilibrated for a particular stage and developmental pattern. The results suggest that cellular antioxidants are involved in both the protection of cells and the regulation of redox levels during the pre-adult stages of *Ostrinia nubilalis*. (C) 2004 Wiley-Liss, Inc.

Keszthelyi, S. (2004). "Second, late summer flight peak of the European corn borer (*Ostrinia nubilalis* HUBNER) in south area of Hungary." *Cereal Research Communications* 32(3): 379-385.

The investigations were induced by the controversial question of the generation number of European corn borer (*Ostrinia nubilalis* HUBNER) in Hungary. Relying on the data of nation-wide light trap network surveys were made in three places in south area of Hungary (Fadd, Kecel, Kiskunfelegyhaza) in previous years maize fields left unharvested, by cutting 4x100 infested stalks to settle the question of a second flight peak. Beside the mentioned places 4x80 stalks were cut in current year maize fields in order to determine the larval stages. The examinations were carried out between 6 and 8 August in accordance with the second flight peak. In the previous year's stalks dead larvae and chrysalis were found without exception, while the examination results of current year's stalks confirmed the development of a second (first summer) generation in this area. It is thus regarded as a fact supported by the data of the national light trap system that in South-East Hungary a true second generation has for years been developing.

Krakowsky, M. D., M. Lee, W. L. Woodman-Clikeman, M. J. Long and N. Sharopova (2004). "QTL mapping of resistance to stalk tunneling by the European corn borer in RILs of maize population B73 x De811." *Crop Science* 44(1): 274-282.

Considerable effort has been expended toward the genetic characterization of native resistance to stalk tunneling by the European corn borer [ECB; *Ostrinia nubilalis* (Hubner)], indicative of the importance of this pest and the difficulty in obtaining conclusive results. In this study, 191 recombinant inbred lines (RILs) of B73 maize (*Zea mays* L.) (susceptible to stalk tunneling by ECB) X De811 (resistant) were evaluated for stalk tunneling, anthesis, and plant height in Iowa at two locations in 1998 and one location in 1999 with the objectives of (i) determining the genetic relationship between these traits and (ii) mapping quantitative trait loci (QTL) associated with resistance to stalk tunneling. The genotypic correlation between plant height and stalk tunneling ($r(g) = 0.1$) was negligible, but the correlation between stalk tunneling and anthesis was very high ($rg -0.8$) necessitating the adjustment of the means of former with the latter. Ten QTL for stalk tunneling adjusted for anthesis associated with 42% of the phenotypic variation were observed in the mean across trials, only one of which was observed in each of the individual trials. The lack of consistent QTL detection

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across environments is a common characteristic among studies of ECB tunneling and underscores a major problem of breeding for resistance. QTL observed in F-3 lines of the same cross and in RILs of B73 X B52 are linked to three QTL each for the mean across trials herein, providing further evidence of association between these genomic regions and resistance to stalk tunneling.

Kuang, X. Q., D. D. Calvin, M. C. Knapp and F. L. Poston (2004). "Female European corn borer (Lepidoptera : Crambidae) ovarian developmental stages: Their association with oviposition and use in a classification system." *Journal of Economic Entomology* 97(3): 828-835.

Reproductive development of female European corn borer, *Ostrinia nubilalis* (Hubner), was investigated and a classification system proposed. Females collected in a blacklight trap during 1982 and 1983 were dissected and their reproductive system examined. Female reproductive systems were divided into six stages based on ovum development within the ovarioles, ovum depletion, ovariole appearance, and fat body color and shape. The female reproductive systems were also staged on the basis of spermatophore appearance. The time necessary to classify a female is also reported. Based on the classification system, the relationship between female age and stage of ovarian development was quantified under three temperature regimes. Females were found to experience a 3- to 5-d preoviposition period before initiation of egg deposition under optimal temperature conditions. This delay between adult emergence and initiation of egg laying corresponded with more advanced ovarian developmental stages collected in blacklight traps and indicates that actively ovipositing females are primarily being collected in blacklight traps.

Kuhar, T. P., V. M. Barlow, M. P. Hoffman, S. J. Fleischer, E. Groden, J. Gardner, R. Hazzard, M. G. Wright, S. A. Pitcher, J. Speese and P. Westgate (2004). "Potential of *Trichogramma ostrinae* (Hymenoptera : Trichogrammatidae) for biological control of European corn borer (Lepidoptera : Crambidae) in solanaceous crops." *Journal of Economic Entomology* 97(4): 1209-1216.

We assessed the ability of *Trichogramma ostrinae* (Peng & Chen) to locate and parasitize *Ostrinia nubilalis* (Hubner) eggs in crops other than corn, and we evaluated the efficacy of inundative releases of the parasitoid in two solanaceous crops, pepper and potato. Despite a greater plant surface area to search, parasitism of *O. nubilalis* eggs was consistently higher in sweet corn than dicotyledonous crops such as pepper, snap bean, broccoli, potato, and melon, in choice and no-choice experiments. Nonetheless, in 2002 and 2003, we made four to five separate inundative releases of approximately 30,000-50,000 *T. ostrinae* per 0.02 ha in nine pepper fields in Virginia, Pennsylvania, and Massachusetts and compared *O. nubilalis* egg parasitization and fruit damage in those plots with spatially isolated nonrelease plots. Egg parasitization averaged 48.7% in *T. ostrinae* release plots, which was significantly higher than in nonrelease plots (1.9%). Also, cumulative pepper fruit damage averaged 8.7% in release plots, which was significantly less than in nonrelease plots (27.3%). In potatoes in 2002 and 2003, we made two releases of approximately 75,000 *T. ostrinae* per 0.2 ha in nine fields in Maine and Virginia and compared *O. nubilalis* damage in those plots with that in nonrelease plots. *T. ostrinae* releases significantly reduced the number of tunnel holes and number of *O. nubilalis* larvae in potato stems. We conclude that this parasitoid has great potential as a biocontrol agent for *O. nubilalis* in solanaceous crops.

Li, H. R., J. Gonzalez-Cabrera, B. Oppert, J. Ferre, R. A. Higgins, L. L. Buschman, G. A. Radke, K. Y. Zhu and F. N. Huang (2004). "Binding analyses of Cry1Ab and Cry1Ac with membrane vesicles from *Bacillus thuringiensis*-resistant and -susceptible *Ostrinia nubilalis*." *Biochemical and Biophysical Research Communications* 323(1): 52-57.

The binding properties of *Bacillus thuringiensis* toxins to brush border membrane vesicles of Dipel-resistant and -susceptible *Ostrinia nubilalis* larvae were compared using ligand-toxin immunoblot analysis, surface plasmon resonance (SPR), and radiolabeled toxin binding assays. In ligand-toxin immunoblot analysis, the number of Cry1Ab or Cry1Ac toxin binding proteins and the relative toxin binding intensity were similar in vesicles from resistant and susceptible larvae. Surface plasmon resonance with immobilized activated Cry1Ab toxin indicated that there were no significant differences in binding with fluid-phase vesicles from resistant and susceptible larvae. Homologous competition assays with radiolabeled Cry1Ab and Cry1Ac toxin and vesicles from resistant and susceptible larvae resulted in similar toxin dissociation constants and binding site concentrations. Heterologous competition binding assays indicated that Cry1Ab and Cry1Ac completely competed for binding, thus they share binding sites in the epithelium of the larval midguts of *O. nubilalis*. Overall, the binding analyses indicate that resistance to Cry1Ab and Cry1Ac in this Bt-resistant strain of *O. nubilalis* is not associated with a loss of toxin binding. (C) 2004 Elsevier Inc. All rights reserved.

Li, H. R., B. Oppert, R. A. Higgins, F. N. Huang, K. Y. Zhu and L. L. Buschman (2004). "Comparative analysis of proteinase activities of *Bacillus thuringiensis*-resistant and -susceptible *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Insect Biochemistry and Molecular Biology* 34(8): 753-762.

Proteinase activities were compared in soluble and membrane fractions of guts obtained from larvae of *Bacillus thuringiensis*-resistant and -susceptible *Ostrinia nubilalis*. Overall, serine proteinases from soluble fractions of the susceptible strain were more active than those of the resistant strain. The soluble trypsin-like proteinase activity of the resistant strain was approximately half that of the susceptible strain. The number and relative molecular masses of soluble and membrane serine proteinases were different. However, there were no significant differences in the activities of serine proteinases and aminopeptidases extracted from midgut membranes of the two strains. Cry1Ab protoxin hydrolysis by soluble proteinase extracts of the resistant strain was reduced approximately 20-30% relative to that of the susceptible strain. Reduced protoxin processing due to decreased activities of Bt protoxin activation proteinases may be associated with resistance to Bt toxin in this resistant strain of *O. nubilalis*. (C) 2004 Elsevier Ltd. All rights reserved.

Malvar, R. A., A. Butron, A. Alvarez, B. Ordas, P. Soengas, P. Revilla and A. Ordas (2004). "Evaluation of the European Union maize landrace core collection for resistance to *Sesamia nonagrioides* (Lepidoptera : Noctuidae) and *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 97(2): 628-634.

Two corn borer species are the principal maize insect pests in Europe, the European corn borer, *Ostrinia nubilalis* (Hübner), and the pink stem borer, *Sesamia nonagrioides* (Lefebvre). Hence, it would be advisable to evaluate the European maize germplasm for corn borer resistance to generate European varieties resistant to corn borer attack. The creation of the European Union Maize Landrace Core Collection (EUMLCC) allowed the screening of most of the variability for European corn borer resistance present among European maize local populations from France, Germany, Greece, Italy, Portugal, and Spain, testing a representative sample. The objective of this study was the evaluation of stem and ear resistance of the EUMLCC to European corn borer and pink stem borer attack. Trials were made at two Spanish locations that represent two very different maize-growing areas. Populations that performed relatively well under corn borer infestation for stem and ear damage were 'PRT0010008' and 'GRC0010085', among early landraces; 'PRT00100120' and 'PRT00100186', among early landraces; 'GRC0010174', among midseason landraces; and 'ESP0070441', among late landraces. Either the selection that could have happened under high insect pressure or the singular origin of determined maize populations would be possible explanations for the higher corn borer resistance of some landraces. Landraces 'PRT0010008', 'FRA0410090', 'PRT00100186', and 'ESP0090214' would be selected to constitute a composite population resistant to corn borers and adapted to short season, whereas populations 'ESP0090033', 'PRT00100530', 'GRC0010174', and 'ITA0370005' would be used to make a resistant composite adapted to longer season.

Martin, S. A., L. L. Darrah and B. E. Hibbard (2004). "Divergent selection for rind penetrometer resistance and its effects on European corn borer damage and stalk traits in corn." *Crop Science* 44(3): 711-717.

Corn (*Zea mays* L.) grain yield is affected by a number of factors, including stalk lodging and pests such as the European corn borer (*Ostrinia nubilalis* Hubner; ECB). European corn borers contribute to stalk lodging and also cause a direct grain yield reduction through physiological effects that decrease the plant's ability to produce and translocate photosynthates. Although much progress has been made in improving standability, stalk lodging remains a major problem, and breeding for stalk lodging resistance continues to be important, especially if it also plays a role in ECB resistance. Missouri Second Cycle Stiff Stalk Synthetic (MoSCSSS) was selected for stalk strength by using a rind penetrometer. Twelve cycles of bidirectional selection have been completed, which has resulted in increased and decreased stalk strength in the high and low directions of selection, respectively. Selected cycles were evaluated for grain yield, stalk lodging, rind penetrometer resistance, first- and second-generation ECB damage, leaf penetrometer resistance at the whorl stage and anthesis, and stalk traits including crude fiber, cellulose, lignin, and silica. Evaluation showed a decrease in grain yield in both directions of selection. Selection for high rind penetrometer resistance was effective at providing resistance to second-generation ECB damage as well as resistance to stalk lodging. Leaf penetrometer resistance was higher in the high direction of selection at whorl stage, but reversed by anthesis where the low direction of selection had higher leaf penetrometer resistance. Crude fiber, cellulose, and lignin increased in the high direction of selection, but silica decreased in the high direction of selection. Significant correlations between the

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stalk traits analyzed demonstrated that stalk composition was important in providing rind penetrometer resistance, stalk lodging resistance, and second-generation ECB resistance.

O'Rourke, P. K. and W. D. Hutchison (2004). "Binomial sequential sampling plans for late instars of European corn borer (Lepidoptera : Crambidae), corn earworm (Lepidoptera : Noctuidae), and damaged kernels in sweet corn ears." *Journal of Economic Entomology* 97(3): 1003-1008.

Late-season infestations of European corn borer, *Ostrinia nubilalis* (Hubner), and corn earworm, *Helicoverpa zea* (Boddie), were sampled to develop binomial sequential sampling plans for larval infestations and damaged kernels in sweet corn, *Zea mays* L., ears, near harvest. Fields were sampled to obtain a range of larval densities likely to be encountered over a range of infestation levels and field conditions. Binomial sampling plans were developed for *O. nubilalis* larvae, *H. zea* larvae, *O. nubilalis*, and *H. zea* larvae combined, and for damaged sweet corn kernels. Observed densities ranged from 0.01 to 4.40 larvae per ear for *O. nubilalis*, 0.005-1.62 larvae per ear for *H. zea*, and 0.004-36.12 damaged kernels per ear. Results of resampling analyses, based on the proportion of ears infested with one or more larvae, or damaged kernels, indicated an average sample size of 34-37 ears was necessary to classify whether larval infestations, or the incidence of damaged kernels, exceeded 5%. Two operating characteristic curves are presented for each of the four sampling plans. Initial results, with upper bounds of 0.10, and alpha (type I) and beta (type II) error rates at 0.10 and 0.05, respectively, resulted in a 90% probability of making the correct management decision at infestation levels >10%. To improve performance of the sampling plans, we modified the binomial plans by reducing the upper bound to 0.075, while maintaining the same error rates. This plan resulted in a higher probability (>95%) of making the correct management decision to reject a sweet corn load when infestation levels are >10%.

Papst, C., M. Bohn, H. F. Utz, A. E. Melchinger, D. Klein and J. Eder (2004). "QTL mapping for European corn borer resistance (*Ostrinia nubilalis* Hb.), agronomic and forage quality traits of testcross progenies in early-maturing European maize (*Zea mays* L.) germplasm." *Theoretical and Applied Genetics* 108(8): 1545-1554.

In hybrid breeding the performance of lines in hybrid combinations is more important than their performance per se. Little information is available on the correlation between individual line and testcross (TC) performances for the resistance to European corn borer (ECB, *Ostrinia nubilalis* Hb.) in maize (*Zea mays* L.). Marker assisted selection (MAS) will be successful only if quantitative trait loci (QTL) found in F-2 derived lines for ECB resistance are still expressed in hybrid combinations. The objectives of our study were: (1) to identify and characterize QTL for ECB resistance as well as agronomic and forage quality traits in a population of testcrossed F-2:3 families; (2) to evaluate the consistency of QTL for per se and TC performances; and (3) to determine the association between per se and TC performances of F-2:3 lines for these traits. Two hundred and four F-2:3 lines were derived from the cross between maize lines D06 (resistant) and D408 (susceptible). These lines were crossed to D171 and the TC progenies were evaluated for ECB resistance and agronomic performance in two locations in 2000 and 2001. Using these TC progenies, six QTL for stalk damage rating (SDR) were found. These QTL explained 27.4% of the genotypic variance in a simultaneous fit. Three QTL for SDR were detected consistently for per se and TC performance. Phenotypic and genotypic correlations were low for per se and TC performance for SDR. Correlations between SDR and quality traits were not significant. Based on these results, we conclude that MAS will not be an efficient method for improving SDR. However, new molecular tools might provide the opportunity to use QTL data as a first step to identify genes involved in ECB resistance. Efficient MAS procedures might then be based on markers designed to trace and to combine specific genes and their alleles in elite maize breeding germplasm.

Pelozuelo, L., C. Malosse, G. Genestier, H. Guenego and B. Frerot (2004). "Host-plant specialization in pheromone strains of the European corn borer *Ostrinia nubilalis* in France." *Journal of Chemical Ecology* 30(2): 335-352.

European corn borer (ECB) feeding on maize (*Zea mays*); mugwort (*Artemisia vulgaris*), and hop (*Humulus lupulus*) are genetically different in France and referred to as host-plant races. Here, we investigated sex pheromone composition as a possible trait linked to the host plant. ECB host races were sampled from 13 different sites in France. GC-MS analysis of female pheromone showed that 175 out of 176 maize females belonged to the Z type with one hybrid. In contrast, mugwort and hop females belonged almost exclusively to the E type. No Z females were found on these plants and only 2 females out of 169 were hybrids. In the three sites of sympatry, the hybrid proportion was far from Hardy-Weinberg expectations. Wind tunnel experiments showed that 76-79% of maize males from three populations were

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attracted by Z females, whereas neither mugwort nor hop males were. Mugwort males from Toussus-le-Noble were attracted by E females originating from an American maize strain. These data showed that maize, mugwort, and hop host races of *O. nubilalis* differ not only in their host plant but also in the sex pheromone they use. Because mugwort and hop are putative ancestral host plants, these results are discussed from the point of view of evolutionary scenarios for the emergence of Z and E strains.

Ponsard, S., M. T. Bethenod, A. Bontemps, L. Pelozuelo, M. C. Souqual and D. Bourguet (2004). "Carbon stable isotopes: a tool for studying the mating, oviposition, and spatial distribution of races of European corn borer, *Ostrinia nubilalis*, among host plants in the field." *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 82(7): 1177-1185.

The European corn borer, *Ostrinia nubilalis* (Hubner, 1796) (Lepidoptera: Crambidae), is a polyphagous corn pest species that includes two host races: one feeding on corn (*Zea mays* L.) and one feeding on mugwort (*Artemisia vulgaris* L.) and hop (*Humulus lupulus* L.). Being able to determine the type of host plant on which field-caught moths fed as larvae would allow for the quantification of mating rates within and between races, as well as the quantification of the spatial distribution and oviposition of both races in the field. We found that stable carbon isotopes ($\delta^{13}\text{C}$) are a reliable indicator of host-plant photosynthetic type (C3 or C4) regardless of adult food and intensity of metabolism; so even when food or metabolism had a significant effect on wing $\delta^{13}\text{C}$ values, the magnitude of this effect was too small to obscure the signal characterizing host-plant type. Egg and spermatophore $\delta^{13}\text{C}$ values similarly reflect female and male host-plant type, respectively, regardless of adult feeding. We found 224 host-plant species of *O. nubilalis* in the literature, including 19 species with C4-type photosynthesis. However, in temperate areas, corn is probably the only significant C4 source of adult moths. Accordingly, wing $\delta^{13}\text{C}$ values were more variable in field-caught moths showing a typical C3-type $\delta^{13}\text{C}$ value than in those showing a typical C4-type $\delta^{13}\text{C}$ value.

Reardon, B. J., R. L. Hellmich, D. V. Sumerford and L. C. Lewis (2004). "Growth, development, and survival of *Nosema pyrausta*-infected European corn borers (Lepidoptera : Crambidae) reared on meridic diet and Cry1Ab." *Journal of Economic Entomology* 97(4): 1198-1201.

Transgenic corn, *Zea mays* L., hybrids expressing crystal protein endotoxin genes from *Bacillus thuringiensis* Berliner are an increasingly popular tactic for managing the European corn borer, *Ostrinia nubilalis* (Hubner), in North America. *O. nubilalis* populations also are often vulnerable to the ubiquitous entomopathogenic microsporidium *Nosema pyrausta* (Paillot). We examined the effect of feeding meridic diet incorporated with purified Cry1Ab on growth, development, and survival of *Nosema*-infected and uninfected neonate *O. nubilalis*. Infected larvae developed more slowly than uninfected larvae. Increasing the concentration of Cry1Ab in diet reduced larval development, and this effect was amplified by microsporidiosis. Infected larvae weighed significantly less than uninfected larvae. The relationship among *Nosema* infection, Cry1Ab concentration, and larval weight was fitted to an exponential function. The LC50 of infected larvae was one-third that of uninfected larvae, indicating that infected larvae are more vulnerable to toxin. This work has implications for resistance management of *O. nubilalis* and demonstrates that it is important to determine whether *N. pyrausta* is present when testing susceptibility of larvae to transgenic corn hybrids.

Siqueira, H. A. A., D. Moellenbeck, T. Spencer and B. D. Siegfried (2004). "Cross-resistance of Cry1Ab-selected *Ostrinia nubilalis* (Lepidoptera : Crambidae) to *Bacillus thuringiensis* delta-endotoxins." *Journal of Economic Entomology* 97(3): 1049-1057.

Corn plants expressing the toxin from *Bacillus thuringiensis* (Berliner) have proven to be effective in controlling lepidopteran pests such as the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae). Several Bt toxins are being tested and incorporated into crop genomes, although tests for cross-resistance among different toxins have been limited by a lack of resistant colonies. Four different colonies of *O. nubilalis* selected with full-length Cry1Ab incorporated into artificial diet developed significant levels of resistance (2.0- to 10-fold) within 10 generations. Additionally, selection with Cry1Ab resulted in decreased susceptibility to a number of other toxins to which the selected colonies were not previously exposed. Significantly, levels of resistance were highest to Cry1Ac with resistance ratios up to 51.0-fold. Low levels (less than five-fold) of cross-resistance were detected with Cry1F. In contrast, Cry9C susceptibility was unaffected by selection with Cry1Ab. These results indicate that the availability of multiple toxins could improve resistance management strategies, provided cross-resistance among toxins is not a factor.

Siqueira, H. A. A., K. W. Nickerson, D. Moellenbeck and B. D. Siegfried (2004). "Activity of gut proteinases from Cry1Ab-selected colonies of the European corn borer, *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Pest Management Science* 60(12): 1189-1196. Susceptibility to the Cry1Ab protoxin and toxin from *Bacillus thuringiensis* (Berliner) and activity of gut proteinases were assessed in both susceptible and Cry1Ab-selected colonies of European corn borer, *Ostrinia nubilalis* (Hubner). Resistance in two different selected colonies was at least 6- and 15-fold for the Cry1Ab protoxin and 108- and 484-fold for the Cry1Ab toxin. Activities of trypsin-like, chymotrypsin-like and elastase-like proteinases were variable among the colonies tested and not indicative of a major contribution to Cry1Ab resistance. Activation of the 130-kDa Cry1Ab protoxin occurred rapidly in all colonies, with no apparent differences among colonies. In addition, there were no apparent changes in activated Cry1Ab processing, indicating that proteolytic degradation was not associated with resistance. These results suggest that mechanisms other than proteolytic activation of protoxin and toxin degradation, such as target site modification may be involved in the resistance to *B. thuringiensis* Cry1Ab in these *O. nubilalis* colonies. (C) 2004 Society of Chemical Industry.

Stanic, B., A. Jovanovic-Galovic, D. P. Blagojevic, G. Grubor-Lajsic, R. Worland and M. B. Spasic (2004). "Cold hardiness in *Ostrinia nubilalis* (Lepidoptera : Pyralidae): Glycerol content, hexose monophosphate shunt activity, and antioxidative defense system." *European Journal of Entomology* 101(3): 459-466.

Many insects in temperate regions overwinter in diapause, during which they are cold hardy. In these insects, one of the metabolic adaptations to the unfavorable environmental conditions is the synthesis of cryoprotectants/anhydroprotectants. The aim of this study was to investigate the connection between the antioxidative system and synthesis of cryoprotectants (mainly glycerol) in diapausing larvae of the European corn borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae). At two periods during diapause (November and February), in three groups of insects (kept under field conditions; -12degreesC for two weeks; 8degreesC for two weeks), the activity of key enzymes of the antioxidative system and oxidative part of the hexose monophosphate shunt were measured: superoxide dismutase, catalase, non selenium glutathione peroxidase, glutathione S-transferase, glutathione reductase, glucose 6-phosphate dehydrogenase and 6-phosphogluconate dehydrogenase, as well that of the antioxidative components: total glutathione and ascorbate, and dehydroascorbate reductase. There was a higher activity of antioxidative enzymes at the beginning of the diapause period (November) compared to late diapause (February), while glutathione and ascorbate were higher in February. Similarly, there was a lower activity of the hexose monophosphate shunt enzymes in February. Exposure of larvae to -12degreesC resulted in an elevation of hexose monophosphate shunt enzyme activity, especially in November. This was accompanied by a significant increase in glycerol content in February. Changes in ascorbate levels and dehydroascorbate reductase activity in both experimental groups (-12degreesC and 8degreesC) suggest a connection between the antioxidative system, metabolism during diapause and cold hardiness. Our results support the notion that antioxidative defense in larvae of *Ostrinia nubilalis* is closely connected with metabolic changes characteristic of diapause, mechanisms of cold hardiness involved in diapause and the maintenance of a stable redox state.

Steffey, K. L., M. Venditti, B. R. Barrido and A. S. Felsot (2004). Effect of *Bacillus thuringiensis* corn on natural enemies of the European corn borer. *Agricultural Biotechnology: Challenges and Prospects*. M. K. Bhalgat, W. P. Ridley, A. S. Felsot and J. N. Seiber. 866: 139-150.

Since the commercialization of transgenic corn expressing endotoxin proteins from *Bacillus thuringiensis* Berliner genes (Bt corn), concern about the potential impact of this biotechnology-derived corn on nontarget organisms has been the focus of considerable attention. Several studies have been conducted in the laboratory and field to determine the impact of Bt corn on natural enemies (i.e., predators, parasitoids, and pathogens) of the European corn borer, *Ostrinia nubilalis*. The published literature is summarized and reviewed. Two types of experiments were conducted in Illinois to assess the impact of natural enemies on populations of first- and second- generation European corn borers. Small plot experiments were conducted in 1994 and 1995, and field-size studies were conducted in both Bt- and non-Bt cornfields during 1997 and 1998. In the small-plot trials, densities of predators in Bt and non-Bt corn plots were not significantly different during both years of the study. In the field-scale trials, corn type did not seem to affect the percentage of larvae parasitized by *Macrocentrus grandii* or the percentage of eggs and larvae infected by *Nosema pyrausta*. However, because densities of European corn borers in Bt corn were significantly lower than densities of European corn borers in non-Bt corn, densities of natural enemies were substantially reduced in Bt corn. Although reduced host

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density is predicted to coincidentally reduce parasitoid density, maintenance and effectiveness of natural enemies should be retained with establishment of non-Bt corn refuges for insect resistance management.

Velasco, P., P. Soengas, P. Revilla, A. Ordas and R. A. Malvar (2004). "Mean generation analysis of the damage caused by *Sesamia nonagrioides* (Lepidoptera : Noctuidae) and *Ostrinia nubilalis* (Lepidoptera : Crambidae) in sweet corn ears." *Journal of Economic Entomology* 97(1): 120-126.

Sesamia nonagrioides (Lefebvre) and *Ostrinia nubilalis* (Hubner) are the main maize (*Zea mays* L.) pests in Mediterranean countries. To develop insect-resistant cultivars, it is helpful to know the genetic control of the resistance. Our objective was to determine the genetic control of the resistance to both borers. For each of two crosses (EP59 x P51 and 15125 x EP61), six generations were evaluated (P-1, P-2, F-1, F-2, BC1, and BC2). Genetic effects X environment interactions were not significant. For the *O. nubilalis* resistance traits; both crosses fitted an additive-dominance model. EP59 x P51 had important dominance and additive effects, whereas for 15125 x EP61 we did not detect significant genetic effects, but significant year effects were detected. For *S. nonagrioides* infestation, both crosses fitted to an additive-dominance model. There were additive effects for most traits in EP59 x P51. The cross 15125 x EP61 showed significant dominance effects for several traits. Resistance to both corn borers fit an additive-dominance model, but genetic effects depend on the cross evaluated. In the resistance to *S. nonagrioides*, additive effects were important for shank resistance, which is a useful trait for avoiding *S. nonagrioides* damage on the ear. Early sowings are recommended to make good use of the resistance to both corn borers. In the late sowings, damage is so high that resistant plants are not able to control the pest.

Wang, B. D., D. N. Ferro, J. W. Wu and S. Q. Wang (2004). "Temperature-dependent development and oviposition behavior of *Trichogramma ostrinae* (Hymenoptera : Trichogrammatidae), a potential biological control agent for the European corn borer (Lepidoptera : Crambidae)." *Environmental Entomology* 33(4): 787-793.

Trichogramma ostrinae Pang and Chen (Hymenoptera: Trichogrammatidae) was reared continuously for seven generations on its native host, the Asian corn borer, *Ostrinia furnacalis* (Guenee) (Lepidoptera: Crambidae). It took 6.7 d at 33degreesC and 20 d at 17degreesC from oviposition to adult emergence with no differences between sexes. Several theoretic models were used to fit the temperature-dependent growth curves of *T. ostrinae*. A transformed day-degree model and the Hilbert-Logan model were the most reliable for predicting temperature development of *T. ostrinae*. The wasps reared on *O. furnacalis* at 27degreesC by the seventh generation had a lower level of parasitism than wasps from other generations and at other temperatures (17-33degreesC). The number of wasps emerged from individual parasitized egg, and percentage of females produced did not differ for any generations and temperatures. The differences among different generations for the amount and proportion of time female wasp spent drumming host eggs did not show any host-and generation-related trends. The time spent drumming by *T. ostrinae* female wasps reared for three generations on *O. furnacalis* and then four and six generations on the rice moth, *Corcyra cephalonica* (Stainton), differed slightly from the other generations. High variability among the tested wasps indicated that a large number of replicates would be needed to detect the probable differences among generations.

Willmot, D. B., B. E. Hibbard, L. L. Darrah, L. M. Pollak, K. Montgomery, R. C. Pratt, C. A. Abel, J. A. Hawk, T. Weldekidan and J. E. Foster (2004). "Effect of environment on resistance to the European corn borer (Lepidoptera : Crambidae) in maize." *Journal of Economic Entomology* 97(5): 1745-1751.

The European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) is a major pest of maize, *Zea mays* L., in many temperate parts of the world. Genotype-by-environment interaction effects can make relative performance unpredictable and may hamper selection for resistance to European corn borer. The objective of this study was to determine the effect of environment on genotypic reaction to European corn borer resistance in maize. A set of 12 maize inbred lines was chosen to represent a range of European corn borer responses. Eleven testing environments ranged from Delaware, Ohio, Illinois, Iowa, Nebraska, Missouri, to Mississippi. For length of stalk tunneling, environmental and genotypic main effects (estimated by restricted maximum likelihood) were >20- and 10-fold larger than their interaction effect, respectively. Length of tunneling means for genotypes (across environments) ranged from 10.1 to 35.4 cm. Several putatively resistant genotypes grouped with the susceptible checks, B73 and Mo17. By breaking factors and the interaction into single degree of freedom components, we observed that GEMS-0001 had significant crossover interactions toward less susceptibility in both Mississippi and the Nebraska environments.

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Environments displaying several crossover interactions indicated that European corn borer screening at these sites would not necessarily apply to other locations, whether due to small differences in experimental conduct and/or environmental effects. The five most resistant genotypes were fairly consistent across environments. Because all environments except Illinois used larvae from the same insectary, and these environments differed in damage intensity and rankings, it is unlikely that insect biotype was a factor contributing to genotype-by-environment effects.

Wilson, A. P., J. A. Hough-Goldstein, M. J. Vangessel and J. D. Pesek (2004). "Effects of varying weed communities in corn on European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera : Crambidae), oviposition, and egg mass predation." *Environmental Entomology* 33(2): 320-327.

Recent advances in weed control technology have changed how vegetational diversity can be managed in agroecosystems. This 2-yr study assessed the impact of altering the timing of herbicide application in herbicide-resistant field corn on the European corn borer, *Ostrinia nubilalis* (Hubner), and on the beneficial insects that prey on *O. nubilalis* egg masses. Treatments in this study were intended to allow weed presence in the field for varying periods of time, but control the weeds before crop yield was negatively impacted. Effects on *O. nubilalis* oviposition were assessed directly by counting egg masses and indirectly by assessing damage to corn stalks resulting from *O. nubilalis* infestations. The impact of weeds on the main generalist predators in this system was quantified through direct counts and predation trials on sentinel egg masses. In this study, altering the timing of herbicide application in herbicide-resistant field corn did not appear to affect the oviposition preference of *O. nubilalis* or the beneficial insects that prey on its egg masses. End-of-season stalk comparisons showed no differences in *O. nubilalis* infestation levels among the treatments. Predation on sentinel egg masses showed few significant differences among treatments, and predator densities were only rarely significantly different by treatment and showed no evident trends. Thus, our data suggest that under the conditions of this experiment, manipulating herbicide applications to minimize *O. nubilalis* damage is not a viable management technique in field corn.

Anderson, P. L., M. J. Weiss, R. L. Hellmich, M. P. Hoffmann and M. G. Wright (2003). "Millet preference, effects of planting date on infestation, and adult and larval use of proso millet by *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 96(2): 361-369.

The interaction between millet and European corn borer, *Ostrinia nubilalis* (Hubner), was investigated to gain insight into whether millet could serve as a refuge or trap crop for *O. nubilalis* management. In 1995, 1996, and 1999, millet selection studies were conducted in North Dakota and New York with four millet species. Proso millet, *Panicum milliaceum* L., had the highest infestation and widest distribution of *O. nubilalis* developmental stages, indicating the presence of both univoltine and bivoltine ecotypes. Siberian foxtail millet, *Setaria italica* (L.) Beauvois, harbored the greatest number of adults, followed by German foxtail millet, *Setaria italica* (L.) Beauvois. These two millets appeared to serve as better aggregation sites than proso millet. In North Dakota in 1997, proso millet planting date studies showed later planting dates were more heavily infested than earlier dates; in 1998, this trend was reversed. The change in trends between years was probably a result of differences in the respective growing seasons and subsequent differences in *O. nubilalis* flights. Adult sampling showed that both old and young females aggregated in proso millet during the day; however, at night, it appeared that young females moved out of millet to oviposit, whereas old females remained in millet. Egg masses were detected in proso, millet over a 7-d period in 1997 and a 4-d period in 1998. Larval sampling showed planting proso millet between late May and mid-June may maximize the presence of individuals from both *O. nubilalis* ecotypes. Once the optimal combination of planting date, plant density, and millet type is found, millet may serve as an effective refuge or trap crop for *O. nubilalis* management.

Bohn, M., T. Magg, D. Klein and A. E. Melchinger (2003). "Breeding early maturing European dent maize (*Zea mays* L.) for improved agronomic performance and resistance against the European corn borer (*Ostrinia nubilalis* HB.)." *Maydica* 48(3): 239-247.

The prime objective of maize breeding programs in Western Europe is improving yield, maturity, and stalk quality. Increasing the resistance to the European corn borer (*Ostrinia nubilalis* Hb., ECB) is of secondary importance, despite its significance as a major pest of maize in Western Europe. Given this priority setting, the overall goal of the Hohenheim ECB breeding program, initiated in 1992, was to select lines with improved per se and testcross performance for multiple agronomic traits and ECB resistance. Objectives of this study were to describe the used breeding scheme and

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the results obtained after ten years of intensive selection work. In the standard breeding scheme, line development started from a segregating S₁ population. Genotypes were evaluated for their line per se ECB resistance in generations S-1, S-3, and S-5. Lines from the S-2, S-4, and S-5 generations were testcrossed and evaluated for their agronomic performance. Selection was based on ECB resistance and TC performance for grain yield and maturity. The five newly developed lines showed only a minor improvement for ECB resistance. This can be explained by the negative correlation between the used selection index for agronomic traits and ECB resistance. The population fraction selected based on index performance did not contain the lines with the highest level of resistance. None of the selected lines showed associations between SSR haplotypes at ECB resistance gene clusters and their level of ECB resistance. These results demonstrated that a simultaneous improvement of important agronomic traits and ECB resistance is difficult to accomplish, if conventional tools typically used by maize breeders are applied. Further research is needed to develop new breeding methods to overcome these limitations.

Bourguet, D., J. Chaufaux, M. Seguin, C. Buisson, J. L. Hinton, T. J. Stodola, P. Porter, G. Cronhohn, L. L. Buschman and D. A. Andow (2003). "Frequency of alleles conferring resistance to Bt maize in French and US corn belt populations of the European corn borer, *Ostrinia nubilalis*." *Theoretical and Applied Genetics* 106(7): 1225-1233.

Farmers, industry, governments and environmental groups agree that it would be useful to manage transgenic crops producing insecticidal proteins to delay the evolution of resistance in target pests. The main strategy proposed for delaying resistance to *Bacillus thuringiensis* (Bt) toxins in transgenic crops is the high-dose/refuge strategy. This strategy is based on the unverified assumption that resistance alleles are initially rare ($<10^{-3}$). We used an F-2 screen on >1,200 isofemale lines of *Ostrinia nubilalis* Hifter (Lepidoptera: Crambidae) collected in France and the US corn belt during 1999-2001. In none of the isofemale lines did we detect alleles conferring resistance to Bt maize producing the Cry1Ab toxin. A Bayesian analysis of the data indicates that the frequency of resistance alleles in France was $<9.20 \times 10^{-4}$ with 95% probability, and a detection probability of >80%. In the northern US corn belt, the frequency of resistance to Bt maize was $<4.23 \times 10^{-4}$ with 95% probability, and a detection probability of >90%. Only 95 lines have been screened from the southern US corn belt, so these data are still inconclusive. These results suggest that resistance is probably rare enough in France and the northern US corn belt for the high-dose plus refuge strategy to delay resistance to Bt maize.

Flint-Garcia, S. A., L. L. Darrach, M. D. McMullen and B. E. Hibbard (2003). "Phenotypic versus marker-assisted selection for stalk strength and second-generation European corn borer resistance in maize." *Theoretical and Applied Genetics* 107(7): 1331-1336.

Maize (*Zea mays* L.) stalk lodging is breakage of the stalk at or below the ear, which may result in loss of the ear at harvest. Stalk lodging is often intensified by the stalk tunneling action of the second-generation of the European corn borer (2-ECB) [*Ostrinia nubilalis* (Hubner)]. Rind penetrometer resistance (RPR) has been used to measure stalk strength and improve stalk lodging resistance, and quantitative trait loci (QTL) have been identified for both RPR and 2-ECB damage. Phenotypic recurrent selection (PS) increases the frequency of favorable alleles over cycles of selection. Several studies have indicated that marker-assisted selection (MAS) is also a potentially valuable selection tool. The objective of this study was to compare the efficiency of PS versus MAS for RPR and 2-ECB. Marker-assisted selection for high and low RPR was effective in the three populations studied. Phenotypic selection for both high and low RPR was more effective than MAS in two of the populations. However, in a third population, MAS for high RPR using QTL effects from the same population was more effective than PS, and using QTL effects from a separate population was just as effective as PS. Marker-assisted selection for resistance and susceptibility to 2-ECB using QTL effects from the same population was effective in increasing susceptibility, but not in increasing resistance. Marker-assisted selection using QTL effects from a separate population was effective in both directions of selection. Thus, MAS was effective in selecting for both resistance and susceptibility to 2-ECB. These results demonstrated that MAS can be an effective selection tool for both RPR and 2-ECB resistance. These results also validate the locations and effects of QTL for RPR and 2-ECB resistance identified in earlier studies.

Harmon, J. P., J. A. White and D. A. Andow (2003). "Oviposition behavior of *Ostrinia nubilalis* (Lepidoptera : Crambidae) in response to potential intra- and interspecific interactions." *Environmental Entomology* 32(2): 334-339.

Oviposition behavior is an important mechanism for establishing spatial distribution and mitigating potential interactions among community members. We studied the oviposition behavior of the European corn borer, *Ostrinia*

nubilalis Hubner. In the presence of conspecific larvae, the aphid *Rhopalosiphum maidis* (Fitch). and corn pollen to determine whether these potential interacting factors affect the distribution of European corn borer egg masses laid on sweet corn in field cages. We found that ovipositing females in the field differentiate between adjacent corn plants in response to conspecific larvae. We also found that European corn borers laid significantly fewer egg masses on plants with large aphid colonies compared with adjacent plants with few aphids. Furthermore, fewer egg masses were laid on the top one third of the plant where, the aphid colonies were located. We also tested for a fitness advantage of European corn borer's oviposition behaviour in response to aphids and found that neonate larvae inoculated on plants with small aphid colonies had higher establishment (survivorship + retention) than larvae on plants with large aphid colonies. Pollen disentanglement from any effects of differential plant stage did not seem to affect oviposition behavior. These results may have important implications for understanding the spatial distribution and interaction of European corn borer with its natural enemies and potential management strategies.

Hinton, J. L. and D. A. Andow (2003). "Mating frequency of European corn borer (Lepidoptera : Crambidae) in Minnesota, Kansas, and Texas." *Great Lakes Entomologist* 36(3-4): 156-159.

The frequency of mating and polyandry in natural populations are important parameters for understanding evolutionary dynamics. Mating frequency among natural populations of *Ostrinia nubilalis* (Hubner) [Lepidoptera: Crambidae] are quite variable. Showers et al. (1974) found 91.1, 73.8, and 71.3% of females had mated during the second flight over 1971-3 at one location in Iowa. During 1971, only 10% mated multiple times, with lower levels of polyandry in subsequent years. In an earlier study in Iowa, Pesho (1961) found that 65-100% of females had mated and up to 43% had mated more than once. A population in southwestern Ontario averaged 73% mating and 37% polyandry for the 5-year period from 1971-5, a higher rate of polyandry than during the same period in Iowa (Elliot, 1977). In this note, we amplify these previously published results by reporting the mating status of female *O. nubilalis* captured in light traps in Minnesota, Kansas and Texas. We also provide evidence that some females in natural populations may be sperm-limited.

Keszthelyi, S. (2003). "Studies on the swarming of the European corn borer (*Ostrinia nubilalis* Hubn.) in Hungary in 1999-2001 on the basis of light trap data." *Novenytermeles* 52(6): 647-656.

The aim of the experiments was to obtain as much information as possible on the swarming dynamics of the European corn borer (*Ostrinia nubilalis* Hubn.) in recent years, to compare swarming peaks at 45 locations in Hungary, to determine whether the average data for the years 1999, 2000 and 2001 were in line with swarming dynamics published for earlier years, to reveal correlations between the sowing areas per county and the mean number of trapped corn borers, and to determine how abiotic factors influence the number of moths caught in light traps. It could be seen that the area where two swarming peaks are observed is moving northwards in Hungary, due to the mild springs and the hot, wet summers. This is confirmed by the relevant values of the generation quotients, which had mean values of 3.94 in Csongrad County and 0.22 in Gyor-Moson-Sopron County. Differences were observed in the swarming of the European corn borer in different parts of Hungary. The distribution of these swarming types is related to distinct geographical regions with differing climatic conditions. The number of trapped moths per county was found to increase with the sowing area. This was especially perceptible in Hajdu-Bihar, Fejer, Csongrad, Veszprem and Heves counties, where a close correlation was found between the maize sowing area and the number of European corn borers trapped in the county. This correlation clearly indicates the extent of damage caused in regions with a high proportion of maize production. Meteorological factors had a significant influence on the number of trapped moths. Significant correlations were found between the number of trapped moths and the maximum temperature ($P = 99.2\%$; $r = 0.472$), the minimum temperature ($P = 99.8\%$; $r = 0.549$), the mean temperature ($P = 99.8\%$; $r = 0.534$), the precipitation ($P = 95.7\%$; $r = -0.327$) and the relative humidity ($P = 97.3\%$; $r = -0.265$).

Kolliker-Ott, U. M., F. Bigler and A. A. Hoffmann (2003). "Does mass rearing of field collected *Trichogramma brassicae* wasps influence acceptance of European corn borer eggs?" *Entomologia Experimentalis Et Applicata* 109(3): 197-203.

The purpose of our study was to identify a trait that changes quickly during *Trichogramma* mass rearing, and that could therefore be used to monitor stock deterioration. Quality deterioration in mass reared *Trichogramma* wasps was evaluated by examining host acceptance behaviour of *Trichogramma brassicae* Bezdenko (Hymenoptera: Trichogrammatidae) on the target host *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae). We compared three

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replicate lines (designated 'E') reared in the laboratory on the factitious host *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) for 27 generations, a line 'O' reared in the laboratory on *O. nubilalis* for 24 generations, and a line 'F' reared in the laboratory on *O. nubilalis* for only two generations. All lines were initiated from field collections of *O. nubilalis* egg masses. We also evaluated natal host effects by rearing each line on *E. kuehniella* as well as on *O. nubilalis* for the last generation prior to testing. The percentage of wasps accepting the *O. nubilalis* egg mass was significantly higher for the E lines (69.6%) than for the F line (46.5%), while wasps of the O line showed intermediate (57.4%) acceptance. Thus, wasps laboratory reared on *E. kuehniella* performed better than wasps which had recently been collected in the field. Wasps of the O line showed extended probing behaviour compared to the other lines. Lines did not differ in the duration from the first host contact to the beginning of the drilling, probing or trembling behaviour. Natal host (*E. kuehniella* or *O. nubilalis*) did not affect acceptance of the target host *O. nubilalis*. Even though there is some evidence of adaptation to laboratory rearing conditions, we found no indication for quality deterioration in terms of acceptance behaviour of the target host *O. nubilalis* when *T. brassicae* was mass reared on the factitious host *E. kuehniella*

Magg, T., M. Bohn, D. Klein, V. Merditaj and A. E. Melchinger (2003). "Concentration of moniliformin produced by *Fusarium* species in grains of transgenic Bt maize hybrids compared to their isogenic counterparts and commercial varieties under European corn borer pressure." *Plant Breeding* 122(4): 322-327.

The European corn borer (ECB), *Ostrinia nubilalis* Hb., is a major pest of maize in Central Europe and is suspected to promote infection of maize with *Fusarium* species. The objectives of this study were to (1) determine moniliformin (MON) concentration in early maturing European Bt maize hybrids, their isogenic counterparts, commercial cultivars and experimental hybrids, (2) evaluate the association between MON concentration and ECB resistance and (3) correlate MON concentration with concentrations of other mycotoxins determined from the same plant materials. The field experiments were performed at five locations in Germany. MON concentration was significantly higher with manual infestation of ECB larvae (296 µg/kg) than under insecticide protection (66 µg/kg). Bt hybrids showed significantly lower MON concentrations and higher grain yields under manual ECB infestation than their corresponding isogenic counterparts, as well as commercial and experimental hybrids. All ECB resistance traits and grain yield under ECB infestation were significantly correlated with MON concentration. Correlations between concentrations of MON and other *Fusarium* mycotoxins were not significant. The use of Bt maize hybrids or insecticides to control ECB reduces the contamination of maize grains with MON in Central Europe. The presence of resistance genes against *Fusarium* species in the current elite maize germplasm was indicated by ECB susceptible non-Bt hybrids with low-MON concentrations.

Martel, C., A. Rejasse, F. Rousset, M. T. Bethenod and D. Bourguet (2003). "Host-plant-associated genetic differentiation in Northern French populations of the European corn borer." *Heredity* 90(2): 141-149.

The phytophagous insects that damage crops are often polyphagous, feeding on several types of crop and on weeds. The refuges constituted by noncrop host plants may be useful in managing the evolution in pest species of resistance to the *Bacillus thuringiensis* toxins produced by transgenic crops. However, the benefits of these refuges may be limited because host-plant diversity may drive genetic divergence and possibly even host-plant-mediated sympatric speciation. The European corn borer, *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae), is the main pest of maize in Europe and North America, where it was introduced early in the 20th century. It has a wide host range but feeds principally on mugwort (*Artemisia vulgaris* L.) and maize (*Zea mays* L.). *O. nubilalis* is found on mugwort only in the northern part of France, whereas it is found on maize throughout France. The extent of genetic variation at allozyme markers was investigated in populations collected from the two host plants over the entire geographical distribution of the European corn borer on mugwort in France. Allelic differentiation between pairs of populations and hierarchical analyses of pools of samples from each host plant indicate that the group of populations feeding on maize differed from the group of populations feeding on mugwort. Our results suggest (1) host-plant-related divergent selection at the genomic region surrounding the *Mpi* locus and (2) limited gene flow between the populations feeding on mugwort and those infesting maize fields. These data indicate that adults emerging from mugwort would not be useful for managing the evolution of resistance to the *B. thuringiensis* toxins in European corn borer populations.

Monetti, L., R. A. Malvar, A. Ordas and A. Cordero-Rivera (2003). "Parasitoids incidence and diversity on maize stem borers *Sesamia nonagrioides* Lefebvre and *Ostrinia nubilalis* Hubner in NW SPAIN." *Maydica* 48(2): 133-139.

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The most important insect pests on maize in Spain are the pink stem borer *S. nonagrioides* (Lefebvre) and the European corn borer *O. nubilalis* (Hubner). Parasitoid degree of control on stem borers and other maize pests in Spain is not known. The aim of this research was to evaluate the incidence and diversity of parasitoids on maize stem horns in the province of Pontevedra (NW Spain). Samplings of hybrid field maize plants (DMB-1570) were taken in four locations, from March 1999 to November 2000. Plants were dissected and stem borer overwintering and non-overwintering larvae were collected in separated plastic boxes. Larvae of *Mythimna* spp. and *Helicoverpa armigera* were also collected. Larvae were reared in the insectary and adult parasitoids obtained from them were determined. Diversity of parasitoids was in general very ton,. The most frequently found species on non-overwintering larvae was *Lydella thompsoni* (Herting) (Diptera: Tachinidae). Differences in percentage of parasitism (PP) between *O. nubilalis* and *S. nonagrioides* were significant. *Lydella thompsoni* was also the dominant parasitoid on overwintering larvae. Its PP was higher on *O. nubilalis* than on *S. nonagrioides*. The correlation between number of stem borer per plant and percentage of parasitised larvae was not significant, neither for *S. nonagrioides* nor for *O. nubilalis*. Shannon-Wiener index as a measure of parasitoid diversity was similar in the different hosts. In conclusion, a very low parasitoid natural control on maize borers, in hybrid corn crops grown at the province of Pontevedra was found. Low numbers of parasitoids and low percentage of parasitism in the studied area make difficult to draw definitive conclusions. Stem borers seem to be protected from parasitoids by several circumstances, specifically the development of their immature stages within refuges (the stalks), but other factors probably would contribute to the situation.

Musser, F. R. and A. M. Shelton (2003). "Predation of *Ostrinia nubilalis* (Lepidoptera : Crambidae) eggs in sweet corn by generalist predators and the impact of alternative foods." *Environmental Entomology* 32(5): 1131-1138.

Generalist predators are common in most agricultural cropping systems. However, pest control from these predators is often overlooked as a component of integrated pest management (IPM) because the extent of predation is generally unknown and difficult to assess. In western New York sweet corn (*Zea mays* L.), the primary predators are *Orius insidiosus* (Say), *Coleomegilla maculata* (DeGeer), and *Harmonia axyridis* (Pallas). European corn borer [*Ostrinia nubilalis* (Hubner)] is the primary insect pest. The objectives of this study were to compare *O. nubilalis* egg predation rates for these three species and to understand how egg predation by these predators is affected by the availability of alternative food. Laboratory data indicate that all three predators feed on *O. nubilalis* eggs. *C. maculata* consumed more eggs than *H. axyridis* or *O. insidiosus*. Immatures of *C. maculata* and *O. insidiosus* readily completed development on a diet of *O. nubilalis* eggs, but *H. axyridis* larvae could not complete development on this diet. The presence of corn leaf aphids [*Rhopalosiphum maidis* (Fitch)] and corn pollen reduced egg predation per insect for some stage of all species. The reduction in *O. nubilalis* egg predation associated with the presence of aphids was confirmed in field cage studies and was similar among the coccinellid populations tested. Field studies comparing aphids, predator populations, and *O. nubilalis* egg predation show that reduced egg predation per insect more than offsets the higher populations encountered when aphids and pollen are numerous, resulting in less biological control of *O. nubilalis* when alternative foods are available.

O'Rourke, P. K. and W. D. Hutchison (2003). "Sequential sampling plans for estimating European corn borer (Lepidoptera : Crambidae) and corn earworm (Lepidoptera: Noctuidae) larval density in sweet corn ears." *Crop Protection* 22(7): 903-909.

We developed a flexible fixed-precision sequential sampling plan for estimating the density of European corn borer, *Ostrinia nubilalis* Hubner and corn earworm, *Helicoverpa zea* (Boddie), larvae, using infestation data collected from 1994 to 2000. The purpose of each sampling plan was to provide statistically sound estimates of larval densities for each pest in sweet corn ears, near harvest, with minimal cost. Sweet corn variety plots and commercial production fields were sampled to obtain a wide range of *O. nubilalis* and *H. zea* densities typically found in sweet corn, in the Midwestern USA. Sampling parameters were estimated from 84 and 68 data sets for *O. nubilalis* and *H. zea*, respectively. An additional 15 independent data sets, for each species, were used to validate the fixed-precision sequential sampling plans with resampling software. Dispersion patterns for *O. nubilalis* and *H. zea* were determined to be random and uniform, respectively, from Taylor's power law. For *O. nubilalis*, at densities of 0.24-4.08 larvae/ear, an average sample number (ASN) of only 38 ears was necessary to achieve a desired precision level (SE/mean) of 0.25. As the precision level was increased to 0.10, average sample size increased to 227 ears. For *H. zea*, at densities of 0.20-2.05 larvae/ear, an ASN of 27 ears was required to achieve a desired precision level of 0.25. As the precision level was increased to 0.10, sample size increased to 160 ears. The sequential sampling plans will be useful to researchers for

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quantitative assessment of integrated pest management (IPM) strategies, via rapid estimation of larval density per ear, the primary determinant of IPM efficacy and product quality near harvest. Additionally, these plans can be used to determine the background density necessary for estimating the frequency of *O. nubilalis* or *H. zea* larvae found in transgenic Bt sweet corn ears expressing *Bacillus thuringiensis* proteins. (C) 2003 Elsevier Science Ltd. All rights reserved.

Pilcher, C. D. and M. E. Rice (2003). "Economic analysis of planting dates to manage European corn borer (Lepidoptera : Crambidae) with Bt corn." *Journal of Economic Entomology* 96(3): 941-949.

Planting dates of transgenic *Bacillus thuringiensis* Berliner (Bt) corn were adjusted to determine the utility in managing European corn borer, *Ostrinia nubilalis* (Hubner). Transgenic Bt (events 176 and Bt11) corn and non-Bt corn were planted at three different times to use the early and late-planted corn as a potential trap crop for ovipositing European corn borer moths. Grain moisture and yields were recorded to determine the economic benefits of Bt corn planted on the different dates, based on European corn borer populations and corn damage data collected before harvest. Data were recorded from three locations in southwestern, central, and northeastern Iowa for three summers (1996-1998). Economic benefits are discussed in relation to EILs and yield results. Adjusting the planting dates of Bt and non-Bt corn provided variable economic differences among planting dates in northern Iowa; however, greater economic benefits were realized when Bt corn was planted late during the planting sequence in central and southwestern Iowa. These results suggest that planting corn should be conducted in a timely manner and, if delayed or required to plant late, planting Bt corn would likely provide greater economic benefits. Although yield and economic variability were high, using Bt corn in combination with planting date adjustments may be a viable option for managing European corn borer.

Spangler, S. M., D. D. Calvin and M. A. Nemeth (2003). "Infestation of European corn borer (Lepidoptera : Crambidae) in sweet corn as predicted by time of oviposition." *Journal of Economic Entomology* 96(2): 413-419.

Oviposition by European corn borer, *Ostrinia nubilalis* Hubn, was examined in relation to sweet corn development from 1994 to 1996, and related to harvest infestation levels. Stepwise multiple regression and linear regression showed that 79-87% of the variability of larvae per ear or proportion of ears infested at harvest was explained by the number of egg masses laid from about anthesis to brown silk stages. The analyses indicated three periods of oviposition with differing implications to harvest infestation level: (1) eggs laid from 784-337 degree-days (DD) before harvest (before green tassel) had very low correlation to harvest infestation; (2) eggs laid from 336-169 DD before harvest (green tassel to green silk) were highly correlated with harvest infestation; and (3) eggs laid during the last 168 DD of sweet corn development (green silk to harvest) had low to moderate correlation with harvest infestation. The 336-169 DD period corresponded to the anthesis to brown silk growth stages, which was approximate to 14-21 d long, and would be the likely period for optimum chemical control. The results of this study are compared with existing recommendations from the midwestern and northeastern U.S., and potential explanations for the patterns observed are discussed.

Thomas, Y., M. T. Bethenod, L. Pelozuelo, B. Frerot and D. Bourguet (2003). "Genetic isolation between two sympatric host-plant races of the European corn borer, *Ostrinia nubilalis* Hubner. I. sex pheromone, moth emergence timing, and parasitism." *Evolution* 57(2): 261-273.

Adaptation to different environments may be a powerful source of genetic differentiation between populations. The biological traits selected in each environment can pleiotropically induce assortative mating between individuals of these genetically differentiated populations. This situation may facilitate sympatric speciation. Successful host shifts in phytophagous insects provide some of the best evidence for the ecological speciation that occurs, or has occurred, in sympatry. The European corn borer, *Ostrinia nubilalis* (Lepidoptera: Crambidae), colonized maize after its introduction into Europe by humans about 500 years ago. In northern France, two sympatric host races feed on maize (*Zea mays*) and mugwort (*Artemisia vulgaris*), respectively. We investigated the factors involved in the genetic isolation of these two races at a field site near Paris, France. We identified two biological differences that might make a significant contribution to the genetic divergence between sympatric populations feeding on the two host plants. First, assortative mating may be due to differences in the moth emergence pattern between the two races: mugwort-race moths emerged on average 10 days earlier than maize-race moths. In addition, the males emerged earlier than females in both races. Hence, the likelihood of mating between maize-race males and mugwort-race females was higher than that

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of mating between mugwort-race males and maize-race females. Second, the females feeding on mugwort and maize produced sex pheromones with different E/Z isomeric ratios of Delta-11-tetradecenyl acetate. This difference in mate recognition systems reinforces the potential for assortative mating in the two races. During the experiment, overwintering mortality was much lower on maize than on mugwort. This difference was due to a braconid parasitoid wasp, *Macrocentrus cingulum*, that killed more than 50% of the larvae overwintering on mugwort but did not infest larvae diapausing on maize. Hence, by colonizing maize, European corn borer populations probably escaped from numerous predators, competitors, and parasitoids, such as *M. cingulum*. This decrease in host-associated selection may have favored the colonization of this new host. Finally, throughout this experiment we observed selection at two allozyme loci (or at linked loci): *Tpi* and *Mpi*. The *Tpi* locus is tightly linked with the genes involved in the response of the male to the sex pheromone and in developmental timing. The location of these traits on the Z chromosome may play a role in shortening the time required for the evolution of premating barriers.

- Yue, B. S., G. E. Wilde and F. Arthur (2003). "Evaluation of thiamethoxam and imidacloprid as seed treatments to control European corn borer and Indianmeal moth (Lepidoptera : Pyralidae) larvae." *Journal of Economic Entomology* 96(2): 503-509.
- Efficacy of thiamethoxam (Cruiser) and imidacloprid (Gaucho) were evaluated as seed treatments for controlling European corn borer, *Ostrinia nubilalis* (Hubner) and Indianmeal moth, *Plodia interpunctella* (Hubner) larvae in stored grain. At approximate to 22-26 degrees C, all fifth instar European corn borers died after two or 4 d of exposure to corn treated with 250 and 500 ppm thiamethoxam, respectively, while mortality of larvae exposed for two and 4 d on corn treated with 6.3-937.5 ppm imidacloprid did not exceed 48% at any concentration. At 29 degrees C, all nondiapausing fifth instars were killed after 3, 4, and 6-d exposure to 400, 300 and 200-ppm thiamethoxam, respectively, while survival increased at successively lower concentrations of 100, 50, 25, and 12.5 ppm. At 29 degrees C, the LC50 decreased from 85.9 to 7.2 ppm as the duration of exposure on treated corn increased from 2 to 6 d. All second and third instar Indianmeal moth larvae died after a 5 d exposure period to corn grain treated with thiamethoxam at 50 ppm or higher, but as the larvae aged, higher concentrations and longer exposure periods were required to give 100% mortality of each larval instar. Similar results were obtained when larval Indianmeal moths were exposed on corn treated with imidacloprid, or on sorghum treated with thiamethoxam. Mature wandering phase fifth instars were the most tolerant larval stage of the Indianmeal moth.
- Zoerb, A. C., T. Spencer, R. L. Hellmich, R. J. Wright and B. D. Siegfried (2003). "Larval distribution and survival of second generation European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera : Crambidae) on Event 176 Bt Corn." *Crop Protection* 22(1): 179-184.
- European corn borer *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae) larvae that have completed development on Event 176 Bt corn hybrids have either survived exposure to sublethal doses of Cry1Ab Bt toxin or exploited plant tissues that do not express the toxin. To evaluate the impact of such exposure on larval establishment and survival, Event 176 plants with and without tassels and a non-Bt isolate were infested with *O. nubilalis* egg masses during anthesis. On the non-Bt plants, larval establishment occurred primarily on pollen collecting in the leaf axils, silks and ears. In contrast, almost no larvae were recovered from leaf axils of the Bt treatments and at least 50% fewer larvae were recovered from the silks and ears during the first 2 weeks after infestation relative to the non-Bt plants. The larvae recovered from Bt treatments weighed significantly less than those observed in the non-Bt isolate at 4 weeks after infestation. By the eighth week, the larval weights of all three treatments were similar in three of four different field tests, suggesting that second generation larvae have the ability to compensate for initial exposure to sublethal doses of Bt toxin. In laboratory assays involving exposure of neonate larvae to silks of Event 176 and non-Bt corn, survival of neonate *O. nubilalis* was not different although larval weights were significantly reduced (2- to 6-fold). These results suggest that second generation larvae completing development on Event 176 corn do not completely avoid exposure to the Bt toxin, although those that do survive are able to compensate for these sublethal effects. The implication of these results is that Event 176 hybrids do not appear to satisfy requirements for high dose that are recommended for resistance management purposes. (C) 2002 Elsevier Science Ltd. All rights reserved.
- Ahmad, A., S. B. Maqbool, S. Riazuddin and M. B. Sticklen (2002). "Expression of synthetic CRY1AB and CRY1AC genes in Basmati rice (*Oryza sativa* L.) variety 370 via Agrobacterium-mediated transformation for the control of the European corn borer (*Ostrinia nubilalis*)." *In Vitro Cellular & Developmental Biology-Plant* 38(2): 213-220.

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Movement of pests to non-host crops due to resistance of their host plants is discussed. We report the simultaneous control of the European corn borer (*Ostrinia nubilalis*) and protection of transgenic rice (*Oryza sativa*) from the damages of this non-host pest. Indica rice Basmati 370 variety was genetically engineered via the Agrobacterium-mediated system for expression of *Bacillus thuringiensis* (*cry1Ab* and *cry1Ac*), hygromycin resistance (*hpt*) and beta-glucuronidase (*gus*) genes. Molecular analysis of R0 and R1 progeny plants confirmed the integration, transcription and translation of all transgenes, with a 100% cointegration of linked genes. Southern blot analysis revealed the integration of transgenes in the range of one to three copy numbers. Northern blots revealed the presence of intact, full-length transcripts of the *cry1Ab* and *cry1Ac*. The expression of *Cry1Ab* and *Cry1Ac* was estimated up to 0.1% of total soluble protein. Inheritance of the introduced genes to R1 progeny was found to be in agreement with the Mendelian ratio in most of the transgenic lines. Bioassays, feeding of R1 progeny, of four independent transgenic lines, showed high levels of resistance to the European corn borer. Transgenic lines showed 100% mortality 5 d after the infestation in the bioassay experiments.

Andow, D. A. (2002). "Ancestral feeding and survival of offspring in European corn borer." *Entomologia Experimentalis Et Applicata* 103(2): 115-122.

Experiments were conducted to evaluate the influence of ancestral adult feeding by European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae), on larval survival in the field and neonate movement behavior in laboratory. Larval survival was higher when either the grandparental or parental generation had fed, but the feeding sites of the surviving larvae were not affected by ancestral feeding condition. This is the first evidence that grandparental feeding could influence larval survival in the field. Larval movement was observed in the laboratory. Silking speed of neonates was faster when either grandparents or parents had fed, while walking speed was faster only when parents had fed. No broad-sense genetic correlation was found between silking speed and walking speed. Broad-sense heritability among feeding histories were not significant for silking speed, but was significantly greater than zero for walking speed when grandparents fed and parents did not. These intergenerational effects could induce complex population dynamics in this species.

Baute, T. S., M. K. Sears and A. W. Schaafsma (2002). "Use of transgenic *Bacillus thuringiensis* Berliner corn hybrids to determine the direct economic impact of the European corn borer (Lepidoptera : Crambidae) on field corn in eastern Canada." *Journal of Economic Entomology* 95(1): 57-64.

Transgenic corn expressing *Bacillus thuringiensis* Berliner (Bt corn) (Maximizer and Yieldgard hybrids, Novartis Seeds), non-Bt isolines and high-performance (check) hybrids were evaluated for European corn borer, *Ostrinia nubilalis* (Hubner), damage and grain yield in commercial strip plots across Ontario in 1996 and 1997. Bt corn hybrids reduced stalk tunneling damage by 88-100%. In 1996, minimal damage was found in locations where only one generation of European corn borer occurred per year. Bt corn proved its greatest potential for reducing the number and length of, cavities below the primary ear in locations where two generations of European corn borer were present. A yield response to using Bt hybrids only occurred when levels of tunneling damage exceeded 6 cm in length. European corn borer infestations resulted in a 6 and 2.4% reduction in yield for 1996 and 1997, respectively, when Bt hybrids were compared with their non-Bt isolines. A linear relationship was found between tunnel length per plant in centimeters (x) and yield protection (%) obtained from using Bt corn (y) ($y = 1.02 + 0.005x$, $r(2) = 0.7217$). At a premium of \$34.58 Canadian (CDN) per hectare for Bt corn seed, an infestation of at least 6 cm of corn borer tunneling per plant was required to break even at a market price for corn of \$2.50 per bushel CDN. During the period of study, low infestations (0-2 cm) of European corn borer occurred at 25% of the locations assessed, moderate infestations (4-6 cm) occurred at 42% of the locations, and high infestations (>6 cm) occurred at 33% of the locations. At a corn price of \$3.00 per bushel CDN and seed premiums of \$34.58 per hectare CDN, 5 cm of tunneling was required for a return on investment in Bt seed, comprising only 55% of the growers in the study. With infestations of more than 6 cm of tunneling occurring only 33% of the time, a return on seed investment would be realized in only one of three growing seasons. At a seed premium of \$24.70 per hectare CDN per year, at least \$74 per hectare CDN in the year of infestation would be required to make up for the two years of no. return. In this study, a \$74 per hectare CDN return at a corn price of \$9.26 per hectare CDN with >16 cm of tunneling damage would have occurred only 7.3% of the time.

Durham, E. W., B. D. Siegfried and M. E. Scharf (2002). "In vivo and in vitro metabolism of fipronil by larvae of the European corn borer *Ostrinia nubilalis*." *Pest Management Science* 58(8): 799-804.

In vivo and in vitro metabolism of [14 C]fipronil was examined in a susceptible European corn borer (*Ostrinia nubilalis*, Hubner) laboratory strain. [C-14]Fipronil penetrated the larval integument slowly, with 71.5% of the applied radioactivity recovered from surface rinses 24h after topical application. Despite this slow penetration, radioactivity was detected in both the excrement and internal organo-soluble fractions. Radioactivity in the internal aqueous fraction and tissue pellet accounted for less than 0.8% of total radioactivity. The in vivo studies suggest that fipronil oxidation to its sulfone metabolite is the major route of metabolic conversion. In vitro studies were performed using subcellular microsomal fractions isolated from European corn borer larval midguts. Cytochrome P450-dependent monooxygenase activity (methoxyresorufin O-demethylase) was consistently observed in midgut preparations, and formation and detection of the sulfone metabolite in the same midgut preparations was also NADPH-dependent and inhibited by piperonyl butoxide. In vitro metabolism results indicate microsomal monooxygenases are responsible for the conversion of fipronil to its sulfone form in the European corn borer. (C) 2002 Society of Chemical Industry.

Gatch, E. W. and G. P. Munkvold (2002). "Fungal species composition in maize stalks in relation to European corn borer injury and transgenic insect protection." *Plant Disease* 86(10): 1156-1162.

The maize stalk rot complex is comprised of several fungal pathogens, including *Gibberella zeae*, *Colletotrichum graminicola*, *Stenocarpella maydis*, and several members of the genus *Fusarium*. The European corn borer (ECB) (*Ostrinia nubilalis*) can contribute to stalk rot development by creating entry wounds and by serving as a vector of some stalk rot pathogens, particularly *Fusarium verticillioides*. Transgenic insect protection of maize hybrids with insecticidal proteins derived from *Bacillus thuringiensis* greatly reduces ECB injury and may therefore alter the species composition and diversity of the stalk rot complex. Field experiments were conducted in 1998, 1999, and 2000 to compare the species composition and diversity of fungi infecting stalks of Bt and non-Bt maize hybrids. Hybrids representing five Bt types (or "events") and their near-isogenic non-Bt counterparts were subjected to manual and natural infestations with ECB larvae. Stalk tissue samples were cultured to determine fungal species composition. At least one species was isolated from nearly every stalk and from both diseased and symptomless tissues. *G. zeae* was the most common species in 1998 and 1999, but *C. graminicola* was most common in 2000. The mean proportions of stalks infected with *F. verticillioides*, *F. proliferatum*, and *F. subglutinans* were significantly lower in Bt hybrids than in non-Bt hybrids in 2 of the 3 years. Conversely, the mean proportion of stalks infected with *G. zeae* was higher in some Bt hybrids than their non-Bt counterparts in two of the three years. *F. verticillioides* was more likely to be isolated from ECB-injured tissue, whereas *G. zeae* and *C. graminicola* were more likely to be isolated from tissue not associated with ECB injury. The overall species diversity of the stalk rot complex was lower in some Bt hybrids compared with their non-Bt counterparts in 1998 and 1999. ECB activity appeared to alter fungal species composition in stalks, reflecting the association between ECB injury and specific stalk rot pathogens, particularly *F. verticillioides*. The species composition of fungi infecting stalks of Bt hybrids differed from that of non-Bt hybrids, but the implication, of this result are not yet clear.

Hoffmann, M. P., M. G. Wright, S. A. Pitcher and J. Gardner (2002). "Inoculative releases of *Trichogramma ostrinae* for suppression of *Ostrinia nubilalis* (European corn borer) in sweet corn: field biology and population dynamics." *Biological Control* 25(3): 249-258.

The effectiveness of inoculative releases of *Trichogramma ostrinae* Pang and Chen for suppression of *Ostrinia nubilalis* (Hubner) in sweet corn was assessed. Early-season, low-density (75,000 females ha⁻¹) releases were made, and establishment, levels of parasitism and sex ratios of emerging *T. ostrinae* quantified. *T. ostrinae* established effectively for each season that they were released, but appeared to be unable to overwinter. Parasitism levels tracked egg mass numbers closely, and *T. ostrinae* persisted in fields even where insecticides were applied. Parasitism by indigenous *Trichogramma* species was similar to 3%. Field populations of *T. ostrinae* were distinctly female biased (similar to 78%), with males produced in the majority of broods. Numbers of males did not increase linearly with number of *O. nubilalis* eggs parasitized, but appeared to remain constant above an egg mass size of about 20 eggs. A Type-I functional response to increasing egg and egg mass density was found under field conditions, where the proportion of egg masses parasitized remained constant with increasing egg mass density. A relatively consistent percentage of eggs per egg mass was parasitized, with a linear increase in number of eggs parasitized with increasing number of eggs per egg mass. These results show that *T. ostrinae* established viable reproductive populations in sweet corn following

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inoculative release, with the potential to contribute to reduced dependence on insecticides for the control of *O. nubilalis* in an integrated pest management program. (C) 2002 Elsevier Science (USA). All rights reserved.

Huang, F. N., L. L. Buschman, R. A. Higgins and H. R. Li (2002). "Survival of Kansas Dipel-resistant European corn borer (Lepidoptera : Crambidae) on Bt and Non-Bt corn hybrids." *Journal of Economic Entomology* 95(3): 614-621.

The Kansas Dipel-resistant and susceptible European corn borer, *Ostrinia nubilalis* (Hubner), were evaluated in the greenhouse on different Bt transgenic events expressed in corn hybrids. There were important differences in the resistance offered by the different Bt event corn hybrids. Hybrid comparison tests indicate that these Dipel-resistant first-instar European corn borer were not able to survive to adulthood on whorl-stage MON810, Bt11, or 176 Bt event corn plants. Third instars did not survive to adulthood on whorl-stage MON810 or Bt11. event corn plants but a small number of fifth instars were found on whorl-stage DBT418 plants infested with Dipel-resistant larvae. First and third instars of these Dipel-resistant European corn borers caused more leaf-feeding damage and more tunneling on whorl-stage Bt-corn plants than did the Dipel-susceptible European corn borers. However, in the single Bt corn hybrid test, there was no survival of the Dipel-resistant European corn borers on DK580BtX or MAX454 Bt plants 35 to 42 d after they had been infested with first instars. These results demonstrate that the current Kansas selection of Dipel-resistant European corn borer strain cannot establish reproducing populations in the tested Bt corn lines and hybrids.

Huang, Y. P., T. Takanashi, S. Hoshizaki, S. Tatsuki and Y. Ishikawa (2002). "Female sex pheromone polymorphism in adzuki bean borer, *Ostrinia scapularis*, is similar to that in European corn borer, *O. nubilalis*." *Journal of Chemical Ecology* 28(3): 533-539.

Individual analysis of the female sex pheromone of the adzuki bean borer, *Ostrinia scapularis*, has shown that the sex pheromone of this species comprised (E)-11-tetradecenyl acetate (E11-14:OAc) and (Z)-11-tetradecenyl acetate (Z11-14:OAc) at variable blend ratios. The pheromone blend could be tentatively categorized into three types with respect to the proportion of E11-14:OAc: E type (94-100%, median 99.2%), Z type (0-16%, median 3.0%), and intermediate type (I type, 48-85%, median 63.7%). In addition to the identity of components, the blend ratios in the three types were similar to those of the E strain, Z strain, and hybrid of the European corn borer, *O. nubilalis*, respectively. This finding suggests that two closely related but morphologically distinct species, *O. scapularis* and *O. nubilalis*, share almost the same sex pheromone communication systems. The significance of this similarity in the two sibling species is discussed.

Jamptong, C., M. D. McMullen, B. D. Barry, L. L. Darrah, P. F. Byrne and H. Kross (2002). "Quantitative trait loci for first- and second-generation European corn borer resistance derived from the maize inbred Mo47." *Crop Science* 42(2): 584-593.

European corn borer (ECB), *Ostrinia nubilalis* (Hubner), family Crambidae, order Lepidoptera, is a serious insect pest of maize (*Zea mays* L.) in the USA. Understanding the genetic basis for ECB resistance should increase the efficiency of breeding insect-resistant germplasm. The objectives of this study were to determine the number, genomic positions, and genetic effects of quantitative trait loci (QTL) conferring resistance to leaf feeding damage cause by first-generation ECB (1ECB, defined as the trait of leaf feeding damage) and stalk, tunneling caused by second-generation ECB (2ECB, defined as the trait of stalk tunnel damage). The study included 244 F-2:3 families derived from the cross of B73Ht (susceptible) x Mo47 (resistant). Inbred Mo47 represented a novel source of ECB resistance containing 50% tropical germplasm. The QTL analyses for three individual environments and combined across environments were performed by composite interval mapping using QTL Cartographer. Nine QTLs were identified for 1ECB on chromosomes 1 (three QTLs), 2, 4 (two QTLs), 5, 6, and 8, on the basis of data combined across environments. Seven QTLs for 2ECB were found on chromosomes 2, 5 (two QTLs), 6 (two QTLs), 8, and 9. Several of the QTLs detected are located in genomic regions reported for resistance to other stem borer pests of maize. Inconsistency of QTLs across environments complicate., use of Mo47 for marker-assisted selection of ECB resistance.

Keszthelyi, S. and A. Najat (2002). "Effect of damage caused by European corn borer (*Ostrinia nubilalis* Hubn.) on the weight and chemical quality of maize hybrids (Colomba and Occitan)." *Novenytermeles* 51(1): 39-47.

The aim of the field survey was to determine what damage was caused by the European corn borer (*Ostrinia nubilalis* Hubn.) to maize hybrids in addition to the primary symptoms (lodging, tassel fracture, etc.). The observations were carried out on the hybrids Colomba (PIONEER) and Occitan (NOVARTIS) in four replications. The hybrids responded to corn borer damage with a clearly perceptible reduction in ear weight. Changes in chemical quality parameters were also recorded. In Colomba there was a positive correlation between corn borer damage and crude fat content ($P=99.8\%$,

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$r=0.9037$). There was also a close correlation between damage and mean car weight ($P=99.3\%$, $r=0.6407$). It was clear from the results that for this hybrid there was a close correlation between the crude fat content and the mean car weight ($P=99.7\%$, $r=0.8862$). In Occitan a positive correlation was observed between the starch content and the damage ($P=96.8\%$), while the correlation between the starch content and the mean car weight was also significant ($P=94.5\%$, $r=0.6971$). Combined statistical analysis was also carried out on all the samples. The reduction in the mean car weight was closely correlated with the extent of damage ($P=99.3\%$, $r=0.6407$), which could be explained by changes in the fat content ($r=0.6455$) and the starch content ($r=0.6825$). In the combined analysis the closest correlation was found between the crude fat content and the damage ($P=99.7\%$, $r=0.6900$). The significant reduction in the starch content exhibited a less close correlation ($P=91.5\%$, $r=0.4440$), while the change in the crude protein content was not significant ($P=82.8\%$, $r=0.3593$). The change in the starch content as the result of damage proved to depend on the hybrid ($P=97.9\%$, $r=0.5698$).

Krakowsky, M. D., M. J. Brinkman, W. L. Woodman-Clikeman and M. Lee (2002). "Genetic components of resistance to stalk tunneling by the European corn borer in maize." *Crop Science* 42(4): 1309-1315.

Identification of the genes conferring resistance to European corn borer (ECB) [*Ostrinia nubilalis* (Hubner)] is an important step in understanding how resistance is expressed and whether different sources of maize (*Zea mays* L.) germplasm can be combined to enhance protection. The locations of genes for resistance to ECB tunneling have been reported but are inconsistent across studies. The objectives of this study were to map and characterize quantitative trait loci (QTL) for resistance to tunneling in De811 and compare these with related studies and with QTL for anthesis and ear height. Inbred De811 (resistant) was crossed to susceptible inbred B73 to produce a population of 147 F-3 lines. The population was artificially infested and evaluated in three environments. The F3 lines were genotyped at 88 restriction fragment length polymorphism (RFLP) loci to facilitate QTL mapping with composite interval mapping (CIM). Seven QTL for ECB tunneling were detected on chromosomes 1, 3, 4, 5, and 8, associated with 42% of the phenotypic variation. The F₃ exhibits partial dominance for resistance but only one QTL with dominant gene action was observed. An F₃ population of B73 x B52 that was evaluated in the same environments facilitated comparisons of genetic heterogeneity between inbreds De811 and B52. Only one QTL for tunneling was common between the populations, indicating that the two inbreds may contribute different genes for resistance in crosses with B73. This information could be useful for combining the favorable alleles of De811 and B52.

Kuhar, T. P., M. G. Wright, M. P. Hoffmann and S. A. Chenus (2002). "Life table studies of European corn borer (Lepidoptera : Crambidae) with and without inoculative releases of *Trichogramma Ostrinae* (Hymenoptera : Trichogrammatidae)." *Environmental Entomology* 31(3): 482-489.

Life table studies of European corn borer, *Ostrinia nubilalis* (Hubner) populations with and without inoculative releases of *Trichogramma ostrinae* (Peng & Chen) were conducted in sweet corn and field corn. Inoculative releases of *T. ostrinae* (at 72,000 females per hectare) provided relatively high parasitism of European corn borer eggs (approximately 37%) throughout the season. The increase in egg parasitism was not offset by compensatory changes in other mortality rates such as egg predation, eggs not hatching, and death of early instars after egg hatch. Early instar disappearance was a key mortality factor accounting for >70% of total mortality from egg deposition to established larvae. Egg parasitism by *T. ostrinae* was also a key mortality factor. Releases of *T. ostrinae* increased total egg and larval mortality of *O. nubilalis* from 61 to 92% in sweet corn and from 80 to 93% in field corn.

Lewis, L. C., D. J. Bruck and R. D. Gunnarson (2002). "On-farm evaluation of *Beauveria bassiana* for control of *Ostrinia nubilalis* in Iowa, USA." *Biocontrol* 47(2): 167-176.

Ostrinia nubilalis is (Lepidoptera: Crambidae) a severe pest of corn in the major corn growing areas of the United States. The efficacy of a *Beauveria bassiana* application, for season-long suppression of *O. nubilalis* was evaluated in 1996 and 1997 at locations across Iowa. *Beauveria bassiana*, Mycotech 726 (Mycotech Corporation, Butte, MT) formulated on corn grit granules (14-20 mesh) at 2.2×10^9 conidia/g and applied with a hand-held applicator at the rate of 0.4 g/plant (8.8×10^8 conidia/plant). Applications were made when plants were in the V7 or R1 growth stage. The length of larval tunneling, percentage of plants not infested with *O. nubilalis*, percentage of plants with an endophyte, and yield from treated and control plots were determined. Whorl-stage application of *B. bassiana* in 1996 resulted in a significant reduction in centimeters of tunneling (46-55%) and the percentage plants not infested by *O.*

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nubilalis. In 1997, *B. bassiana* caused significant reductions in larval tunneling at all locations (20-53%); however, a significant increase in the percentage of plants not infested with *O. nubilalis* occurred at only one location. Treatment of plants with *B. bassiana* in 1997 did not significantly increase the percentage of plants with an endophyte; however, the trend, with the exception of one site, was for a greater percentage of endophytic plants in treated versus untreated plots. A whorl-stage application of a granular formulation of *B. bassiana* was most efficacious in reducing *O. nubilalis* larval damage.

Losey, J. E., M. E. Carter and S. A. Silverman (2002). "The effect of stem diameter on European corn borer behavior and survival: potential consequences for IRM in Bt-corn." *Entomologia Experimentalis Et Applicata* 105(2): 89-96.

The ability of non-crop plants to support complete development of insect pests is an important factor for determining the impact of those plants on resistance management programs for transgenic crops. We assessed the effect of one physical factor, plant stem diameter, on the ability of plants to support full development of the European corn borer (ECB), *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae), the target pest of transgenic Bt-corn. In the field, European corn borer larvae were significantly more likely to tunnel and survive in plants with larger stem diameters. Larvae were 40 x more likely to survive on corn, the largest plant tested, compared to many of the smaller plants. In the laboratory, larvae were more likely to survive in and less likely to abandon the largest diet-filled artificial stems that varied only in stem diameter. In conditions simulating those that an ECB larvae would encounter upon abandoning a host, larvae survived up to three weeks and were able to locate corn as a new host with a significantly higher frequency than would be expected if they were foraging randomly. These results indicate that the probability of ECB larval survival to maturity on a plant other than corn is relatively low and thus these smaller stemmed non-corn plants may not make a substantial contribution to the pool of susceptible adults. Conversely, since more mature larvae are not as susceptible as neonates, any larvae that partially develop on non-corn plants and subsequently colonize Bt-corn may not be exposed to a lethal dose of the toxin. Since some proportion of the individuals that survive could be partially resistant heterozygotes the presence of non-corn host plants could facilitate the development of resistant ECB populations.

Ma, P. W. K. and W. L. Roelofs (2002). "Sex pheromone gland of the female European corn borer moth, *Ostrinia nubilalis* (Lepidoptera, Pyralidae): Ultrastructural and biochemical evidences." *Zoological Science* 19(5): 501-511.

The sex pheromone gland of the female European corn borer moth, *Ostrinia nubilalis* was studied using light and electron microscopy. The pheromone gland is formed by hypertrophied epidermal cells at the mid-dorsal region of the intersegmental membrane between abdominal segments 8 and 9/10. Active glandular cells contain extensive apical membrane foldings, a single nucleus, many free ribosomes, numerous mitochondria, microtubules and lipid droplets. Smooth endoplasmic reticulum is scanty. In young moths, the glandular cells are smaller in size, the microvilli at the apical membrane are poorly developed and the cytoplasm contains fewer mitochondria, microtubules, and no lipid droplets. The surrounding unmodified epidermal cells are small cuboidal or squamous cells. These cells have ill-defined apical membrane foldings and do not contain lipid droplets in the cytoplasm and the overlying cuticle. Fatty acids analyses revealed the presence of the sex pheromone components, (E)-11-tetradecenyl acetate, and their immediate precursors, methyl (E)-11 - and methyl (Z)-11-tetradecenoate, only in the dorsal portion of the cylindrical intersegmental membrane. Results of the present study show that the sex pheromone gland of *O. nubilalis* is restricted to the dorsal aspect of the intersegmental membrane between segments 8-9/10 and is not a ring-gland.

Magg, T., A. E. Melchinger, D. Klein and M. Bohn (2002). "Relationship between European corn borer resistance and concentration of mycotoxins produced by *Fusarium* spp. in grains of transgenic Bt maize hybrids, their isogenic counterparts, and commercial varieties." *Plant Breeding* 121(2): 146-154.

The European corn borer (ECB), *Ostrinia nubilalis* Hb., is a major pest of maize in central Europe and promotes the infection of maize with *Fusarium* spp. In this study, transgenic Bt maize hybrids Acre compared with their isogenic counterparts, and with commercial hybrids from the recommended list with regard to their level of ECB resistance and their concentration of deoxynivalenol (DON), its 15-acetyl (15-A-DON) and 3-acetyl (3-A-DON) derivatives, nivalenol (NIV), fusarenon-X (FUS-X), fumonisins (FUM), and zearalenon (ZEN) in harvested grains. The field experiments Acre performed in Germany at four locations in 1999 and at five locations in 2000. Transgenic Bt hybrids showed significantly lower means than their corresponding isogenic counterparts and than commercial hybrids for all resistance traits: damage rating of stalks, number of larvae per plant, number of larvae per ear, and percentage of damaged plants or

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ears under infestation. Among all mycotoxins analysed, DON consistently showed the highest concentration across all year x location combinations, Mycotoxin concentrations varied significantly between locations, years and genotypes, whereas mycotoxin concentrations were not significantly different between infested and protected plots. Associations between ECB resistance traits and mycotoxin concentrations were not consistent across years. It is concluded that under central European conditions, the use of Bt maize hybrids will only slightly reduce the contamination of maize kernels with mycotoxins produced by *Fusarium* spp.

Marion-Poll, F. and C. Descoins (2002). "Taste detection of phytoecdysteroids in larvae of *Bombyx mori*, *Spodoptera littoralis* and *Ostrinia nubilalis*." *Journal of Insect Physiology* 48(4): 467-476.

A number of plants produce significant amounts of phytoecdysteroids that can disrupt the hormonal levels of insects feeding upon them. Insects equipped with taste receptors sensitive to phytoecdysteroids are able to avoid such plants. How common is this strategy? By recording from the lateral and medial sensilla styloconica in two polyphagous species (*Ostrinia nubilalis* and *Spodoptera littoralis*) and in a monophagous species (*Bombyx mori*), we tested whether the receptors could detect three commonly occurring phytoecdysteroids 20-hydroxyecdysone (20E), ponasterone A (ponA) and ecdysone (E). In *B. mori*, 20E and ponA elicited dose-dependent responses with a threshold of 1 μM only in the medial sensilla. In *O. nubilalis*, 20E, E and ponA elicited responses at threshold of 1 μM in both sensilla. In *S. littoralis*, 20E elicited responses with a threshold of 10 μM in both sensilla. By means of behavioural choice tests, we show that 20E is an effective feeding deterrent for *O. nubilalis* and *S. littoralis* first instar larvae. This suggests that the perception of phytoecdysteroids is more common among phytophagous lepidoptera than previously thought, although their toxicity or antifeedancy varies between species. (C) 2002 Elsevier Science Ltd. All rights reserved.

Pilcher, C. D., M. E. Rice, R. A. Higgins, K. L. Steffey, R. L. Hellmich, J. Witkowski, D. Calvin, K. R. Ostlie and M. Gray (2002). "Biotechnology and the European corn borer: Measuring historical farmer perceptions and adoption of transgenic Bt corn as a pest management strategy." *Journal of Economic Entomology* 95(5): 878-892.

A 3-yr, multi-state survey of farmers who had planted transgenic *Bacillus thuringiensis* (Bt) corn was conducted to evaluate perceptions of Bt corn performance and its utility as a management option for European corn borer, *Ostrinia nubilalis* (Hubner). A questionnaire was sent to farmers in Illinois, Iowa, Kansas, Minnesota, Nebraska, and Pennsylvania who had grown Bt corn during the growing seasons of 1996, 1997, or 1998. There were 7,427 usable questionnaires returned with the following response percentages: 1996 (42.1%), 1997 (35.0%), and 1998 (22.6%). Adoption rates, based on percentage of acreage planted to Bt corn, increased dramatically from 1996 (10.5%) to 1998 (40.7%). The states growing the highest percentage of Bt corn were Minnesota, Iowa, and then Nebraska. However, Illinois, was adopting Bt corn at the fastest rate. Historical use of insecticides did not influence the adoption of Bt corn. In addition, of those farmers who used insecticides to control European corn borer, the percentage that decreased their use of insecticides nearly doubled from 13.2% (1996) to 26.0% (1998) over this 3-yr period. The primary reason farmers planted Bt corn was to eliminate the yield loss caused by European corn borer. Scouting for European corn borers decreased from 91% (scouting 2.2 times a year) in 1996 to 75% (scouting 1.8 times a year) in 1998. The percentage of farmers not scouting for European corn borers increased from 9.6% (1996) to 25% (1998). Most farmers believed yields of Bt hybrids were either similar to or greater than the yields of non-Bt hybrids. Minnesota farmers perceived the greatest yield advantages. Farmers are becoming more aware of insect resistance management guidelines; however, they also clearly show preferences for having the flexibility to use different spatial plantings of Bt and non-Bt corn. Finally, after having planted Bt corn and obtained excellent control of European corn borer, most farmers believed that this insect had been causing more yield loss than they previously had suspected in their non-Bt corn. The data represented here provide an historical foundation for how transgenic Bt corn was used by farmers during the first 3 yr of commercial availability, their initial perceptions on the performance of this technology, and their attitudes regarding management of the European corn borer.

Puskas, J., L. Nowinszky, C. Karossy, Z. Toth, P. Nemeth and E. Nagy (2002). Relationship between UV-B radiation of the Sun and the light trapping of the European corn borer (*Ostrinia nubilalis* Hbn.). *Ultraviolet Ground- and Space-Based Measurements, Models, and Effects*. J. R. Slusser, J. R. Herman and W. Gao. 4482: 363-366.

Biological systems are extremely sensitive to changes in ultraviolet radiation reaching the Earth's surface. Atmospheric ozone absorbs considerable part of the UV radiation coming from the Sun and harmful for biosphere so only a very

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small part of it can reach the Earth's surface thus organisms adapted to that intensity. The light-trap success of European corn borer (*Ostrinia nubilalis* Hbn.) was examined at those nights when during the previous day the UV-B radiation had different intensity. UV-B data used for examination come from measurements in the Keszthely observatory of the Hungarian Meteorological Service by Robertson-Berger UV-Biometers. The light-trap catch data of European corn borer originated from the national light-trap network between 1994-1998. Relative catch (RC) values were calculated from the daily data of UV-B radiation relating to the summer half-year. The daily data were divided with the weighted average values of previous, actual and following ten days. We calculated RC values from daily light-trap results of European corn borer for all observing stations and swarming times. The RC values were categorised into UV-B groups belonging to each day. Three points moving averages were made from average values of the 14 groups with using our own method. We made correlation calculation between the related values of UV-B and RC. Our results prove light-trap catch is low if the values of UV-B radiation are significantly lower considering to the average. Currently we can not explain how the nocturnal insects can take notice of low UV-B radiation measured during the previous day. The RC is similar to the expectable value if the value of UV-B radiation is more than the average, but the RC has a little bit decreasing tendency. These results can be well valuable for the plant protection prognostic.

Ramputh, A. I., J. T. Arnason, L. Cass and J. A. Simmonds (2002). "Reduced herbivory of the European corn borer (*Ostrinia nubilalis*) on corn transformed with germin, a wheat oxalate oxidase gene." *Plant Science* 162(3): 431-440.

The strategy of targeting expression of a constitutively regulated gene to generate H₂O₂ in the extracellular matrix, to reduce herbivory of the European corn borer (ECB) [*Ostrinia nubilalis* (Hubner)] was tested by transforming corn with germin, a wheat oxalate oxidase (OXO) gene, regulated by the rice actin promoter elements (pAct-OXO). With two independent transformation events, enzyme activity was stable over seven generations of backcrossing into three maize inbred lines. Enzyme activity remained associated with the cell wall debris fraction of water extracted tissues. Leaf tissue of the germin transgenics had elevated levels of H₂O₂. In vitro leaf feeding bioassays demonstrated that ECB larvae feeding was significantly reduced and larval growth and development were delayed on all ECB infested germin transgenic lines. This reduced ECB feeding was confirmed under field conditions. Most significantly, stalk tunneling damage, measured at plant harvest, was substantially reduced in all germin transgenic lines. The reduction of tunneling by 50% in the transgenic lines is indicative of lower levels of ECB survival which should be significant in ECB epidemiology. Possible mechanisms of resistance include modifications in plant cell wall chemistry, activation of pathogen resistance genes and effects of H₂O₂ and germin on insect physiology are discussed. (C) 2002 Elsevier Science Ireland Ltd. All rights reserved.

Schmitz, G., I. Rothmeier, G. Greib, M. Ross-Nickoll and D. Bartsch (2002). "Process and potential of the spreading of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in Northwest Germany." *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection* 109(6): 624-629.

In Germany, the Z race of the European Corn Borer (*Ostrinia nubilalis*) has recently been spreading northwards. The insect has been moving into the southern Rhineland since about 1996. Its northern border was described in detail in 2000. Continued mapping in 2001 showed that the northern border had shifted again by up to 12 km. Preliminary estimations of the further spreading process are made in consideration of the major migration factors.

Wright, M. G., T. P. Kuhar, M. P. Hoffmann and S. A. Chenus (2002). "Effect of inoculative releases of *Trichogramma ostrinae* on populations of *Ostrinia nubilalis* and damage to sweet corn and field corn." *Biological Control* 23(2): 149-155.

European corn borer (*Ostrinia nubilalis*) is one of the most injurious pests of sweet and field corn in the United States. We report here on controlled experiments in which an egg parasitoid (*Trichogramma ostrinae*) was released inoculatively (75,000 females ha⁻¹) early in the growing season (when corn plants were at the early to mid-whorl stage) to test its efficacy as a biological control agent of *O. nubilalis*. Releases were made in fields of sweet corn and field corn. Numbers of eggs laid in experimental plots, larval tunnels, and larvae and proportion of damaged ears were determined. Mass of ears was determined for field corn plots. In sweet corn, despite greater oviposition by *O. nubilalis* in *T. ostrinae* release plots, the number of borer larvae, stalk tunnels, and damaged ears was reduced by similar to 50% compared with those in nonrelease plots. This reduction in damage was consistent for early and late-planted sweet corn. In the field corn plots, larger numbers of *O. nubilalis* eggs were again laid in some release plots than in control plots. However, *O. nubilalis* damage appeared to be suppressed in *T. ostrinae* release plots, although no significant

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differences were found in most. These results, were promising, but further work is required in field, corn. The results for sweet corn demonstrated that inoculative releases of *T. ostrinae* provide suppression of *O. nubilalis* populations adequate to reduce damage significantly. (C) 2001 Elsevier Science.

Wright, R. J., T. A. Devries, L. J. Young, K. J. Jarvi and R. C. Seymour (2002). "Geostatistical analysis of the small-scale distribution of European corn borer (Lepidoptera : Crambidae) larvae and damage in whorl stage corn." *Environmental Entomology* 31(1): 160-167.

The small-scale spatial distribution of European corn borer, *Ostrinia nubilalis* (Hubner), larvae and damage in whorl stage corn, *Zea mays* L., was characterized using geostatistics. Spatial distribution of *O. nubilalis* larval feeding damage was studied at Clay Center, North Platte, and Concord, NE, during June-July 1992-1994, and spatial distribution of *O. nubilalis* larvae and damage was studied at Clay Center in June 1997. Semivariograms were calculated to model the change in spatial correlation with increasing distance between samples. Spatial distribution of larval damage during 1992-1994 was best described using a spherical model. Damage was spatially correlated among plants at distances up to 2.84 m apart. The spatial distribution of larvae in 1997 was best described using an exponential model for three of seven data sets, a spherical model for one of seven data sets and no model fit three of seven data sets. Larvae were spatially correlated among plants at distances up to 3.05 m apart. These data have implications for developing sampling plans for management of *O. nubilalis*, and for site-specific agriculture.

Andow, D. A. (2001). "Patterns of feeding and mortality of adult European corn borer (Lepidoptera : Crambidae) in the laboratory." *Annals of the Entomological Society of America* 94(4): 563-565.

I studied the diurnal and ontological patterns of feeding by European corn borer adults, *Ostrinia nubilalis* (Hubner), and characterized the effect of feeding on adult mortality in the laboratory. Adults were provided a sucrose diet and water ad libitum, and were observed at periodic intervals to estimate the proportion feeding on sucrose or water. Dead adults were counted daily to estimate mortality. Adults preferred to feed on the sucrose diet during the first Meek of life, but not thereafter. Feeding occurred mainly just after the lights were turned off but also just after lights were turned on, and this time preference also waned by the second Meek of life. Daily mortality rates increased during adult life. These results are consistent with other studies on adult mortality, and suggest that feeding on sugar may be beneficial for adults only when their life expectancy exceeds 4 d.

Andow, D. A. and T. J. Stodola (2001). "Detecting subtle effects of diet preservatives on European corn borer (Lepidoptera : Crambidae)." *Journal of Entomological Science* 36(3): 285-296.

A wheat germ-casien-agar diet for rearing European corn borer, *Ostrinia nubilalis* Hubner, contains five preservatives, sorbic acid (0.055% w/w), para-hydroxybenzoic acid methyl ester (methyl paraben, 0.144% w/w), propionic acid (0.488% w/w), aureomycin (0.292% w/w), and phosphoric acid (0.084% w/w). We conducted studies to determine if the first four of these preservatives can be reduced. In the first experiment we eliminated simultaneously propionic acid and aureomycin and either retained all sorbic acid and methyl paraben or reduced them by 50% or eliminated them as well. The diet with full sorbic acid and methyl paraben and no propionic acid and aureomycin performed similar to the unchanged control. All other diets resulted in microbial contamination that reduced survival of larvae. In the second experiment, we compared 5 diets, the full complement of sorbic acid and methyl paraben with elimination or 50% reduction of both propionic acid and aureomycin, elimination of aureomycin and 50% reduction in propionic acid. The last diet had no aureomycin or propionic acid and 50% reduction in methyl paraben. Some of the replicate dishes with diets without any propionic acid or aureomycin had microbial contamination that reduced survival of larvae. Larval survival was similar for the remaining diets. The diet without aureomycin and 50% reduction in propionic acid produced large larvae that were about half as variable in size as those from the control diet, suggesting that a reduction in these preservatives would increase moth uniformity. No differences in development rate were observed among the diets.

Barriere, Y., R. Verite, P. Brunschwig, F. Surault and J. C. Emile (2001). "Feeding value of corn silage estimated with sheep and dairy cows is not altered by genetic incorporation of Bt176 resistance to *Ostrinia nubilalis*." *Journal of Dairy Science* 84(8): 1863-1871.

A genetically modified Bt176 corn hybrid (Rh208Bt)-providing control of European corn borer damage-and the conventional isogenic hybrid (Rh208)-harvested as whole plant silage-were evaluated in three separate feeding trials to

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verify that the in vivo feeding value was substantially equivalent among modified and conventional hybrids. In the first trial, after a week of preexperiment, two sets of six Texel sheep, housed in digestibility crates, were fed silage sources of Rh208 and Rh208Bt; hybrids, and silage of three additional control varieties of low, intermediate, and high feeding value (Rh289, Adonis, and Adonis bm3) for 1 wk. Feed offered to sheep was adjusted to maintenance requirements based on metabolic body weight. Agronomic and biochemical traits were similar among the Rh208 and Rh208Bt; hybrids. Organic matter digestibility (67.1 and 67.6%), crude fiber digestibility (52.9 and 54.2%), and neutral detergent fiber digestibility (50.2 and 49.0%) were not significantly different among Rh208 and Rh208Bt hybrids. In the second trial, two sets of 24 Holstein cows were fed silage from Rh208 and Rh208Bt corn hybrids for 13 wk, 9 wk after calving, and including 2 wk of preexperiment. Fat-corrected milk yield (31.3 and 31.4 kg/d), protein content (31.7 and 31.6 g/kg) and fat content (36.7 and 37.0 g/kg) in milk of dairy cows were unaffected by hybrid source. Body weight gains of cattle were not different. However, intake was significantly higher in cows fed Rh208Bt silage. In the third trial, five midlactation multiparous Holstein cows were successively fed the silage from Rh208 and Rh208Bt corn hybrids 2 or 3 wk. Data were considered only for the last week of each period. There were no significant effects on protein fractions, fatty acid composition, or coagulation properties of milk between Rh208 and Rh208Bt fed cattle. Cattle and sheep can perform equally well with a conventional or a genetically modified Bt176 corn silage.

Bruck, D. J., L. C. Lewis and R. D. Gunnarson (2001). "Interaction of *Nosema pyrausta* and temperature on *Ostrinia nubilalis* egg production and hatch." *Journal of Invertebrate Pathology* 78(4): 210-214.

Nosema pyrausta is an obligate pathogen causing reduced fecundity and longevity of *Ostrinia nubilalis*. This study was conducted to determine the combined effects of *N. pyrausta* infection and temperature on *O. nubilalis* egg production and hatch. *N. pyrausta*-infected and noninfected *O. nubilalis* were maintained in two different temperature regimes. The first regime allowed females to oviposit under optimum conditions (27degreesC, 65% RH, 16:8 (L:D)), while females in the second regime were held initially under the same humidity and light conditions, but a constant temperature of 16degreesC for 1 week after which they were transferred to optimum ovipositional conditions. Studies were performed initially with *O. nubilalis* populations and later with individual mating pairs. In studies with *O. nubilalis* populations, the mean number of eggs laid per female under optimum conditions was 660, while *N. pyrausta*-infected females held initially at 16degreesC laid 116 eggs per female. In studies with individual mating pairs, *N. pyrausta* infection reduced egg production per female 53 and 11% in the 16 and 27degreesC temperature regimes, respectively, compared to noninfected females under optimum conditions. Exposure to 16degreesC temperatures early in the ovipositional period had a more profound impact on reducing egg production in *N. pyrausta*-infected than noninfected *O. nubilalis*. (C) 2001 Elsevier Science (USA).

Burkness, E. C., W. D. Hutchison, P. C. Bolin, D. W. Bartels, D. F. Warnock and D. W. Davis (2001). "Field efficacy of sweet corn hybrids expressing a *Bacillus thuringiensis* toxin for management of *Ostrinia nubilalis* (Lepidoptera : Crambidae) and *Helicoverpa zea* (Lepidoptera : Noctuidae)." *Journal of Economic Entomology* 94(1): 197-203.

Field studies were done in 1995-1996 to assess the efficacy of three sweet corn hybrids that express the *Bacillus thuringiensis* (Bt) toxin, CryIAb, against two lepidopteran pests. *Ostrinia nubilalis* (Hubner) and *Helicoverpa zea* (Boddie). The Bt hybrids tested were developed by Novartis Seeds, using tale event BT-11, which expresses Bt toxin in green tissue as well as reproductive tissues including the tassel, silk, and kernel. Bt hybrids were compared with a standard non-Bt control or tale non-Bt isoline for each hybrid; none of the hybrids were treated with insecticides during the study. Hybrid efficacy was based on larval control of each pest, as well as plant or ear damage associated with each pest. In both ears, control of *O. nubilalis* larvae in primary ears of all Bt hybrids was 99-100% compared with the appropriate non-Bt check. Plant damage was also significantly. reduced in all Bt hybrids. In 1996, control of *H. zea* in Bt hybrids ranged from 85 to 88% when compared with the appropriate non-Bt control. In 1996, a University of Minnesota experimental compared with the appropriate non-Bt control. In 1996, a University non-Bt hybrid (MN2 X MN3) performed as well as the Bt hybrids for control of *O. nubilalis*. Also. in 1996, two additional University of Minnesota experimental non-Bt hybrids (A684su X MN94 and MN2 X MN3) performed as well as Bt hybrids for percent marketable ears (ears with no damage or larvae). In addition, compared with the non-Bt hybrids, percent marketable ears were significantly higher for all Bt hybrids and in most cases ranged from 98 to 100%. By comparison, percent marketable ears for the non-Bt hybrids averaged 45.5 and 37.4% in 1995 and 1996, respectively. Results from the 2-yr study strongly suggest that Bt sweet corn hybrids will provide high levels of larval control for growers in both fresh and

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processing markets. Specifically, Bt sweet corn hybrids, in the absence of conventional insecticide use, provided excellent control of *O. nubilalis*, and very good control of *H. zea*. However, depending on location of specific production regions, anti the associated insect pests of sweet corn in each area, some insecticide applications may still be necessary.

Cardinal, A. J., M. Lee, N. Sharopova, W. L. Woodman-Clikeman and M. J. Long (2001). "Genetic mapping and analysis of quantitative trait loci for resistance to stalk tunneling by the European corn borer in maize." *Crop Science* 41(3): 835-845.

The European corn borer (ECB), *Ostrinia nubilalis* (Hubner), is an important pest of temperate maize (*Zea mays* L.). Damage to the stalk could be minimized by breeding for resistant genotypes but selection is hindered by a laborious phenotypic assay. Knowledge of the position of quantitative trait loci (QTL) conferring resistance to ECB tunneling could greatly simplify selection for this trait. This study was conducted to map QTL for resistance to ECB tunneling, plant height, and anthesis. Recombinant inbred lines of the maize single-cross population B73xB52, were grown at two locations in Iowa in 1997 and 1998. Genotypic and phenotypic data were obtained from each line to perform the QTL analysis. Nine QTL were detected for ECB tunneling, and they were associated with 59% of the genetic variation. Genetic effects for decreased tunneling were derived from the resistant parent, B52, at six QTL. One digenic interaction was detected between QTL for ECB tunneling. Eight and 10 QTL were detected for anthesis and plant height, respectively. ECB tunneling was not significantly correlated with either trait. Several QTL for ECB tunneling reported herein, QTL for ECB tunneling in other maize populations, and QTL for resistance to leaf damage by insect pests of tropical maize are located at similar positions of the maize genetic map.

Chaufaux, J., M. Seguin, J. J. Swanson, D. Bourguet and B. D. Siegfried (2001). "Chronic exposure of the European corn borer (Lepidoptera : Crambidae) to CryIAb *Bacillus thuringiensis* toxin." *Journal of Economic Entomology* 94(6): 1564-1570.

Transgenic corn expressing the insecticidal toxin from *Bacillus thuringiensis* Berliner is gaining support as an effective control technology for use against lepidopteran pests, particularly European corn borer, *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae). However, there is concern that widespread adoption of transgenic plants will rapidly lead to *B. thuringiensis* toxin resistance. Thus, long-term selection of *O. nubilalis* populations with the Cry1Ab *B. thuringiensis* toxin has been undertaken in several laboratories in the United States and in Europe. We present results from two independent selection experiments performed in laboratories at the University of Nebraska and at the Institut National de Recherche Agronomique in France. Although the protocols and methods used by the two laboratories were different, the results were comparable. The highest level of resistance occurred at generation 7 (14-fold), generation 9 (13-fold), and generation 9 (32-fold) for three different strains. For each strain, the level of resistance fluctuated from generation to generation, although there were consistently significant decreases in toxin susceptibility across generations for all selected strains. These results suggest that low levels of resistance are common among widely distributed *O. nubilalis* populations.

Clark, T. L., J. F. Witkowski and J. E. Foster (2001). "Parasitism rates in European corn borer (Lepidoptera : Crambidae) larvae collected from six maize hybrids." *Journal of Entomological Science* 36(4): 342-351.

The parasitoid complex and level of parasitism of European corn borer, *Ostrinia nubilalis* (Hubner), larvae in six maize, *Zea mays* L., hybrids was determined in Nebraska during 1995 and 1996. Three parasitoids, *Eriborus terebrans* (Gravenhorst), *Macrocentrus grandii* Goidanich, and *Lixophaga* sp., were reared from field-collected European corn borer larvae. Larvae collected from Hoegemeyer 2626 exhibited the highest percentage parasitism for the 1995 first generation in Lancaster (37.2%) and Dixon (28.6%) counties. No significant differences were identified for the 1995 second generation at both sites because of reduced sample size and high larval mortality caused by naturally-occurring entomopathogens. During 1996, there were several significant differences in percentage parasitism of larvae collected from the hybrids. Larvae collected from Northrup King N7070 exhibited the highest first-generation parasitism (23.8%), while larvae collected from Hoegemeyer 1125W exhibited the highest second-generation parasitism (46.0%) in Dixon Co. In Lancaster Co., parasitism of first-generation larvae collected from Hoegemeyer 1125W (10.3%) was only significantly greater than parasitism of larvae collected from Hoegemeyer 2626 (1.1%). Results indicate that European corn borer larval parasitism is significantly affected by the maize hybrid planted in the field; however, differences may vary among years and generations as environmental factors affect the maize phenology.

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Gardner, J., M. P. Hoffmann, M. E. Smith and M. G. Wright (2001). "Influence of plant age and genotype on resistance to European corn borer in sweet corn." *Maydica* 46(2): 111-116.

Experiments were conducted to determine if the reaction of sweet corn (*Zea mays* L.) to European corn borer (*Ostrinia nubilalis* Hubner) was affected by plant age, genotype, or the interaction of plant age and genotype. Additionally, we wished to determine whether delayed larval development or exclusion of larvae was responsible for resistance. The experiments were conducted using a split plot design with six planting dates as main plots and three cultivars with different maturation rates, 'GH1703', 'GH2690', and 'Prime Plus' (73, 78, and 85 day, respectively, Idaho standard) as sub-plots. Two distinct plant ages for each cultivar were concurrently infested with colony-reared neonatal European corn borer (ECB) larvae. Plants were harvested after heat accumulation had reached 325-335 degree days (base 10C). Three to ten plants from each plot were destructively sampled. The number of larvae, number of tunnels, and length of each tunnel were recorded to evaluate plant damage. The mass and developmental stage of each larva were recorded to determine if plant age or genotype affected larval development. There were significant interactions of plant age and cultivar affecting plant damage and larval number. In general, corn infested with ECB at V10-V12 stage (approximately 10-12 fully expanded leaves and palpable tassel development) sustained greater damage, more larvae, and greater larval development than did corn infested in the V6-V8 stage (6-8 fully expanded leaves). We conclude that ranking cultivars for resistance can be complicated by the interaction of genotype and plant age: resistance observed in corn infested in the V6-V8 stage was not apparent when infested in the V10-V12 stage. Exclusion or mortality of larvae appears to be a more important mechanism of resistance than does delayed larval development.

Hoffmann, M. P., P. R. Ode, D. L. Walker, J. Gardner, S. van Nouhuys and A. M. Shelton (2001). "Performance of *Trichogramma ostrinae* (Hymenoptera: trichogrammatidae) reared on factitious hosts, including the target host, *Ostrinia nubilalis* (Lepidoptera: crambidae)." *Biological Control* 21(1): 1-10.

The performance of the parasitoid *Trichogramma ostrinae* (Pang et Chen) on eggs of four factitious hosts, *Ostrinia nubilalis* (Hubner), *Sitotroga cerealella* (Olivier), *Trichoplusia ni* (Hubner), and irradiated *Ephestia kuehniella* (Zeller), is presented. We measured parasitoid longevity, individual and population levels of parasitism, survival of progeny to emergence, and progeny sex ratio for 9 to 11 generations in laboratory colonies. Wasps reared from each source were tested on the source host and on the target host, European corn borer (*O. nubilalis*). Under the conditions tested, *E. kuehniella* was a poor host, *T. ni* and *O. nubilalis* were good hosts, and *S. cerealella* was intermediate. We found no evidence that being reared for many generations on an alternate host decreased the performance on the target host, *O. nubilalis*. Sex ratio was female biased and did not change over time. There may have been an increase in performance of wasps reared on *S. cerealella* and *E. kuehniella* over time. We discuss the information gained from different measures of parasitoid performance and the possible causes for variation in performance over time under laboratory conditions. (C) 2001 Academic Press.

Holmstrom, K. E., M. G. Hughes, S. D. Walker, W. L. Kline and J. Ingerson-Mahar (2001). "Spatial mapping of adult corn earworm and European corn borer populations in New Jersey." *Horttechnology* 11(1): 103-109.

In 1998, Rutgers Cooperative Extension (RCE) and the Grant F. Walton Center for Remote Sensing and Spatial Analysis (CRSSA) at Rutgers University began a joint program to use global positioning system (GPS) and geographic information systems (GIS) technologies to map the spatial distribution of corn earworm (*Helioverpa zea* Boddie (Lepidoptera: Noctuidae)) and European corn borer (*Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae)). In 1999 the Rutgers Cooperative Extension Vegetable Integrated Pest Management (IPM) Program operated a network of 81 blacklight insect survey traps in New Jersey. These 15 W blacklight traps were used to monitor adult populations of vegetable crop pests including corn earworm and European corn borer. All blacklight trap sites were mapped using a hand held GPS unit. Average daily corn earworm and European corn borer population data were imported into a GIS software package, and then linked to corresponding mapped locations throughout New Jersey. State wide spatial distributions of adult corn earworm and European corn borer populations were produced weekly, and distributed via extension newsletters and web sites to augment the current RCE IPM outreach program.

Hua, G., L. Masson, J. L. Jurat-Fuentes, G. Schwab and M. J. Adang (2001). "Binding analyses of *Bacillus thuringiensis* Cry delta-endotoxins using brush border membrane vesicles of *Ostrinia nubilalis*." *Applied and Environmental Microbiology* 67(2): 872-879.

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Transgenic corn expressing the *Bacillus thuringiensis* CryIAb gene is highly insecticidal to *Ostrinia nubilalis* (European corn borer) larvae. We ascertained whether CryIF, Cry9C, or Cry9E recognizes the CryIAb binding site on the *O. nubilalis* brush border by three approaches. An optical biosensor technology based on surface plasmon resonance measured binding of brush border membrane vesicles (BBMV) injected over a surface of immobilized Cry toxin. Preincubation with CryIAb reduced BBMV binding to immobilized CryIAb, whereas preincubation with CryIF, Cry9C, or Cry9E did not inhibit BBMV binding. BBMV binding to a CryIF-coated surface was reduced when vesicles were preincubated in CryIF or CryIAb but not Cry9C or Cry9E. A radioligand approach measured (125)I-CryIAb toxin binding to BBMV in the presence of homologous (CryIAb) and heterologous (CryIAc, CryIF, Cry9C, or Cry9E) toxins. Unlabeled CryIAc effectively competed for (125)I-CryIAb binding in a manner comparable to CryIAb itself, unlabeled Cry9C and Cry9E toxins did not inhibit (125)I-CryIAb binding to BBMV. CryIF inhibited (125)I-CryIAb binding at concentrations greater than 500 nM. CryIF had low-level affinity for the CryIAb binding site. Ligand blot analysis identified CryIAb, CryIAc, and CryIF binding proteins in BBMV. The major CryIAb signals on ligand blots were at 145 kDa and 154 kDa, but a strong signal was present at 220 kDa and a weak signal was present at 167 kDa. CryIAc and CryIF binding proteins were detected at 220 and 154 kDa. Anti-*Manduca sexta* aminopeptidase serum recognized proteins of 145, 154, and 167 kDa, and anti-cadherin serum recognized the 220 kDa protein. We speculate that isoforms of aminopeptidase and cadherin in the brush border membrane serve as CryIAb, CryIAc, and CryIF binding proteins.

- Huang, F. N., L. L. Buschman and R. A. Higgins (2001). "Larval feeding behavior of Dipel-resistant and susceptible *Ostrinia nubilalis* on diet containing *Bacillus thuringiensis* (Dipel ES (TM))." *Entomologia Experimentalis Et Applicata* 98(2): 141-148.
Diet choice tests were conducted to examine the effects of *Bacillus thuringiensis* Berliner on larval feeding behavior of Dipel-resistant and susceptible strains of European corn borer, *Ostrinia nubilalis* (Hubner). Larvae (first through fourth instars) were presented an untreated standard diet and three diets incorporating different concentrations of a commercial formulation of *B. thuringiensis*, Dipel ES(TM). Significantly higher proportions of susceptible and resistant larvae were found on the control diet compared to the proportions recorded on any of the Dipel-treated diets. Soon after release (0.5 to 3 h), the occurrence of larvae on each of the diets was similar across different instars. The number of first and second instars on the control diet increased steadily over 72 h after release, when 43 to 75% of larvae were found on the control diet. The proportion of third and fourth instars on the control diet also increased initially, with an equilibrium occurring 12 to 24 h later when 30 to 40% of larvae were found on the control diet. Both strains appeared to avoid the Dipel-treated diets and their responses were similar over different Dipel concentrations. The Dipel-resistant strain showed higher ability to avoid the treated diets than the susceptible strain.
- Hunt, T. E., L. G. Higley, J. F. Witkowski, L. J. Young and R. L. Hellmich (2001). "Dispersal of adult European corn borer (Lepidoptera : Crambidae) within and proximal to irrigated and non-irrigated corn." *Journal of Economic Entomology* 94(6): 1369-1377.
The European corn borer, *Ostrinia nubilalis* (Hubner), causes economic damage to corn, *Zea mays* L., throughout the Corn Belt. Because this insect has become the primary target of *Bacillus thuringiensis* Berliner (Bt) transgenic corn, current efforts addressing the management of *O. nubilalis* resistance to Bt corn require information on adult European corn borer dispersal and factors affecting its dispersal. In 1998 we conducted mark-release-recapture, release-recapture, and caged-mating studies to directly measure and compare local dispersal patterns of *O. nubilalis* adults within and proximal to irrigated and non-irrigated cornfields. Releases of marked adults were made corresponding to the first and second flight of *O. nubilalis* in eastern Nebraska. Adult dispersal was significantly different between irrigated and non-irrigated cornfields. Released adults tended to remain in and near irrigated cornfields, but dispersed out of and away from non-irrigated cornfields. When released at the edge of the cornfield, neither male nor unmated female *O. nubilalis* displayed an initial tendency to move out of irrigated corn and into the mixed smooth bromegrass (*Bromus inermis* Leyss) and broadleaf-weed field edge. Mating efficiency in a late-season cornfield was not significantly different than in dense foxtail (*Setaria* spp.). Generally, we found that adult *O. nubilalis* dispersal may vary depending on variables such as action-site availability and agronomic practices and their interaction with *O. nubilalis* life history.
- Losey, J. E., D. D. Calvin, M. E. Carter and C. E. Mason (2001). "Evaluation of noncorn host plants as a refuge in a resistance management program for European corn borer (Lepidoptera : Crambidae) on Bt-corn." *Environmental Entomology* 30(4): 728-735.

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Studies in New York and Pennsylvania compared egg mass recruitment and larval survival on corn and other hosts of the European corn borer, *Ostrinia nubilalis* (H[umlaut]ubner), to assess the potential of these plants to act as a refuge in its resistance management program. Assessments were made on replicated plantings and natural plant stands in the field and under controlled conditions in the laboratory. Scouting of mixed field plantings revealed more egg masses on corn than any other crop or weed species. At least twice as many larvae per plant were recovered from naturally infested corn compared with the next best host plant across both years. Larval recovery from noncorn host plants varied widely. Fewer adults emerged from overwintering weed stubble than from corn stubble, and the parasitoid *Afacrocnhis grandii* (Goidanich) was found associated only with corn stubble. Survival on plants infested with corn borer larvae was consistently higher on corn than on other plants. In a laboratory study, the number of corn borer tunnels in corn was double the next best host, ragweed. Noncorn hosts appear unlikely to provide a substantial number of corn borer individuals susceptible to *B. thuringiensis* (Berliner) in comparison with the number expected from the 20% planting refuge mandated by EPA registration of Bt-corn. Evidence from these studies does not support a recommendation of reducing refuge planting areas in the northeastern United States.

Magg, T., A. E. Melchinger, D. Klein and M. Bohn (2001). "Comparison of Bt maize hybrids with their non-transgenic counterparts and commercial varieties for resistance to European corn borer and for agronomic traits." *Plant Breeding* 120(5): 397-403.

The European corn borer (ECB), *Ostrinia nubilalis* (Hubner), is a major pest of maize (*Zea mays* L.) in Central Europe. In order to compare transgenic Bt maize hybrids with their non-transgenic counterparts and commercial hybrids, field trials and a laboratory bioassay were conducted. The field experiments were performed at four locations with natural and manual infestation of ECB larvae in 1998 and 1999. Transgenic Bt hybrids showed significantly lower means than their corresponding non-transgenic counterparts and commercial hybrids for all resistance traits (damage rating of stalks, number of larvae per plant, and percentage of damaged plants or ears under infestation). Bt hybrids containing the CryIA(b) gene under the control of green tissue and pollen-specific promoters (event 176) showed a significantly higher percentage of damaged ears than Bt hybrids carrying the CryIA(b) gene under the control of a constitutive promoter (Mon810). Bt and non-Bt hybrids showed no significant differences for all agronomic traits, except for plant height under insecticide protection and grain yield reduction under infestation, whereas Bt hybrids had significantly lower means than their nontransgenic counterparts and other commercial hybrids. All resistance traits were significantly correlated with grain yield reduction. The laboratory bioassay confirmed the level of antibiosis of Bt hybrids against neonate ECB larvae. Bt hybrids showed the highest level of ECB resistance and therefore are an attractive method of preventing ECB damage within an integrated pest-management system.

Nault, B. A., J. Speese, G. G. Kennedy, J. Linduska and G. P. Dively (2001). "Response of potato tuber yield to stem injury by European corn borer (Lepidoptera : Crambidae) in the Mid-Atlantic United States." *Journal of Economic Entomology* 94(5): 1162-1169.

The response of potato, *Solanum tuberosum* L., tuber yield to stem injury by European corn borer, *Ostrinia nubilalis* (Hubner), larvae was investigated in the Mid-Atlantic region of the United States for 3 yr. This response was described for 'Superior', 'Atlantic', and 'Snowden' potato, which are early-season, midseason, and late-season maturing cultivars, respectively. To model the yield/injury relationship, a range of corn borer injury levels was established in the field by augmenting the natural infestation with varying densities of laboratory-reared larvae. Linear and nonlinear regression analyses (plateau and second-order polynomial models) were used to describe the relationship between yield of US No. 1 grade tubers and the percentage of stems injured by corn borer larvae. The maturity of the cultivar did not affect the response of potato yield to stem injury. In nine of 14 experiments, potato tolerated high levels of corn borer injury (55-90% of stems injured) without yield loss, suggesting that control of corn borer may not be necessary. Yet, in one of five Superior tests, in two of four Atlantic tests and in two of five Snowden tests corn borer injury significantly reduced yield. Of the five data sets in which corn borer injury reduced yield, the plateau model fit two data sets and the quadratic model fit one data set. In two of the three cases, these models accounted for nearly identical amounts of total variation in yield as that accounted for by the linear model. The linear model fit four of the five data sets, but the R values were low for three of the four tests (0.10, 0.18, and 0.31). The parameter or parameters that interact with corn borer injury to cause tuber yield reduction should be identified before economic injury levels and thresholds are developed.

Papst, C., A. E. McKhinger, J. Eder, B. Schulz, D. Klein and M. Bohn (2001). "Qtl mapping for resistance to European corn borer (*Ostrinia nubilalis* HB.) in early maturing European dent maize (*Zea mays* L.) germplasm and comparison of genomic regions for resistance across two populations of F-3 families." *Maydica* 46(3): 195-205.

The European corn borer (ECB, *Ostrinia nubilalis* Hubner) is a major pest of maize in central Europe, The objectives of our study were to (1) identify QTL for resistance to ECB (2) estimate their genetic effects, and (3) investigate the consistency of QTL across two different populations. A total of 230 F-2:3 families derived from cross 1396A (resistant) x F478 (susceptible) were used for QTL analyses. Each F-2:3 family was evaluated for resistance traits tunnel length (TL), stalk damage ratings (SDR), and relative grain yield (RGY) using manual infestation with ECB larvae. The agronomic traits comprised grain yield under insecticide protection (GYP) and manual infestation (GYI), date of anthesis (ANT), dry matter content (DMC), and in vitro digestible organic matter (IV-DOM) of stover. The field experiment was performed with two replications in two environments in 1995. Two QTL for SDR and two QTL for TL were detected explaining 24.7% and 26.0% of the genotypic variance ($\sigma^2(g)$), respectively. For agronomic traits one to three QTL were found, explaining between 2.0% and 11.8% of $\sigma^2(g)$. No common QTL for resistance traits were found across population 1396AxF478 and a second population of 230 F-2:3 families derived from cross D06 (resistant) x D408 (susceptible). Two QTL for IVDOM and DMC were in common among both populations. Due to the low consistency of QTL across populations, marker-assisted selection (MAS) is not recommended for improving ECB resistance in early maturing dent germplasm.

Peterson, C. J., B. F. Binder and J. R. Coats (2001). "Effects of two isoflavonoids, osajin and pomiferin, from *Maclura pomifera* for growth and feeding disruption in *Ostrinia nubilalis*." *Journal of Pesticide Science* 26(3): 261-265.

Phoofolo, M. W., J. J. Obrycki and L. C. Lewis (2001). "Quantitative assessment of biotic mortality factors of the European corn borer (Lepidoptera : Crambidae) in field corn." *Journal of Economic Entomology* 94(3): 617-622.

Five treatments were used to exclude naturally occurring predators and parasitoids, based on body size and flight ability, to assess their effect on *Ostrinia nubilalis* (Hubner) populations on corn plants. Two initial *O. nubilalis* egg densities (one egg mass and three egg masses per plant) were assigned to each treatment. Egg predation was higher in uncaged treatments than in caged treatments. Flying insect predators, primarily *Coleomegilla maculata* DeGeer (Coleoptera: Coccinellidae), reduced egg densities by 50%. Thirty-five to 84% of *O. nubilalis* larvae were infected with *Nosema pyrausta* (Puillot) (Microspora: Nosematidae). The incidence of *Beauveria bassiana* (Balsamo) Vuillemin (Deuteromycotina: Hyphomycetes), ranged from 0 to 21%, whereas larval parasitism, mainly by *Macrocentrus cingulum* Reinhard (Hymenoptera: Braconidae) ranged from 0 to 31%. In contrast to previous studies, this 3-yr field study documents that egg predation and larval infections of *O. nubilalis* were significant and consistent biotic mortality factors.

Pierce, C. M. F., L. F. Solter and R. A. Weinzierl (2001). "Interactions between *Nosema pyrausta* (Microsporidia : Nosematidae) and *Bacillus thuringiensis* subsp. *kurstaki* in the European corn borer (Lepidoptera : Pyralidae)." *Journal of Economic Entomology* 94(6): 1361-1368.

Larval susceptibility to *Bacillus thuringiensis* was determined for *Nosema pyrausta*-infected and uninfected European corn borers, *Ostrinia nubilalis* (Hubner), in bioassays using a commercial formulation of *B. thuringiensis* subsp. *kurstaki*, Dipel ES, incorporated into diet. LC50 values for *N. pyrausta*-infected larvae were significantly lower ($P < 0.0001$) than for uninfected larvae and declined with increasing levels of infection. LC50 values for a 15-d bioassay using field-colony first instars were 0.006 and 0.027 mg of Dipel ES/kg of diet for larvae moderately infected by *N. pyrausta* and uninfected larvae, respectively. *Nosema pyrausta*-infected larvae reared on Dipel ES-amended diets produced 70-fold fewer spores ($P < 0.0001$) than larvae reared on standard diet. For example, 15 d after placement as first instars on standard diet, infected field-colony larvae produced 7.6-8.7 million *N. pyrausta* spores per larva; similar larvae placed on diet containing 0.09 mg of Dipel ES/kg of diet produced 85-103 thousand spores per larva. Infected larvae also weighed less and failed to mature on Dipel ES-amended diets. Increased susceptibility of *N. pyrausta*-infected larvae to Dipel ES and reduced *N. pyrausta* spore production in larvae feeding on diet containing Dipel ES suggest that Bt corn will have a direct adverse effect on the survival and continual impact of *N. pyrausta* as a regulating factor on European corn borer populations.

Pilcher, C. D. and M. E. Rice (2001). "Effect of planting dates and *Bacillus thuringiensis* corn on the population dynamics of European corn borer (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 94(3): 730-742.

Field studies were conducted to determine how field corn, *Zea mays* L., phenologies in combination with transgenic *Bacillus thuringiensis* Berliner (Bt) corn and non-Bt (near isogenic) corn could affect egg laying by female European corn borer, *Ostrinia nubilalis* (Hubner), and subsequent larval injury. Transgenic Bt (events 176 and Bt11) and non-Bt corn was planted at three different times to assess the use of early- and late- planted Bt corn as a means for egg recruitment to these targeted planting dates. Plant growth stages, egg densities, and stalk tunneling was recorded at four locations in southwestern, central, and northern Iowa for three summers (1996-1998). No significant differences in egg densities were observed between Pt and non-Bt corn during the first and second generation for all three years. Significant differences did occur among planting dates. Between 50 and 100% of the eggs were laid in the early planting during the first generation. In addition, between 40 and 65% of the eggs were laid in the late planting for the second generation. Correlations between egg density and larval tunneling were inconsistent from year to year. Additional inconsistencies stemming from yearly phenological differences among sequential plantings and variable *O. nubilalis* populations increases the difficulty in recommending planting date adjustments as a practical management tool for European corn borer and Pt corn.

Pilcher, C. D., M. E. Rice, R. A. Higgins and R. Bowling (2001). "Pollen drift from *Bacillus thuringiensis* corn: Efficacy against European corn borer (Lepidoptera : Crambidae) in adjacent rows of non-Bt corn." *Environmental Entomology* 30(2): 409-414.

Commercial non-*Bacillus thuringiensis* (Bt) corn was planted adjacent to Bt corn to determine the effects of Bt corn pollen falling on non-Bt plants for control of European corn borer larvae, *Ostrinia nubilalis* (Hubner). Field plots in Iowa and Kansas consisted of two center rows of Bt corn with eight rows of adjacent non-Bt corn on each side. In mid-September 1996 and 1997, we counted European corn borer larvae and larval tunnels in the stalk and ear shank. There were no significant differences in European corn borer numbers across non-Bt rows and the slope of the regression line was not significantly different from zero. In a single plot in Iowa, however, fewer tunnels were observed in rows of corn that were closer to Bt corn. This site was isolated from natural infestations and probably does not reflect a typical field situation. Our results suggest that Bt pollen has minimal or no control of European corn borer larvae in adjacent rows of non-Bt corn under natural conditions. Bt pollen drifting onto adjacent non-Bt plants should not increase the risks related to resistance management.

Rahman, K. M. A. and L. Cagan (2001). "Effect of *Nosema pyrausta* (Microsporida, Nosematidae) on food consumption and utilisation in the European corn borer, *Ostrinia nubilalis* (Lepidoptera, Crambidae)." *Biologia* 56(2): 183-189.

The effect of *Nosema pyrausta* infection on food consumption and utilisation by the European corn borer, *Ostrinia nubilalis* was studied under laboratory conditions, using a semi-synthetic diet. The consumption index, which reflects the rate of food intake in a given period, differed significantly between the infected and control larvae. Infection by *N. pyrausta* had no significant effect on the total amount of food consumed by different larval instars of *O. nubilalis*, but it affected the feeding period by shortening the development time of the 3rd and 4th instar. The digestibility, weight gain, growth rate and frass produced did not significantly differ between healthy and *Nosema*-infected larvae. In contrast, the efficiency of conversion of ingested food to body substance was significantly affected by *Nosema* infection, which resulted in significant decrease of pupal weight in infected individuals. The time of infection was also important - pupae originating from larvae infected earlier (3rd instar) were significantly lighter than those of larvae infected in the 4th or 5th instar.

Reed, J. P. and W. R. Halliday (2001). "Establishment of Cry9C susceptibility baselines for European corn borer and southwestern corn borer (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 94(2): 397-402.

In 1997 and 1998, Cry9SC susceptibility baselines were established for field-collected populations of European corn borer, *Ostrinia nubilalis* (Hubner), and southwestern corn borer, *Diatraea grandiosella* Dyar. Bioassay of neonate European corn borer larvae of 16 colonies collected from the midwestern United States indicated LC50 values ranging from 13.2 to 65.1 ng of Cry9C protein per square centimeter. Neonate European corn borer LC50 values ranged from 46.5 to 214 ng/cm². Neonate larvae of three colonies of southwestern corn borer collected from the southern and southwestern United States exhibited LC50 values from 16.9 to 39.9 ng of Cry9C protein per square centimeter. Southwestern corn borer neonate LC50 confidence limit values ranged from 40.3 to 157 ng of Cry9C protein per

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centimeter. The most sensitive southwestern corn borer colon was collected from the Mississippi delta exhibiting an LC50 value of 22.6 ng of Cry9C per cm² and also displayed the widest LC90 confidence limits of 40.3-94.8 ng of Cry9C per cm². Geographic baseline susceptibility data establishes the natural genetic variation and provides the foundation for future testing of insect populations exposed to increased use of *Bacillus thuringiensis*-based crops. Insect resistance management and stewardship of Cry9C will rely upon baseline data for the validation of discriminating dose assays for European corn borer and southwestern corn borer.

Showers, W. B., R. L. Hellmich, M. E. Derrick-Robinson and W. H. Hendrix (2001). "Aggregation and dispersal behavior of marked and released European corn borer (*Lepidoptera* : *Crambidae*) adults." *Environmental Entomology* 30(4): 700-710.

To observe the aggregation and dispersal behavior of adult European corn borer, *Ostrinia nubilalis* (Hubner), males in search of mates, two populations were marked, each with a different dye. One population was continuously reared in the laboratory (>5 yr) and the other was collected annually from the field. From 1986 to 1988, marked adults were released in two release sets per year, with three to five releases per release set, coinciding with the Spring and summer flights of European corn borer in central Iowa. Traps for recapture contained lures baited with 40 Ag of synthetic 97:3 Z:E-11-tetradecenyl acetate. Traplines extended from 200 in to 48 km. Each trap was assigned a compass direction. Males from the laboratory-reared population dispersed similarly to males just 1 generation from the wild. European corn borer males and females dispersed 23-49 km and some were recovered 14 km from the release site within 100 min after release. Sampling of aggregation sites demonstrated that on the nights of release, many adults aggregated in adjacent dense vegetation and did not disperse until the following night. Upon dispersal, these adults seemingly moved many meters or kilometers before settling again. Recapture of marked adults at 200 in might have been influenced by open landscapes (short, vegetative-growth corn). Recapture at 800 m or beyond, however, was unaffected by open landscapes, and in 1988 a greater proportion of marked males was recaptured while the landscape was closed (tall, mature-growth corn). In 1987, during the first flight of European corn borer, displacement to 800 in was southeasterly, south, or west, but during first flights in 1986 and 1988, displacement to 800 in was predominately northeasterly. During the second flight in midsummer, displacement to 800 in for all 3 yr of the study also was northeasterly. Recapture results from 1986 suggest that male movement > 800 m is common. During the first release set (early summer), 37% of the males recaptured flew 800 in or more and 8% flew 3.2 km or more. During the second release set (late summer), 51% of the males recaptured flew 800 m or more and 11% flew 3.2 km or more. The recommendation for placement of nontransgenic corn (*Zea mays* L.) as refuge in the Corn Belt is a half mile or closer to *Bacillus thuringiensis* Berliner (Bt)-corn if the refuge corn is not sprayed and a quarter mile or closer when the refuge corn is sprayed. Based on the dispersal results from this study, at least in Iowa, a half-mile proximity recommendation should be robust. Studies still should be conducted in other regions, especially where corn is commonly irrigated, to determine whether European corn borer adult movement patterns are similar.

Siegfried, B. D., A. C. Zoerb and T. Spencer (2001). "Development of European corn borer larvae on Event 176 Bt corn: influence on survival and fitness." *Entomologia Experimentalis Et Applicata* 100(1): 15-20.

European corn borer larvae, *Ostrinia nubilalis* (Hubner) (*Lepidoptera*: *Crambidae*) that have completed development on Event 176 Bt corn hybrids have survived exposure to sublethal doses of the Cry1Ab Bt toxin or are exploiting plant tissues that do not express the toxin. To evaluate the impact of such exposure, diapausing larvae were collected from Event 176 and conventional hybrids and compared for rates of pupation, parasitism, fitness (pupal weight, longevity, and fecundity) and susceptibility to the Cry1Ab toxin. Larvae completing development on Event 176 corn exhibited approximately 10% higher survival rates and correspondingly lower parasitism rates than larvae completing development on conventional hybrids. No significant differences were detected in pupal weight, fecundity, longevity or susceptibility to the Cry1Ab Bt toxin. These results indicate that survival on Event 176 corn are not adversely affect fitness and does not cause increased tolerance to the Cry1Ab toxin in subsequent generations.

Spangler, S. M. and D. D. Calvin (2001). "Vertical distribution of European corn borer (*Lepidoptera* : *Crambidae*) egg masses on sweet corn." *Environmental Entomology* 30(2): 274-279.

Within-plant height (leaf position) of European corn borer, *Ostrinia nubilalis* (Hubner) egg masses were analyzed in four sweet corn hybrids planted across four planting dates from 1994 to 1996. From the five-leaf to 15-leaf vegetative stages, the mean leaf position of an egg mass was typically at the midpoint of available (nonsenescent) leaves. The

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mean leaf position of egg masses gradually increased from early to late leaf stages as new leaves were added and continued to increase during the first reproductive stage (green tassel). The increase in vertical position during vegetative stages was modeled as $y = -0.766 + 0.653(x)$, where y = nodal leaf position, and x = total leaves expanded ($r^2 = 0.94$). However, when the mean egg mass position was expressed as the mean position within available (expanded and nonsenescent) leaves: no relationship was found. These data indicate that during vegetative stages the mean egg mass position increases relative to ground level, but remains near the midpoint of available available (nonsenescent) leaves. Mean egg position during the next four reproductive stages (anthesis, green silk, brown silk, and postharvest) stabilized at ear height, or within the intermediate two leaf positions above the ear. The distributions of egg masses among leaf positions during the vegetative and reproductive stages generally exhibited normal distributions: where sample sizes were sufficient, 80% (17/21) of the comparisons (having sufficient sample sizes) did not deviate from normality. This study represents the most detailed examination to date on vertical distribution of European corn borer egg masses in corn. Implications of the study in ovipositional ecology and pest management are discussed.

Warnock, D. F., W. D. Hutchison, C. B. S. Tong and D. W. Davis (2001). "Evaluating maize for allelochemicals that affect European corn borer (Lepidoptera : Crambidae) larval development." *Crop Science* 41(6): 1761-1771.

European corn borer (ECB), *Ostrinia nubilalis* (Hubner), larvae develop resistance to management protocols in laboratory and field environments. Laboratory bioassays, tissue elemental analyses, and field resistance evaluations were conducted on ear tissues of maize, *Zea mays* L., to (i) identify genotypes and tissues which affect ECB development, (ii) isolate tissue extracts detrimentally affecting larvae, (iii) determine if high performance liquid chromatography (HPLC) absorption peaks are associated with biological activity, (iv) determine if ferulic acid and p-coumaric acid affect ECB larvae, and (v) determine if laboratory and field resistance are related. Tissue and genotype did not affect larval survival. Silk tissue from W182E, 'Apache', MN 3153, and MN 276 reduced 10-d larval weight, increased time to pupation, reduced pupal weight, and increased time to moth emergence compared with kernel tissue, which did not differ from the cellulose control. Methanol fractions of silks reduced 10-d larval weight, but not larval survival, compared with the cellulose control. No methanol fraction of silks, except from MG 15, reduced 10-d larval weight as much as nonextracted Apache silk, suggesting that some allelochemicals were not captured or were lost during extraction. HPLC analysis detected three to four large peaks only found in active methanol fractions. Ear tissue element levels, except for manganese ($r = -0.70$), were not associated with decreased 10-d larval weight. Larvae reared on diet containing ferulic acid (2.61 and 1.67 mg/g) or p-coumaric acid (<0.20 mg/g) had 10-d weights similar to the control. Laboratory and field resistance were not correlated, suggesting that multiple resistance mechanisms exist in maize. The identification of allelochemicals affecting ECB larvae will allow breeding programs to select resistant maize genotypes.

Wilson, T. A. and R. L. Wilson (2001). "Leaf extracts from Peruvian maize affect larval feeding and development of European corn borer (Lepidoptera : Crambidae)." *Journal of the Kansas Entomological Society* 74(1): 32-39.

The main chemical involved in leaf-feeding resistance to European corn borer, *Ostrinia nubilalis* (Hubner), in Midwest-adapted maize (*Zea mays* L.) cultivars has been linked to 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA). But, 11 accessions of Peruvian maize have been identified as having non-DIMBOA resistance to European corn borer leaf feeding. Methanol extracts of leaf material from the 11 accessions of maize were evaluated in laboratory bioassays to measure differences in mortality, larval or pupal weight, and developmental times. Larvae reared on diets with leaf extracts from accessions PI 503720, PI 503725, PI 503728, and PI 503731 were significantly smaller than larvae reared on controls. These data suggest that a biochemical product responsible for resistance can be extracted from some of the maize accessions.

Wright, M. G., M. P. Hoffmann, S. A. Chenus and J. Gardner (2001). "Dispersal behavior of *Trichogramma ostrinae* (Hymenoptera : Trichogrammatidae) in sweet corn fields: Implications for augmentative releases against *Ostrinia nubilalis* (Lepidoptera : Crambidae)." *Biological Control* 22(1): 29-37.

The dispersal behavior of *Trichogramma ostrinae* Pang et Chen, a potential biological control agent of European corn borer, *Ostrinia nubilalis* Hubner, was investigated in fields of sweet corn in central New York. The aims of the study were to quantify *T. ostrinae* dispersal, to determine whether they persisted in release fields, and what minimum number of release points per unit area would be adequate to ensure uniform distribution of the wasps for augmentative releases. Dispersal was monitored from central release points over distances from 35 to 230 m, in a square 9 ha grid of

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monitoring points, using yellow sticky cards and *O. nubilalis* sentinel egg masses to detect *T. ostriniae*. Results showed that the wasps dispersed rapidly, up to 180 m in 6 days and 230 m in 21 days. The number of *T. ostriniae* captured on sticky cards and sentinel egg mass parasitism decreased with distance from point of release, although 11-40% parasitism of egg masses occurred in monitoring positions most distant from the release points. Uniform parasitism of sentinel egg masses was achieved in areas of 1-2 ha surrounding central release points. It is suggested that a single release point per hectare should be adequate to ensure uniform dispersal of *T. ostriniae* into sweet corn fields. (C) 2001 Academic Press.

Abel, C. A., M. A. Berhow, R. L. Wilson, B. F. Binder and B. E. Hibbard (2000). "Evaluation of conventional resistance to European corn borer (Lepidoptera : Crambidae) and western corn rootworm (Coleoptera : Chrysomelidae) in experimental maize lines developed from a backcross breeding program." *Journal of Economic Entomology* 93(6): 1814-1821.

Plant resistance is a promising control method for the two most damaging insect pests of maize, *Zea mays* L.: the European corn borer, *Ostrinia nubilalis* (Hubner), and the western corn rootworm, *Diabrotica virgifera virgifera* LeConte. Fifteen experimental lines of maize, derived from a backcross breeding program designed to introgress resistance to European corn borer from Peruvian maize into two U.S. Corn Belt adapted inbred lines, were evaluated for resistance to European corn borer and western corn rootworm. The experimental lines were in the second generation of backcrossing. All experimental lines were resistant to leaf blade feeding by European corn borer. These lines had low levels of 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one, a chemical commonly associated with leaf blade feeding resistance, indicating that this was not the mechanism of resistance to leaf blade feeding in these lines. Eleven experimental lines were resistant to leaf sheath and collar feeding by European corn borer. Useful sources of European corn borer ovipositional nonpreference and root feeding resistance to western corn rootworm were not identified. Some of the lines evaluated in this study may provide useful sources of resistance to both leaf blade and leaf sheath and collar feeding by European corn borer.

Andow, D. A., D. M. Olson, R. L. Hellmich, D. N. Alstad and W. D. Hutchison (2000). "Frequency of resistance to *Bacillus thuringiensis* toxin Cry1Ab in an Iowa population of European corn borer (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 93(1): 26-30.

The refuge plus high-dose strategy for resistance management assumes that the frequency of resistance alleles is low. We used an F-2 screen to estimate the frequency of resistance to transgenic corn that produces *Bacillus thuringiensis* Berliner Cry1Ab toxin (Bt corn) in an Iowa population of European corn borer, *Ostrinia nubilalis* (Hubner). We also proposed a modification to the statistical analysis of the F-2 screen that extends its application for nonuniform prior distributions and for repeated sampling of a single population. Based on a sample of 188 isofemale lines derived from females caught at light traps during the 2nd flight of 1997, we show with 95% confidence that the frequency of resistance to Bt corn was $<3.9 \times 10^{-3}$ in this Iowa population. These results provide weak evidence that the refuge plus high-dose strategy may be effective for managing resistance in *O. nubilalis* to Bt corn. Partial resistance to Cry1Ab toxin was found commonly. The 95% CI for the frequency of partial resistance were $[8.2 \times 10^{-4}, 9.4 \times 10^{-3}]$ for the Iowa population. Variable costs of the method were \$14.90 per isofemale line. which was a reduction of 25% compared with our initial estimate.

Archer, T. L., G. Schuster, C. Patrick, G. Cronholm, E. D. Bynum and W. P. Morrison (2000). "Whorl and stalk damage by European and Southwestern corn borers to four events of *Bacillus thuringiensis* transgenic maize." *Crop Protection* 19(3): 181-190.

Twenty-eight transgenic maize hybrids producing the *Bacillus thuringiensis* (Bt) endotoxin (Cry1A(b) or Cry9c) and several of their non-Bt isolines were evaluated for control of the southwestern corn borer, *Diatraea grandiosella* Dyar, and the European corn borer, *Ostrinia nubilalis* (Hubner). The Pt hybrids represented four events (Mon810 [Cry1A(b)], Bt11 [Cry1A(b)], 176 [Cry1A(b)], and CBH354 [Cry9c]) from seven seed companies. Maize hybrids were grown in four locations ranging from the northern to the southern Texas Panhandle, a semi-arid environment with hot days, cool nights and < 220 mm of rain during the growing season. Maize was infested with each species of corn borer using the Davis applicator at the mid-whorl (first-generation borer) and tassel (second-generation borer) growth stages. All Bt hybrids controlled first generation infestations of both species of corn borers. In contrast, second-generation corn borers were controlled well only by maize with the Mon810, Bt11, or CBH354 events. Second-generation corn borer control by event 176 hybrids was not adequate when compared with the other events. Percentage infestation, larval

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survival, and damage to most of the event 176 hybrids by second-generation corn borers was similar to non-Pt hybrids. Second-generation SWCB larvae surviving on event 176 were weighed and their survival through the winter (January - March) was monitored. Larvae collected from root crowns of event 176 hybrids weighed the same as those surviving on a non-Bt hybrid from Novartis. SWCB larvae survived the winter equally well in maize stalks of transgenic and non-Pt plants. Yields were not significantly enhanced by control of corn borers by the Bt hybrids. (C) 2000 Elsevier Science Ltd. All rights reserved.

Bohn, M., B. Schulz, R. Kreps, D. Klein and A. E. Melchinger (2000). "QTL mapping for resistance against the European corn borer (*Ostrinia nubilalis* H.) in early maturing European dent germplasm." *Theoretical and Applied Genetics* 101(5-6): 907-917.

European corn borer (ECB, *Ostrinia nubilalis* Hubner) is a major pest of maize in Central Europe. We mapped and characterized quantitative trait loci (QTLs) involved in resistance of maize against ECB damage, compared them with QTLs for agronomic traits, and evaluated the usefulness of marker-assisted selection (MAS) for improving ECB resistance in early maturing European maize, germplasm. A total 226 F-3 families from the cross D06 (resistant) x D408 (susceptible), together with 93 RFLP and two SSR markers were used for the QTL analyses. For each F-3 family we measured the length of tunnels produced by larval stalk mining (TL), stalk damage ratings (SDR), and relative grain yield (RGY) in field experiments, with two replications in two environments in 1 year. The agronomic traits comprised grain yield under insecticide protection (GYP) and manual ECB larval infestation (GYI), the date of anthesis (ANT), and the in vitro digestibility of organic matter (IVDOM) of stover. Estimates of genotypic variance ($\sigma^2(g)$) were highly significant for all traits. Six QTLs for TL and five QTLs for SDR were detected, explaining about 50.0% of $\sigma^2(g)$. Most QTLs showed additive gene action for TL and dominance for SDR. No QTL was found for RGY. The number of QTLs detected for the agronomic traits ranged from two for GYI to 12 for ANT, explaining 12.5 to 57.3% of $\sigma^2(g)$, respectively. Only a single QTL was in common between the two resistance traits, as expected from the moderate trait correlation and the moderate proportions of $\sigma^2(g)$ explained. Based on these results, MAS for improving ECB resistance can be competitive when cost-effective PCR-based marker systems are applied. However, it remains to be established whether the putative QTL regions for ECB resistance detected in the population D06 x D408 are consistent across other early maturing European maize germplasms.

Bourguet, D., M. T. Bethenod, N. Pasteur and F. Viard (2000). "Gene flow in the European corn borer *Ostrinia nubilalis*: implications for the sustainability of transgenic insecticidal maize." *Proceedings of the Royal Society B-Biological Sciences* 267(1439): 117-122.

Strategies proposed for delaying resistance to *Bacillus thuringiensis* toxins expressed by transgenic maize require intense gene flow between individuals that grew on transgenic and on normal (referred to as refuges) plants. To investigate gene flow in the European corn borer, *Ostrinia nubilalis* (Hubner), the genetic variability at 29 sampled sites from France was studied by comparing allozyme frequencies at six polymorphic loci. Almost no deviations from Hardy-Weinberg expectations occurred, and a high stability of allelic distribution was found among samples collected in the same site over two or three different generations, indicating a high stability of the genetic structure over time. The overall genetic differentiation was low at the region and whole country level, suggesting a high and homogeneous gene flow. These results are discussed in relation to the sustainability of transgenic insecticidal maize.

Bourguet, D., M. T. Bethenod, C. Trouve and F. Viard (2000). "Host-plant diversity of the European corn borer *Ostrinia nubilalis*: what value for sustainable transgenic insecticidal Bt maize?" *Proceedings of the Royal Society B-Biological Sciences* 267(1449): 1177-1184.

The strategies proposed for delaying the development of resistance to the *Bacillus thuringiensis* toxins produced by transgenic maize require high levels of gene flow between individuals feeding on transgenic and refuge plants. The European corn borer *Ostrinia nubilalis* (Hubner) may be found on several host plants, which may act as natural refuges. The genetic variability of samples collected on sagebrush (*Artemisia* sp.), hop (*Humulus lupulus* L.) and maize (*Zea mays* L.) was studied by comparing the allozyme frequencies for six polymorphic loci. We found a high level of gene flow within and between samples collected on the same host plant. The level of gene flow between the sagebrush and hop insect samples appeared to be sufficiently high for these populations to be considered a single genetic panmictic unit. Conversely the samples collected on maize were genetically different from those collected on sagebrush and hop. Three of the six loci considered displayed greater between-host-plant than within-host-plant differentiation in

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comparisons of the group of samples collected on sagebrush or hop with the group of samples collected on maize. This indicates that either there is genetic isolation of the insects feeding on maize or that there is host-plant divergent selection at these three loci or at linked loci. These results have important implications for the potential sustainability of transgenic insecticidal maize.

Clark, T. L., J. E. Foster, S. T. Kamble and E. A. Heinrichs (2000). "Comparison of Bt (*Bacillus thuringiensis* Berliner) maize and conventional measures for control of the European corn borer (*Lepidoptera* : *Crambidae*)." *Journal of Entomological Science* 35(2): 118-128.

Field experiments were conducted in 1997 to compare the efficacy of Bt (*Bacillus thuringiensis* Berliner) maize hybrids and two conventional measures for control of the European corn borer, *Ostrinia nubilalis* (Hubner). Treatments consisted of transgenic Bt maize hybrids and their non-Bt isolines, and isolines treated with a formulated Bt or permethrin insecticide. All control measures significantly reduced *O. nubilalis* damage in terms of tunnels per plant, length of tunneling, and larvae per plant. The following hierarchy in terms of *O. nubilalis* efficacy was observed: transgenic Bt > permethrin > formulated Bt > control. In most cases, transgenic Bt maize was most effective in preventing European corn borer damage to ear shanks and generally produced the highest grain yields.

Davis, P. M. and D. W. Onstad (2000). "Seed mixtures as a resistance management strategy for European corn borers (*Lepidoptera* : *Crambidae*) infesting transgenic corn expressing Cry1Ab protein." *Journal of Economic Entomology* 93(3): 937-948.

Dispersal of neonate European corn borers, *Ostrinia nubilalis* (Hubner), in seed mixtures of transgenic corn expressing Cry1Ab protein (Bt+) and nontransgenic corn (Bt-) was evaluated in a 2-yr field study. The main objective was to determine if larval dispersal limits the effectiveness of seed mixtures as a resistance management strategy. Mixtures evaluated included (1) all Bt+ plants, (2) every fifth plant Bt- with remaining plants Bt+, (3) every fifth plant Bt+ with remaining plants Bt-, and (4) all Bt- plants. The transformation events MON 802 (B73 BC1F2 X Mo17) and MON 810 (B73 BC1F1 X Mo17), which express the Cry1Ab endotoxin isolated from *Bacillus thuringiensis* subsp. *kurstaki*, were used as the sources of Bt+ seed in 1994 and 1995 respectively (YieldGard, Monsanto, St. Louis, MO). At corn growth stage V6-V8, subplots within each mixture (15-20 plants each) were infested so that every fifth plant in mixtures 1 and 4, every Bt- plant in mixture 2, and every Bt+ plant in mixture 3 received two egg masses. Larval sampling over a 21-d period indicated increased neonate dispersal off of Bt+ plants, reduced survival of larvae that dispersed from Bt+ plants to Bt- plants, and a low incidence of late-instar movement from Bt- plants to Bt+ plants. Computer simulations based on mortality and dispersal estimates from this study indicate that seed mixtures will delay the evolution of resistant European corn borer populations compared with uniform planting of transgenic corn. However, resistant European corn borer populations likely will develop faster in seed mixes compared with separate plantings of Bt and non-Bt corn.

Ewete, F. K., J. T. Arnason, T. Durst and S. Mackinnon (2000). "Toxicity of gedunin, piperine and crude extracts of their natural products on growth and development of *Ostrinia nubilalis* Hubner (*Lepidoptera* : *Pylalidae*)." *Discovery and Innovation* 12(1-2): 67-72.

Gedunin, a limonoid from *Meliaceae* and piperine, an amide alkaloid from *Piperaceae* and crude extracts containing these natural products were evaluated for their toxicity on larvae, larval growth inhibition and effects on development of European corn borer (ECB) *Ostrinia nubilalis* Hubner. Gedunin in artificial diet considerably reduced maximum larval weight at 10-40ppm and similar effects were observed with crude extracts of *Cedrela odorata* Linnaeus at 30-100 ppm. Both gedunin and the extract of *C. odorata* prolonged larval development and adult emergence of ECB. Piperine had no marked effect at reducing the maximum larval weight but caused larval mortality. Crude extract of *Piper guineense* Schum and Thonn reduced maximum larval weight at 30-300ppm and prolonged larval and adult emergence periods.

Gardner, J., H. P. Hoffmann and M. E. Smith (2000). "Resistance to European corn borer in processing sweet corn." *Hortscience* 35(5): 871-874.

Trials were conducted in 1997 and 1998 to determine if there is a range of resistance to European corn borer [*Ostrinia nubilalis* (Hubner)] (ECB) in commercially available processing sweet corn (*Zea mays* L.). Twelve processing corn cultivars were tested in 1997 and 18 cultivars in 1998. About 40 first instar larvae of colony-reared ECB were used to infest plants in both whorl and silking stages of growth. At harvest, plants infested at the whorl stage were evaluated for numbers of

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larvae and larval tunnels, and length of larval tunnels. Plants infested at the silking stage were evaluated for number of larvae per ear and were rated for ear damage using a 9-point scale. Resistance rankings among cultivars were consistent between years and between silk- and whorl-infested plants. We conclude that there is a substantial range of resistance already present in processing sweet corn cultivars, and that resistance is probably a combination of both exclusion and suppression of feeding. Our findings have two immediate uses: incorporation into existing IPM programs and incorporation of identifiable resistance bearing cultivars into a long-term breeding program for resistance to ECB in sweet corn.

Gonzalez-Nunez, M., F. Ortego and P. Castanera (2000). "Susceptibility of Spanish populations of the corn borers *Sesamia nonagrioides* (Lepidoptera : noctuidae) and *Ostrinia nubilalis* (Lepidoptera : Crambidae) to a *Bacillus thuringiensis* endotoxin." *Journal of Economic Entomology* 93(2): 459-463.

Baseline susceptibility to the Cry1Ab delta-endotoxin from *Bacillus thuringiensis* (Berliner) was determined for four populations of *Sesamia nonagrioides* (Lefebvre) and two populations of *Ostrinia nubilalis* (Hubner) from Spain. This study shows that *S. nonagrioides* is at least as susceptible as *O. nubilalis* to *B. thuringiensis* Cry1Ab protein. We found small differences in susceptibility among the Spanish populations of *S. nonagrioides* that can be attributed to natural variation, because there are no records of *B. thuringiensis* products being used on corn crops in Spain. There were no differences in susceptibility to Cry1Ab toxin between the two populations of *O. nubilalis*.

Marcon, P., B. D. Siegfried, T. Spencer and W. D. Hutchison (2000). "Development of diagnostic concentrations for monitoring *Bacillus thuringiensis* resistance in European corn borer (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 93(3): 925-930.

Two candidate diagnostic concentrations of the Cry1Ab and Cry1Ac toxins from *Bacillus thuringiensis* corresponding to the LC99 and EC99 (effective concentration that causes 99% growth inhibition) for European corn borer, *Ostrinia nubilalis* (Hubner), were determined based on previously obtained baseline data. Validation experiments using field-collected European corn borer populations from across North America showed that for Cry1Ab, a concentration corresponding to the upper limit of the 95% confidence interval of the LC99, produced mortality >99% for all populations tested. However, for Cry1Ac, adjustments and further validation are probably necessary. Development of *B. thuringiensis* resistance monitoring programs that rely on diagnostic techniques are discussed.

Mensah, R. K., S. Verneau and B. Frerot (2000). "Deterrence of oviposition of adult *Ostrinia nubilalis* Hubner (Lepidoptera : Pyralidae) by a natural enemy food supplement Envirofeast((R)) on maize in France." *International Journal of Pest Management* 46(1): 49-53.

Oviposition deterrent activity of a natural enemy food supplement, Envirofeast(R), against *Ostrinia nubilalis* Hubner females was studied in choice and no-choice tests under laboratory conditions. Maize plants treated with Envirofeast (R) at 25-40 g a.i./l had significantly fewer egg masses per leaf and eggs per egg mass laid on them compared with the untreated control plants in both choice and no-choice tests. However, maize plants treated with Envirofeast(R) concentrations of 10-20 g a.i./l did not significantly deter the insect's oviposition. The optimum rate at which Envirofeast(R) could deter oviposition was 25 g a.i./l. Increasing the rate of Envirofeast(R) application from 25-40 g a.i./l did not significantly increase its oviposition deterrent activity against *O. nubilalis*. However, reducing the rate from 25 to 20 g a.i./l resulted in a significant reduction in the oviposition deterrent activity of Envirofeast(R). The egg masses laid by *O. nubilalis* on Envirofeast(R) treated plants were essentially (80%) located on the lower leaf surfaces in contrast to untreated (control) plants where only 40-60% of the egg masses were deposited on the lower leaf surfaces. The egg masses on the Envirofeast(R) -treated plants were found at sites which did not receive sprays, indicating the importance of good spray coverage when the product is used in the field. The study has demonstrated the oviposition deterrent activity of Envirofeast(R) against *O. nubilalis* on maize and this indicates that Envirofeast(R) may have the potential to be integrated into programmes to assist in the control of *O. nubilalis* on maize.

Nault, B. A. and J. Speese (2000). "Managing Colorado potato beetles (Coleoptera : Chrysomelidae) and European corn borers (Lepidoptera : Pyralidae) in potato with foliar applications of *Bacillus thuringiensis* Berliner." *Journal of Entomological Science* 35(4): 373-384.

Application timing and rate combinations of *Bacillus thuringiensis* Berliner used for protecting Irish potato, *Solanum tuberosum* L., from defoliation by the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), and stem injury by the European corn borer, *Ostrinia nubilalis* (Hubner), were investigated. Significant reductions in defoliation levels during bloom, populations of first-generation potato beetle adults, and the percentage of stems injured by corn borers at the end of the season in *B. thuringiensis*-treated potato were considered criteria for a successful management strategy. Although Colorado potato beetle infestations were managed effectively with *B. thuringiensis*, European corn borer populations were not reduced to a commercially acceptable level. In each of 3 yrs, neither an increase in the number of applications (from 1 to 4) nor an increase in rate (from 0.9 to 3.8 liters/ha) of *B. thuringiensis* subsp. *kurstaki* improved the level of corn borer control. In contrast, results indicated that 1 application of *B. thuringiensis* subsp. *tenebrionis*, timed when there was >1 large potato beetle larva per stem, using a 4.7 liters/ha rate protected the potato crop during the bloom stage. However, this strategy may not be sufficient to prevent significant levels of defoliation by first-generation potato beetle adults during post-bloom or reduce the size of this population, which will infest next season's crop. For this reason, the *B. thuringiensis* subsp. *tenebrionis* timing and rate regimen described above may be most effective in fields where the overwintering potato beetle population is predicted to be low to moderate (e.g., <1 adult per 5 stems), whereas two applications may be most effective in fields where densities are greater.

Ngollo, E. D., E. Groden, J. F. Dill and D. T. Handley (2000). "Monitoring of the European corn borer (Lepidoptera : Crambidae) in central Maine." *Journal of Economic Entomology* 93(2): 256-263.

Pheromone trap types and within-field trap locations were compared for their effectiveness in monitoring the flight activity of European corn borer, *Ostrinia nubilalis* (Hubner), and its relationship to egg mass density and crop damage in sweet corn in central Maine from 1995 to 1996. The use of both 3:97 Z:E-11-tetradecenyl acetate and 97:3 Z:E-11-tetradecenyl acetate pheromone blends confirmed that European corn borer in central Maine is attracted to both pheromone lure types. European corn borer moths were captured predominantly with the E-lure type than with the Z-lure type in both years. The Scentry Heliiothis trap was more effective than the Multi-Pher trap: but similar to the pheromone-baited water pan trap for monitoring European corn borer flights. With the Scentry Heliiothis trap, the grassy border and 1st corn rows were the best locations for moth capture during the early flight period, but during the peak night period, traps located in the middle of the field caught the most moths. Corn damage was recorded before moth captures in some sites and before egg mass counts in others, indicating poor efficacy of traps for early nights. Significant and positive correlations were found between moth captures in the midfield location and egg mass counts, and corn leaf damage, and between egg mass counts and corn leaf damage. However, low coefficients of variation suggest that pheromone trap captures were not good predictors of European corn borer leaf damage in sweet corn.

Schlaepfer, M. A. and J. N. McNeil (2000). "Are virgin male lepidopterans more successful in mate acquisition than previously mated individuals? A study of the European corn borer, *Ostrinia nubilalis* (Lepidoptera : Pyralidae)." *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 78(11): 2045-2050.

Male phenotypic quality may significantly influence female reproductive success. Depletion of sperm and accessory-gland secretions with successive matings represents a reduction in male phenotypic quality and is known to decrease female reproductive output in several lepidopteran species, including the European corn borer (ECB), *Ostrinia nubilalis*. We therefore tested the hypothesis that female ECBs, given the simultaneous choice of an experienced male and a virgin male, preferentially mate with the virgin. However, contrary to prediction, females mated significantly more often with experienced males. Experienced males were significantly lighter than their virgin counterparts, the result of producing three spermatophores that were transferred during previous matings. However, differences in body mass or wing-loading did not appear to play an important role, for within either the experienced or virgin classes, heavier males obtained more matings than lighter ones. Why would females prefer to mate with sexually experienced males? Females may not be exercising any precopulatory choice, and the greater mating success of previously mated males may be related to previous experience. Behavioral observations, however, suggest that female choice occurred. In the process of selecting experienced males, the number of consecutive matings was correlated with low fluctuating asymmetry of the forewing (R-L). This suggests that males who acquired 3 consecutive matings were of above-average quality and were actively selected by females.

Singer, J. W., J. R. Heckman, J. Ingerson-Mahar and M. L. Westendorf (2000). "Hybrid and nitrogen source affect yield and European corn borer damage." *Journal of Sustainable Agriculture* 16(1): 5-15.

Transgenic corn plants that contain cry proteins (Cry1Ab, Cry1Ac, and Cry9C) of *Bacillus thuringiensis* (Bt) offer corn (*Zea mays* L.) growers a more practical and environmentally friendly solution to manage European corn borer (ECB) (*Ostrinia nubilalis* Hubner) induced loss. Bt corn has demonstrated such promising initial results that it may be susceptible to ECB resistance from overuse. The objective of this study was to investigate nitrogen (N) source effects on ECB damage on continuous corn yield. The effects of N source on soil NO₃--N, plant height, 2nd generation ECB damage, and grain yield were investigated on a Quakertown silt loam (Fine-loamy, mixed, mesic, Typic Hapludult) from 1995 to 1998. Based on ECB damage observations in 1995 and 1996, plots were split in 1997 and corn isolines were evaluated to study the ECB and yield response to Bt corn. Corn yield did not respond to manure plus sidedress N over the 4-yr period of this study because soil N levels were adequate without sidedress N, as indicated by the pre-sidedress nitrate test (PSNT). Second generation ECB damage was greater in manure plots in all 4-yr. In 1997, an outbreak year, and 1998, an endemic year, Bt corn and manure yielded 19 and 7% greater than non-Bt corn and manure. Our findings suggest that Bt corn is of significant value on land receiving manure in continuous corn production where ECB damage is high.

Spangler, S. M. and D. D. Calvin (2000). "Influence of sweet corn growth stages on European corn borer (Lepidoptera : Crambidae) oviposition." *Environmental Entomology* 29(6): 1226-1235.

Oviposition rates of the European corn borer, *Ostrinia nubilalis* (Hubner), were examined on corn plants from the S-leaf through postharvest growth stages during 1994-1996. Per-plant rates in the field during vegetative stages showed a gradual increase as new leaves appeared, and a sharp increase when reproductive plant parts emerged. Laboratory studies indicated a similar relationship between oviposition rate and plant growth stage: significantly greater rates occurred on reproductive plants. Laboratory experiments showed that when only 4-leaf to early green tassel (preanthesis) plants were present (simulating conditions during early-season European corn borer activity), per-plant oviposition was significantly greater on the oldest (11-leaf to green tassel) plants. When the oviposition rate was based on leaf area rather than on a per-plant basis, however, statistical differences between vegetative stages were lost. When European corn borer females were given only reproductive plant stages (simulating conditions during late-season European corn borer oviposition), plants in the green tassel, anthesis, green silk, and brown silk stages had generally equal oviposition rates, and these were significantly greater than on postharvest plants. This European corn borer oviposition simulation, when based on leaf area, showed the same pattern as the per-plant oviposition. Thus, leaf area appears to influence oviposition during the vegetative stages, when leaf area is rapidly expanding, but is of little influence after tassels emerge and leaf area is expanding at a slower rate or declining. Moth alighting in the laboratory indicate a behavioral difference between sexes. Females alighted on plants identical to those favored for oviposition. In contrast, males showed no preference for any growth stage of corn.

Trisyono, A., C. L. Goodman, J. J. Grasela, A. H. McIntosh and G. M. Chippendale (2000). "Establishment and characterization of an *Ostrinia nubilalis* cell line, and its response to ecdysone agonists." *In Vitro Cellular & Developmental Biology-Animal* 36(6): 400-404.

A cell line derived from embryonic tissues of the European corn borer, *Ostrinia nubilalis* (UMC-OnE), was established in EX-CELL 401 medium containing 10% fetal bovine serum. The cells grew in suspension, and were mainly spherical in shape. The cell doubling times at the 17th and 79th passages were 56 and 36 h, respectively. DNA amplification fingerprinting showed that the DNA profile of the OnE cell line was different from that of the southwestern corn borer, *Diatraea grandiosella* (UMC-DgE), and that of the cotton bollworm, *Helicoverpa zea* (BCIRL-HZ-AMI). The OnE cell line was responsive to treatments of 20-hydroxyecdysone and the ecdysone agonists, methoxyfenozide (RH-2485) and tebufenozide (RH-5992). These compounds caused similar effects on the cells, which included cell clumping and decreased cell proliferation. The clumps were observed on the third day of incubation, and became larger after 7 d of incubation. After 168 h of incubation, methoxyfenozide and tebufenozide were 35 and 11 times more effective, respectively, in inhibiting proliferation of the OnE cells than was 20-hydroxyecdysone.

Walker, K. A., R. L. Hellmich and L. C. Lewis (2000). "Late-instar European corn borer (Lepidoptera : Crambidae) tunneling and survival in transgenic corn hybrids." *Journal of Economic Entomology* 93(4): 1276-1285.

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Field studies were conducted in 1996 and 1997 to determine injury by and survival of late-instar European corn borer, *Ostrinia nubilalis* (Hubner), on genetically altered *Bacillus thuringiensis* Berliner corn, *Zea mays* L. Cry1Ab events 176, Bt11, MON810, and MON802; Cry1Ac event DBT418; and Cry9C event CBH351 were evaluated. Plants of each corn hybrid were manually infested with two third-, fourth-, or fifth-instar *O. nubilalis*. Larvae were held in proximity to the internode of the plant above the ear with a mesh sleeve. Larvae were put on tie plants during corn developmental stages V8, V16, R1, R3, R4, R5, and R6. This study shows that not all *B. thuringiensis* hybrids provide the same protection against *O. nubilalis* injury. Hybrids with *B. thuringiensis* events Bt11, MON810, MON802, and CHB351 effectively protected the corn against tunneling by late-instar *O. nubilalis*. Event 176 was effective in controlling late-instar *O. nubilalis* during V12 and V16 corn developmental stages; however, significant tunneling occurred by fourth instars during R3 and R5. Event DBT418 was not effective in controlling late-instar *O. nubilalis* during corn vegetative or reproductive stages of development. Whether the *B. thuringiensis* hybrids satisfied high- and ultrahigh-dose requirements is discussed.

Abel, C. A. and R. L. Wilson (1999). "Evaluation of 11 maize populations from Peru for mechanisms of resistance to leaf feeding by European corn borer." *Journal of the Kansas Entomological Society* 72(2): 149-159.

Eleven accessions of maize from Peru were previously identified as resistant to leaf feeding by European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae). A study was conducted to determine the mechanism of resistance. The weight of larvae fed Peruvian maize leaf material was not significantly different from larvae fed a resistant check, CI31A, indicating antibiosis in the Peruvian maize was at a level equivalent to CI31A. The inbred, CI31A, contained high levels of DIMBOA, thus having strong nonpreference and antibiosis properties toward leaf feeding by European corn borer. The rate of larvae leaving artificially infested Peruvian maize plants over a 5-day period was significantly less than CI31A but significantly more than a susceptible check, WF9, indicating nonpreference was a possible mechanism of resistance in the Peruvian maize but at a level lower than CI31A. When Peruvian maize leaf whorl material was added to a standard European corn borer rearing diet, the effects of the resistance factor were lost. The standard diet ingredients may have masked the effect of the resistance factor. Another possibility may be that the resistance factor was a deficiency of a vital nutrient needed for normal European corn borer development. This nutrient may have been supplied to the insect when the standard diet ingredients were added to the Peruvian maize leaf material. Further study in this area is needed to identify the basis of resistance.

Bartels, D. W., W. D. Hutchison, D. J. Bach and T. L. Rabaey (1999). "Evaluation of commercial pheromone lures and comparative blacklight trap catches for monitoring Z-strain European corn borer (Lepidoptera : Crambidae)." *Journal of Agricultural and Urban Entomology* 16(1): 85-94.

Field experiments were conducted during 1997 to evaluate commercially available pheromone lures for Z-strain European corn borer, *Ostrinia nubilalis* (Hubner) at Rosemount and Le Sueur, Minnesota. Improved pheromone lures, available from Trece, Inc. and Hereon Environmental Co., were compared with a University of Minnesota pheromone lure (MN-lure) and a conventional blacklight trap. The phenology of *O. nubilalis* flights, based on pheromone and blacklight trap data, also was compared. Mean moth counts were similar for the Trece, Hereon, and MN-lures. Although the pheromone and blacklight traps did not differ in total male moth capture, the pheromone-baited trap resulted in a delay of 4 to 8 d in detection of estimated peak capture.

Binder, B. F., J. C. Robbins, R. L. Wilson, C. A. Abel and P. N. Hinz (1999). "Effects of Peruvian maize extracts on growth, development, and fecundity of the European corn borer." *Journal of Chemical Ecology* 25(6): 1281-1294.

Twelve Peruvian maize, Zen mays, accessions were selected because of their relatively high level of field resistance to first-generation European corn borer (ECB), *Ostrinia nubilalis*, larval leaf-feeding. Water extracts of freeze-dried, powdered, leaf tissue were incorporated into a standard ECB diet, fed to larvae, and the effects on larval growth, development, and fecundity were measured. Larval and pupal weights were monitored as were the time elapsed in the larval, pupal, and adult stages. Adult fecundity and egg fertility were recorded. The experiment was a randomized block design (larvae and pupae) or a completely randomized design (adults) and analyzed with ANOVA ($\alpha = 0.05$). Pairwise comparisons were made between groups of insects grown on diets containing extracts from the Peruvian lines, a standard diet, or diets containing extracts of a known susceptible inbred, and a known resistant inbred line. Survival was analyzed with a chi-squared test ($\alpha = 0.05$). Two Peruvian accessions significantly reduced female larval and

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pupal weights, extended pupal adult development time, and decreased survival of pupae and adults. Water extracts also had a pronounced impact on males; two accessions significantly reduced pupal weight and extended the time required to pupate, and one reduced male survival to adults. The results indicate that water-soluble factors from resistant Peruvian accessions inhibit the growth, developmental time, and survival of ECB. These resistance factors could be useful in the development of maize germplasm with insect-resistant traits.

Bohn, M., R. C. Kreps, D. Klein and A. E. Melchinger (1999). "Damage and grain yield losses caused by European corn borer (Lepidoptera : Pyralidae) in early maturing European maize hybrids." *Journal of Economic Entomology* 92(3): 723-731.

The European corn borer, *Ostrinia nubilalis* (Hubner), is a major pest of maize, *Zen mays* L., in Central Europe. The resistance of 8 early maturing commercial maize hybrids and 6 experimental hybrids against European corn borer was assessed during 1996 and 1997 in Germany. Resistance was evaluated by yield reduction and damage ratings under natural and manual infestation in 11 or 6 environments, respectively. The infestation level of European corn borer was assessed by the percentage of damaged plants and number of larvae per plant in each environment. Average grain yield of the commercial hybrids was reduced by 0.28% for each 1% of damaged plants and by 6.05% for each European corn borer larvae per plant. All commercial and experimental hybrids were susceptible to European corn borer attack. The commercial hybrids showed little variation in their resistance to European corn borer. The experimental hybrids derived from crosses between resistant inbreds were more resistant than crosses between intermediate and susceptible inbreds. The evaluation of yield reduction required manual infestation because of the low natural infestation level in most environments. However, a comparison of error variances and repeatabilities revealed that they were of similar magnitude for environments with a high level of natural and manual infestation. Yield reduction and damage ratings were highly correlated ($r(p)$ less than or equal to 0.85) under both infestation regimes. Consequently, the latter trait should be useful for indirect selection to improve European corn borer resistance in maize.

Bokor, P. and L. Cagan (1999). "Phenology, basic biology and parasitism of *Microgaster tibialis* (Hymenoptera, Braconidae), a parasitoid of the European corn borer, *Ostrinia nubilalis*, in Central Europe." *Biologia* 54(5): 567-572.

Phenology, bionomics and parasitism of *Microgaster tibialis*, a parasitoid of the European corn borer, *Ostrinia nubilalis*, was studied in four regions of Central Europe in 1993-1995. Regular parasitism of *O. nubilalis* larvae (1.83-2.95%) was observed at Blatnice in Moravia (eastern part of the Czech Republic). Parasitoid cocoons were also found in SW Slovakia and E Slovakia during 1994-1995 and at Wroclaw (SW Poland) in 1994. These records are the first from Moravia, Slovakia and from Poland. The findings suggest that *M. tibialis* generally pupate at the end of September and at the beginning of October in Central Europe. Parasitoid adults emerged during April. Development threshold temperatures for 50% adult emergence was 2 degrees C, the corresponding thermal constants were 294.6-311.0 Celsius degree-days. *M. tibialis* has probably two generations a year, the first one parasitizing on an alternate host.

Bolin, P. C., W. D. Hutchison and D. A. Andow (1999). "Long-term selection for resistance to bacillus thuringiensis Cry1Ac endotoxin in a Minnesota population of European corn borer (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 92(5): 1021-1030.

Transgenic corn, expressing the insecticidal delta-endotoxin of *Bacillus thuringiensis* Berliner, provides high levels of control of some lepidopteran pests, particularly the European corn borer, *Ostrinia nubilalis* (Hubner). However, resistance to *B. thuringiensis* has been documented recently in laboratory colonies of agronomically important Lepidoptera, including *O. nubilalis*. For the past 4 yr, we have selected for Cry1Ac resistance in a population of *O. nubilalis* from southeastern Minnesota. Increasing resistance to *B. thuringiensis* was noted after only 8 generations of selection, with a peak at 162-fold resistance, based on comparisons of LC(50)S to a nonselected parental strain. This resistance was found to decrease at the same rate in the absence of *B. thuringiensis* selection, with one selected colony becoming nearly as sensitive to the Cry1Ac toxin as the nonselected colony after 9 generations without exposure to *B. thuringiensis*. The most resistant of the colonies, S-I, was only marginally cross-resistant to Cry1Ab, yet another selected colony, S-IV, did demonstrate a 16-fold cross-resistance. In addition, larvae from the S-IV colony had significantly greater weight gain when feeding on diet incorporated with *B. thuringiensis*-transgenic corn than did larvae from the nonselected parental colony. These findings emphasize the need for careful deployment of *B. thuringiensis* corn to preserve this effective pest management technology.

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Bruck, D. J. and L. C. Lewis (1999). "Ostrinia nubilalis (Lepidoptera : Pyralidae) larval parasitism and infection with entomopathogens in cornfields with different border vegetation." *Journal of Agricultural and Urban Entomology* 16(4): 255-272.

Observational studies were conducted in 1995 and 1996 to sample natural enemies of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae) along field borders with differing vegetation levels. Corn fields adjacent to three broad classes of border vegetation: herbaceous, intermediate, and wooded, were studied. A cornfield adjacent to each border class was sampled along the entire length of its respective border. *Ostrinia nubilalis* larvae collected were evaluated for presence of the entomopathogens *Beauveria bassiana* (Balsamo) Vuillemin (Deuteromycotina: Hyphomycetes) and *Nosema pyrausta* (Paillot) (Microspora: Nosematidae) and the parasitoid *Macrocentrus grandii* Goidanich (Hymenoptera: Braconidae). There was a negative interaction noted between larvae parasitized by *M. grandii* and *O. nubilalis* larvae infected with *N. pyrausta*. This antagonism between the two biotic factors may explain why increased food and shelter adjacent to corn bordering diverse vegetation did not result in significantly higher parasitism in limited observations. The levels of entomopathogen infections also were not consistently influenced by border vegetation type.

Cagan, L., T. Turlings, P. Bokor and S. Dorn (1999). "Lydella thompsoni Herting (Dipt., Tachinidae), a parasitoid of the European corn borer, *Ostrinia nubilalis* Hbn. (Lep., Pyralidae) in Slovakia, Czech Republic and south-western Poland." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 123(10): 577-583.

This paper shows that, within Central Europe, parasitism of the European corn borer (ECB) by the tachinid parasitoid, *Lydella thompsoni* (LT) increased from 0.47 to 1.49% in south-western Poland (51 degrees 03'N), to 4.31-21.95% in eastern Slovakia (48 degrees 20'N). The synchrony between the parasitoid LT and its primary host: the ECB, was studied in Central Europe under conditions where the host is univoltine, but the parasitoid is bivoltine. A cumulated total of more than 400 LT was field-collected from overwintering ECB larvae. The parasitoid hibernated as larva inside the host. Pupation started in the second half of the following March and 50% of pupation was surpassed in the first half of April. The first parasitoid adults emerged at the end of April and the majority at the beginning of May. Development threshold temperatures for 50% pupation was determined to be 2.7 degrees C, and for 50% adult emergence 5.0 degrees C; the respective thermal constants were 178.8-179.8 and 237.7-251.8 Celsius degree-days. Emerged adults did not parasitize overwintered ECB larvae in spring, hence there must be an alternate host for the first generation of LT in areas of univoltine life cycle of the ECB. Parasitization of the ECB larvae by LT continued until the end of July. The first parasitoid adults from this second generation emerged in the second half of August. By the end of the season, nearly one-third of LT adults had emerged. The rest of this generation apparently overwintered in the larval stage.

Fadamiro, H. Y. and T. C. Baker (1999). "Reproductive performance and longevity of female European corn borer, *Ostrinia nubilalis*: effects of multiple mating, delay in mating, and adult feeding." *Journal of Insect Physiology* 45(4): 385-392.

In a recent study on the pheromone-mating disruption of the European corn borer, *Ostrinia nubilalis* (Lepidoptera: Crambidae), we recorded a significant reduction in mating frequency, as well as a marked delay in mating in feral females captured in disruptant-treated fields. In order to be able to accurately interpret the results in terms of effective population control, the current study was undertaken on the effects of multiple matings and a delay in mating on reproductive performance. Female *O. nubilalis* that mated at least twice had significantly higher fecundity and fertility, compared with once-mated females. In addition, multiple-mated females deposited a significantly larger portion of their egg complement, relative to single-mated or unmated females. Females that experienced a 3-day delay in mating showed a significant reduction in fecundity compared with females that mated soon after emergence. A 1-week delay in mating resulted in a further reduction in fecundity and a near zero fertility. The effect of sugar feeding on reproduction was not significant. In general, unmated females lived longer than mated females, and sugar-fed mated females had a higher longevity than water-fed mated females. (C) 1999 Elsevier Science Ltd. All rights reserved.

Hellmich, R. L., L. S. Higgins, J. F. Witkowski, J. E. Campbell and L. C. Lewis (1999). "Oviposition by European corn borer (Lepidoptera : Crambidae) in response to various transgenic corn events." *Journal of Economic Entomology* 92(5): 1014-1020.

Oviposition preference by European corn borers, *Ostrinia nubilalis* (Hubner), for or against transgenic corn would influence amounts of refuge required for resistance management. The objective of this research was to determine if various *Bacillus thuringiensis* (Bt) corn transgenic events influence *a. nubilalis* oviposition. All commercially available events (currently 5) were evaluated, plus 1 experimental event. Results from 3 independent studies are reported,

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including 3 field-cage experiments with vegetative corn, 2 field-cage experiments with reproductive corn, and 2 field experiments with natural *O. nubilalis* on reproductive corn. In each case, Bt corn hybrids are compared with their near isogenic hybrids by counting numbers of egg masses on each plant type. More extensive comparisons were made in 3 of the experiments by determining the number, size, and location of egg masses on the corn hybrids. Moths laid more egg masses on Bt corn than on non-Bt corn in 1 cage experiment. These results, however, were not found in any of the other experiments. There is evidence that suggests cage effects influence moth oviposition more than Bt protein. Four of the 5 cage experiments and 2 field experiments indicate that the tested Bt events do not influence *a. nubilalis* oviposition. Larval injury to isogenic corn during the vegetative stage did not influence adult oviposition during the corn reproductive stage when compared with Bt corn and noninjured isogenic corn. Based on these experiments, suggestions are made for future studies that use natural *a. nubilalis* rather than *a. nubilalis* in cages.

Huang, F., L. L. Buschman, R. A. Higgins and W. H. McGaughey (1999). "Inheritance of resistance to *Bacillus thuringiensis* toxin (Dipel ES) in the European corn borer." *Science* 284(5416): 965-967.

Resistance in the European corn borer, *Ostrinia nubilalis* (Hubner), to a commercial formulation of *Bacillus thuringiensis* (Bt) Berliner toxin, Dipel ES, appears to be inherited as an incompletely dominant autosomal gene. This contrasts with the inheritance of resistance to St in other insects, where it has usually been characterized as a recessive trait. The proposed high-dose/refuge strategy for resistance management in St maize depends on resistance being recessive or partially recessive, if field resistance turns out to be similar to this Laboratory resistance, the usefulness of the high-dose/refuge strategy for resistance management in Bt maize may be diminished.

Huang, F., R. A. Higgins and L. L. Buschman (1999). "Heritability and stability of resistance to *Bacillus thuringiensis* in *Ostrinia nubilalis* (Lepidoptera : Pyralidae)." *Bulletin of Entomological Research* 89(5): 449-454.

Realized heritability, h^2 , of resistance in European corn borer, *Ostrinia nubilalis* (Hubner), to *Bacillus thuringiensis* Berliner ssp. *kurstaki* endotoxins was examined in five resistant laboratory colonies. These colonies were reared on a meridic diet that incorporated a commercial formulation of *B. thuringiensis*, Dipel ES. Resistance in these colonies reached 42-67x by the seventh to twentieth selected generations and then plateaued. The realized heritability of resistance averaged 0.17-0.31 over all selected generations for the five colonies. In the three Iowa colonies, the highest realized heritability, 0.18-0.33, occurred during the second period of selection (seventh to thirteenth selected generations). In the two Kansas colonies, the highest realized heritability, 0.36 and 0.46, occurred during the first period of selection (first to sixth selected generations). In the absence of selection pressure, resistance in the southwest Kansas colony decreased from 62x to 42x after two generations, and remained at about that level for the next five generations.

Huang, F. N., L. L. Buschman and R. A. Higgins (1999). "Susceptibility of different instars of European corn borer (Lepidoptera : Crambidae) to diet containing *Bacillus thuringiensis*." *Journal of Economic Entomology* 92(3): 547-550.

The relative susceptibility of different instars of the European corn borer, *Ostrinia nubilalis*, (Hubner), to a commercial formulation of *Bacillus thuringiensis* Berliner subsp. *kurstaki*, Dipel ES, was determined using diet incorporation. European corn borers exposed to Dipel during the 1st instar were much more susceptible than were older larvae. No significant differences in susceptibility were found among 3rd, 4th, and 5th instars at doses of 0.03-0.81 ml of Dipel per kilogram of diet. At high concentrations (2.43 ml/kg of diet), 5th instars had significantly lower mortality than did 3rd or with instars. The LC50 and LC90 of the 5th instars were 98.1- and >168.2-fold higher, respectively, than those of 1st instars. These findings should be accounted for during the development of a resistance management strategy for the use of *B. thuringiensis* toxin as a microbial insecticide and possibly, for Bt-expressing transgenic corn. Differential susceptibility of different instars of European corn borer to *B. thuringiensis* suggests that the "ultra high-dose" or "high-dose" resistance management strategy should be defined in terms of the largest and the least susceptible stage, because larvae may have opportunities to grow and develop on non-Bt-corn or alternate hosts before they attack the Bt-corn plants.

Huang, F. N., K. Y. Zhu, L. L. Buschman, R. A. Higgins and B. Oppert (1999). "Comparison of midgut proteinases in *Bacillus thuringiensis*-susceptible and -resistant European corn borer, *Ostrinia nubilalis* (Lepidoptera : Pyralidae)." *Pesticide Biochemistry and Physiology* 65(2): 132-139.

The midgut proteinases from a *Bacillus thuringiensis*-susceptible (IA-S) and four laboratory-selected resistant strains (KS-SC, KS-NE, IA-1, and IA-3) of European corn borer (*Ostrinia nubilalis*) were characterized using three synthetic substrates, N alpha-benzoyl-L-arginine p-nitroanilide (BAPNA) for trypsin-like, N-succinyl-ala-ala-pro-phe p-nitroanilide (SAAPFpNA) for chymotrypsin-like, and N-succinyl-ala-ala-pro-leu p-nitroanilide (SAAPLpNA) for elastase-like proteinase activities. The hydrolyzing efficiency of trypsinlike proteinases, determined by V-max, decreased 35% in the KS-SC resistant strain compared with the susceptible strain. There were no significant differences in the Michaelis constant (K-m) among the five strains for the same substrate. When the purified B. thuringiensis Cry1Ab protoxin was used as the substrate, there was a detectable reduction in the hydrolysis of protoxin that was mediated by midgut proteinases from the KS-SC strain compared with the IA-S strain. Thus, the reduced trypsin-like proteinase activity appeared to lead to the reduced activation of the B. thuringiensis protoxins. This may confer or contribute to B. thuringiensis resistance in this strain. However, no significant difference was found in trypsin activity between the LA-S strain and the three other resistant strains (i.e., KS-NE, IA-1, and IA-3) and in chymotrypsin activity among all strains examined. These results suggest that other resistance mechanisms are responsible for the B. thuringiensis resistance in the KS-NE, IA-1, IA-2, and IA-3 strains of European corn borer. (C) 1999 Academic Press.

Lee, S., R. Tsao and J. R. Coats (1999). "Influence of dietary applied monoterpenoids and derivatives on survival and growth of the European corn borer (Lepidoptera : Pyralidae)." *Journal of Economic Entomology* 92(1): 56-67.

Sixteen natural monoterpenoids and 6 synthetic derivatives were selected For study of larvicidal activity and growth inhibitory effect against the European corn borer, *Ostrinia nubilalis* (Hubner). For this study, 2 different dietary exposure bioassays were used: compounds applied on the diet surface (on-diet), and compounds incorporated into the diet (in-diet). Most of the monoterpenoid compounds showed some degree of larvicidal activity in both bioassay procedures after a 6-d exposure period. Among the monoterpenoids, pulegone was the most active. Larvicidal toxicities were significantly enhanced for the structurally modified compounds; monoterpenoid derivatives MTEE-25 (2-fluoroethyl thymyl ether) and MTEE-P (propargyl citronellate) were most toxic to borer larvae. When reared on diet containing the monoterpenoids or their derivatives, changes in developmental parameters and pupal weights of the European corn borer also were noted when they were fed several of the compounds. Some larvae reared on treated diet with higher concentrations of the test compounds died before pupating. In general, growth and development of the European corn borer were affected by monoterpenoid compounds, and some compounds such as I-menthol, pulegone, MTEE-25, and MTEE-P acted as insect growth inhibitors.

Linn, C., K. Poole, A. Zhang and W. Roelofs (1999). "Pheromone-blend discrimination by European corn borer moths with inter-race and inter-sex antennal transplants." *Journal of Comparative Physiology a-Sensory Neural and Behavioral Physiology* 184(3): 273-278.

Transplantation of larval antennal imaginal disks between the pheromone races of the European corn borer moth produced males and females of one race with male antennal phenotypes of the race using the opposite pheromone blend. All of the adults with transplanted antennal disks that exhibited a pheromone-mediated response in the flight tunnel did so with the pheromone blend of the recipient's race, even though the respective males and females possessed male antennae of the opposite race. Our results support the conclusion that male antennal response type is not a determining factor in pheromone-blend discrimination in male moths.

Maini, S. and G. Burgio (1999). "*Ostrinia nubilalis* (Hb.) (Lep., Pyralidae) on sweet corn: relationship between adults caught in multibaited traps and ear damages." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 123(3): 179-185.

Infestation with *Ostrinia nubilalis* (Hb.), the European corn borer (ECB) can be detected by using different sampling techniques in the field and statistical models aimed to assess the development time of ECB larvae and crop damage. An appropriate monitoring for this polyphagous species to show a relationship between the kind of sampling or a model and the subsequent damage in a particular crop, is very difficult. Sex pheromone traps, generally, are also not reliable for monitoring ECB. The possibility of employing new types of traps baited with a sex pheromone and a maize kairomone, the phenylacetaldehyde (PAA) (multibaited traps) was investigated. In sweet corn, trapping experiments were conducted over a 2-year period with two kinds of cone traps (XLa and XLb) set up at the borders of fields (four replicates). ECB attacks of first and second generation larvae were evaluated in the corn ears as a percentage of damage and using a damage index (DI). A correlation was found between the number of females caught per trap and

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either the percentage of damaged ears ($r = 0.73$ for XLa; $r = 0.65$ for XLb) and the DI ($r = 0.70$ for XLa; $r = 0.60$ for XLb). Conversely, the number of males caught per trap was not correlated with ECB larval damage. A linear model of multiple correlation fitted to the data of simultaneous captures of males and females showed that the coefficients were not higher than simple correlation. The correlation coefficients obtained by fitting a curvilinear response surface were higher ($r = 0.81$ for XLa and $r = 0.84$ for XLb, respectively, related to percentage of damaged ears; $r = 0.79$ for XLa and $r = 0.76$ for XLb, respectively, related to DI) thus indicating that the simultaneous counting of males and females in cone traps can be an efficient and simple monitoring tool.

Marcon, P., D. B. Taylor, C. E. Mason, R. L. Hellmich and B. D. Siegfried (1999). "Genetic similarity among pheromone and voltinism races of *Ostrinia nubilalis* (Hubner) (Lepidoptera : Crambidae)." *Insect Molecular Biology* 8(2): 213-221.

The genetic variability of seven European corn borer populations, *Ostrinia nubilalis*, from North America and Europe was assessed by polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) analysis and DNA sequencing. The nuclear ribosomal internal transcribed spacer 1 (ITS-1) region (approximate to 500 base pair [bp]) and four mitochondrial (mtDNA) regions (1550 bp total) were examined. The smartweed borer, *Ostrinia obumbratalis*, and south-Western corn borer, *Diatraea grandiosella*, were used for comparisons. Of 106 restriction sites identified (80 in mtDNA and 26 in ITS-1), none differentiated geographical populations, pheromone races, or voltine ecotypes of the European corn borer. The lack of variation in the ITS-1 of European corn borer was confirmed by DNA sequence analysis. The genetic similarity of European corn borer populations, despite their wide geographical range and physiological differences, may be explained by a relatively recent origin for the voltinism and pheromone races, gene flow among races, and/or expansion from genetic bottlenecks.

Marcon, P., L. J. Young, K. L. Steffey and B. D. Siegfried (1999). "Baseline susceptibility of European corn borer (Lepidoptera : Crambidae) to *Bacillus thuringiensis* toxins." *Journal of Economic Entomology* 92(2): 279-285.

Susceptibility to CryIAb and CryIAc toxins from *Bacillus thuringiensis* was determined for 11 populations of neonate European corn borer, *Ostrinia nubilalis* (Hubner), from the United States and 1 from northern Italy. Corn borer larvae were exposed to artificial diet treated with increasing *B. thuringiensis* concentrations, and mortality and growth inhibition were evaluated after 7 d. The range of variation in *B. thuringiensis* susceptibility indicated by growth inhibition was very similar to that indicated by mortality. Although interpopulation variation in susceptibility to both proteins was observed, the magnitude of the differences was small (less than or equal to 4-fold) and comparable to the variability observed among generations within a particular population (less than or equal to 3-fold). Additionally, there was no indication that *B. thuringiensis* susceptibility was influenced by pheromone race, voltine ecotype, or geographic location. These results suggest that the observed susceptibility differences reflect natural variation in *B. thuringiensis* susceptibility among corn borer populations rather than variation caused by prior exposure to selection pressures. Therefore, European corn borers apparently are susceptible to *B. thuringiensis* toxins among populations across most of their geographic range.

Myers, S. W. and J. L. Wedberg (1999). "Development of an economic injury level for European corn borer (Lepidoptera : Pyralidae) on corn grown for silage." *Journal of Economic Entomology* 92(3): 624-630.

Studies were conducted in 1996 and 1997 at 2 locations in Wisconsin to assess the impact of European corn borer, *Ostrinia nubilalis* (Hubner), on corn grown for silage. Relationships between silage yield losses and control costs were used to develop economic injury levels specific to corn grown for silage in Wisconsin. Treatments were established as the percentage of plants infested with European corn borers. Treatment levels of 0, 12, 24, 40, and 84% of plants infested were used to separately examine simulations of 1st- and end-generation European corn borer infestations. Experiments were performed using Pioneer dual purpose hybrids 3394 and 3751. Results from experiments showed that overall whole plant dry matter yields for 3394 were 8.5% > 3751 across the 3 experiments. Increasing European corn borer infestation proved to be highly correlated with a decrease in both whole plant and stover silage yields throughout experiments, hybrids, and simulated European corn borer generations. Differences in the rates of yield reduction were not seen between the 2 hybrids, however simulations of 1st-generation European corn borer infestation caused greater reductions than did simulations of 2nd-generation European corn borers. Linear regression models proved to best fit the yield loss relationships and were developed to describe silage yield losses resulting from European corn borer infestations. Economic injury levels were determined by comparing silage yield reductions and

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associated monetary losses with control costs. Economic injury levels were calculated separately for both 1st- and 2nd-generation European corn borers.

Onstad, D. W. and C. A. Guse (1999). "Economic analysis of transgenic maize and nontransgenic refuges for managing European corn borer (Lepidoptera : Pyralidae)." *Journal of Economic Entomology* 92(6): 1256-1265.

We simulated the population dynamics and population genetics of Europe; in corn borer, *Ostrinia nubilalis* (Hubner), and damage to maize in a hypothetical region containing transgenic and nontransgenic maize and no other crops. The model assumes that the same level of refuge for resistance management is used every year over 15-20 yr and that no European corn borers immigrate into the region over the same period. When complete mixing across blocks between generations is assumed, the transgenic block significantly lowers damage to maize in the refuges. For most scenarios without toxin-titer decline during maize senescence, a 20% refuge is a robust, economical choice based on current value. At extremes of initial pest density or crop value (price X expected yield), refuge levels as low as 8% or as high as 26% can be superior. Nontransgenic maize can be planted as strips (at least 6 rows per strip) within a field or as separate but adjacent blocks to be effective at delaying resistance and providing economic returns at a 20% refuge level. With toxin-titer decline during senescence, the model results are sensitive to several biological parameters and assumptions with a 10% refuge level offering a robust, economic choice.

Pleasants, J. M. and R. J. Bitzer (1999). "Aggregation sites for adult European corn borers (Lepidoptera : Crambidae): A comparison of prairie and non-native vegetation." *Environmental Entomology* 28(4): 608-617.

Moths of the European corn borer, *Ostrinia nubilalis* (Hubner), aggregate in vegetation during the day. We examined the preference of moths for different types of vegetation as aggregation sites and investigated several physical characteristics of vegetation that might determine moth preference. We focused primarily on vegetation types that occur along roadsides adjacent to cornfields. In the Midwest, roadside vegetation typically consists of brome grass, *Bromus inermis* (Leyss). We were especially interested in the moth's preference for prairie vegetation compared with brome because several states have begun planting prairie vegetation along roadsides. At 4 central Iowa study sites, the density of moths was measured in several vegetation types during the 1st and 2nd *O. nubilalis* generations. For each vegetation type we also measured its microclimate and its foliage density at 5 vertical levels. In the 1st generation, moths were most dense in brome, which had 6.9 times more moths than prairie. In the 2nd generation, moths were most dense in foxtail grass, *Setaria* spp. Foxtail had 5.2 times more moths than brome, and brome had 1.6 times more moths than prairie. In both generations, the moth density in a vegetation type was significantly positively correlated with foliage density at 60 cm. Microclimate measurements of different vegetation types were not consistently correlated with moth density. We conclude that *O. nubilalis* moths prefer dense foliage >60 cm tall. We also conclude that replacing roadside brome and the weedy foxtail with native prairie has the potential to reduce the number of adult moths breeding near cornfields.

Schauff, M. E. (1999). "New record of a parasitoid (Hymenoptera : Eulophidae) of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera : Crambidae)." *Proceedings of the Entomological Society of Washington* 101(4): 910-910.

Siegfried, B. D., T. Spencer and P. Marcon (1999). "Susceptibility of European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera : Pyralidae) neonate larvae to fipronil." *Journal of Agricultural and Urban Entomology* 16(4): 273-278.

Susceptibility to technical grade fipronil was determined for 10 populations of the European corn borer, *Ostrinia nubilalis* (Hubner). Field collections were made from 8 locations across the United States. Two laboratory colonies were also tested. Most collections were from sites where the biovoltine Z strain of *O. nubilalis* predominates, but samples of other strains were also obtained. Field-collected larvae or egg masses were reared for one generation in the laboratory, and susceptibility of neonates was determined with feeding bioassays where increasing concentrations of the toxin were applied to the surface of artificial diet. Small differences in LC50 and LC90 values were observed, but the magnitude of the differences was small (<3-fold). These results indicate that the observed susceptibility differences were the result of natural variation among populations and unrelated to previous selection. In addition, these data provide a baseline for future comparisons to determine if susceptibility has changed as the insecticide becomes widely used for corn borer management.

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- Sobek, E. A. and G. P. Munkvold (1999). "European corn borer (Lepidoptera : Pyralidae) larvae as vectors of *Fusarium moniliforme*, causing kernel rot and symptomless infection of maize kernels." *Journal of Economic Entomology* 92(3): 503-509.
- Field and greenhouse experiments were conducted to assess the ability of *Ostrinia nubilalis* (Hubner) larvae to act as vectors of *Fusarium moniliforme* J. Sheld. from maize leaf surfaces to kernels. Leaf surfaces of plants in the dough stage were sprayed with a spore suspension of *F. moniliforme* strain EA-2, after which plants were manually infested with *O. nubilalis* larvae or kernels were mechanically wounded. In 2 greenhouse experiments, *O. nubilalis* larvae significantly increased incidence of kernel rot symptoms and symptomless infection. Strain EA-2 was detected on *O. nubilalis* larvae, in plant debris in the leaf axils, and in 28-39% of *F. moniliforme*-infected kernels from plants manually infested with *O. nubilalis*. In the field, *O. nubilalis* infestation significantly increased incidence of kernel rot symptoms (1995) and symptomless infection (1994 and 1995). Symptomless infection was highest for treatments in which larvae were artificially contaminated with *F. moniliforme* strain EA-4 prior to manual infestation of plants. *F. moniliforme* strain EA-2 (from leaf surfaces) and strain EA-4 (from larvae) were recovered from kernels in the *O. nubilalis*-infested treatments in 1995. Results indicated that *O. nubilalis* larvae can act as vectors of *F. moniliforme*, increasing symptoms of *Fusarium* kernel rot and symptomless infection of kernels by *F. moniliforme*. Kernel wounding also is an important factor contributing to this disease.
- Velasco, P., R. A. Malvar, P. Revilla, A. Butron and A. Ordas (1999). "Ear resistance of sweet corn populations to *Sesamia nonagrioides* (Lepidoptera : Noctuidae) and *Ostrinia nubilalis* (Lepidoptera : Pyralidae)." *Journal of Economic Entomology* 92(3): 732-739.
- Corn borers are the main pests of maize, *Zea mays* L., in temperate areas. In Spain and other Mediterranean countries, the principal corn borer is *Sesamia nonagrioides* Lefebvre, although the European corn borer, *Ostrinia nubilalis* (Hubner), is also an important pest in sweet corn. The objectives of this work were to study resistance to attack of both species in sweet corn populations and to compare the mechanisms of resistance. Twenty sweet corn populations and 1 field corn population were evaluated for ear resistance under artificial infestation, with eggs of *S. nonagrioides* and *O. nubilalis*, under natural conditions, and protected with an insecticide, in 1996 and 1997. There were significant differences between years and the interactions genotype X year and treatment X year were significant for most traits. In 1996, damage produced by *S. nonagrioides* was greater than damage produced by *O. nubilalis*. In 1997, attack of *O. nubilalis* was most important. The insecticide did not protect the crop in 1996, and protection was low in 1997. The field corn synthetic cultivar 'BSCB1(R)C11', and the sweet corn synthetic cultivars 'NE-HY-13A(S)C1', 'NE-HY-13B(S)C1', and 'AS11' were resistant to attack by both species in both years. Stowell's 'W. Evergreen' and 'EPS11' were resistant to *O. nubilalis* and showed some resistance to *S. nonagrioides*. All resistant populations have field corn in their pedigree. Field corn seemed to be more resistant than sweet corn, and mechanisms of resistance to both pests were not entirely independent.
- Wang, B., D. N. Ferro and D. W. Hosmer (1999). "Effectiveness of *Trichogramma ostrinae* and *T. nubilale* for controlling the European corn borer *Ostrinia nubilalis* in sweet corn." *Entomologia Experimentalis Et Applicata* 91(2): 297-303.
- Seven field releases of *Trichogramma ostrinae* and *T. nubilale* (Hymenoptera: Trichogrammatidae) were made separately and in combination in a sweet corn field to compare the level of parasitism in sentinel eggs of the European corn borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae). The results indicate that the levels of egg parasitism among different release dates differed mainly because of changes in weather and plant architecture within the season. The level of egg parasitism by releasing *T. ostrinae* alone was found to be 15% higher than that by releasing *T. nubilale* alone, and 20% higher than by releasing the combination of the two species. Further analyses using the logistic regression model for independent and correlated data indicated *T. ostrinae* to be more efficient at discovering host egg masses and to have higher levels of egg parasitism than *T. nubilale*. Mutual interference between *T. ostrinae* and *T. nubilale* was the main factor for the lower level of egg parasitism when *T. ostrinae* and *T. nubilale* were released together. The results suggest that *T. ostrinae* is the better candidate for augmentative releases for control of the European corn borer, and the two species should not be released into a corn field at the same time.
- Willett, C. S. and R. G. Harrison (1999). "Pheromone binding proteins in the European and Asian corn borers: no protein change associated with pheromone differences." *Insect Biochemistry and Molecular Biology* 29(3): 277-284.

Pheromone binding proteins (PBPs) are thought to play a role in the recognition of sex pheromone in male moth antennae. By binding selectively to different components of pheromone blends, these PBPs could play a role in differentiating between structurally related compounds. In this study we have characterized the pheromone binding proteins of two pheromone strains of the European corn borer (*Ostrinia nubilalis*) and also the closely related Asian corn borer (*O. furnacalis*). We have been able to detect only one PBP gene, which encodes a mature protein that is identical in amino acid sequence in individuals from different pheromone strains and different species. This result suggests that the PBP is not detecting differences between the two isomeric compounds of the European corn borer pheromone or the difference in double bond position between the pheromone molecules of the European and Asian corn borers. (C) 1999 Elsevier Science Ltd. All rights reserved.

Willett, C. S. and R. G. Harrison (1999). "Insights into genome differentiation: Pheromone-binding protein variation and population history in the European corn borer (*Ostrinia nubilalis*)." *Genetics* 153(4): 1743-1751.

Examination of sequence variation at nuclear loci can give insights into population history and gene flow that cannot be derived from other commonly used molecular markers, such as allozymes. Here, we report on sequence variation at a single nuclear locus, the pheromone-binding protein (PBP) locus, in the European corn borer (*Ostrinia nubilalis*). The European corn borer has been divided into three races in New York State on the basis of differences in pheromone communication and life history. Previous allozyme data have suggested that there is a small but significant amount of genetic differentiation between these races. The PBP does not appear to be involved in the pheromone differences between these races. Examination of variation at the PBP locus in the three races reveals no fixed differences between races despite high levels of polymorphism. There also appears to have been considerable recombination in the history of the pheromone-binding protein alleles. Observation of both recombination between alleles and lack of significant nucleotide or insertion/deletion divergence between races leads us to suggest that these populations are either recently diverged or have continued to exchange genetic material subsequent to divergence in pheromone communication and life history.

Andow, D. A., D. N. Alstad, Y. H. Pang, P. C. Bolin and W. D. Hutchison (1998). "Using an F-2 screen to search for resistance alleles to *Bacillus thuringiensis* toxin in European corn borer (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 91(3): 579-584.

We present an application of an F-2 screening method for recovering and estimating the frequencies of rare alleles that confer insect resistance to a transgenic corn variety producing *Bacillus thuringiensis* Berliner crystal protein toxin (Bt corn). Based on a sample of 91 female *Ostrinia nubilalis* (Hubner) we show with 95% confidence that the frequency of *B. thuringiensis* resistance alleles from a wild Minnesota population is <0.013. This is an upper limit to the estimated allele frequency and does not provide clear evidence that 1 of the assumptions of the refuge plus high-dose strategy will or will not be met. With additional sampling, a more precise estimate of resistance allele frequency could be obtained that would clearly support or refute 1 of the assumptions of the refuge plus high-dose strategy. Variable costs of the screening method were \$19.70 per female line, but these could be reduced by improved collecting, rearing; and handling methods.

Baker, T. C., H. Y. Fadamiro and A. A. Cosse (1998). Widely-spaced, high-emission-rate pheromone sources suppress mating of European corn borer females.

The female sex pheromone of *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) was released from two dispenser types and in two deployment patterns, a Shin-Etsu rope formulation spaced 2 m apart and a widely-spaced (35 m) pattern using a high-emission-rate system called the Metered Semiochemical Timed Release System (MSTRS(TM)). Both dispensers were deployed in grassy sites that constitute aggregation areas for *O. nubilalis* mating activity within and around cornfields at three different locations in Iowa. A significant level of disruption of pheromone-source location (averaging 97 percent) was achieved by both dispensers during both first and second flights. More importantly, a significant level of mating disruption was achieved, as measured by the frequency of mating by free-flying feral females. The mean number of matings, as measured by spermatophores, per first generation female was 1.33 in the MSTRS(TM) plots and 1.58 in the rope plots, compared with 1.88 in untreated check plots. During the second flight, the number of matings per female averaged 1.63 in the MSTRS(TM) plots, 1.56 in the rope plots and 2.17 in untreated check plots. There was also a significant reduction in the proportion of females that mated at least once during both

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flights in MSTRS(TM) plots. During the first flight, 17 percent and 10 percent fewer females mated in the MSTRS(TM)-treated and rope-treated fields, respectively. A similar level of disruption of mating was also achieved during the second flight. An overlooked, potential advantage of the area-wide use of mating in the context of increasing use of transgenic corn by growers is that pheromone disruption should differentially reduce mating of any rare, low density, Bt-resistant individuals in grassy areas compared with that of susceptible individuals emerging at higher densities from non-Bt corn fields. Indeed, the delaying of the onset of resistance by using pheromone mating disruption where possible in all transgenic crops may be a general integrated pest management benefit beyond crop damage reduction.

Bartels, D. W. and W. D. Hutchison (1998). "Comparison of pheromone trap designs for monitoring Z-strain European corn borer (Lepidoptera : Crambidae)." *Journal of Economic Entomology* 91(6): 1349-1354.

Several pheromone trap designs have been reported as being effective for monitoring European corn borer, *Ostrinia nubilalis* (Hubner). Field experiments were conducted during 1995-1996 at Rosemount and Le Sueur, MN, to determine the most efficient pheromone trap design for monitoring Z-strain *O. nubilalis* males. Designs tested included several versions of the Hartstack wire-mesh cone trap, a nylon-mesh cone trap, an aerial water-pan trap, and a bucket trap. In addition to total catch, we compared the timing of *O. nubilalis* nights based on Hartstack and blacklight trap data. The conventional Hartstack trap, with a 75-cm base, was the most efficient pheromone trap for *O. nubilalis* males. There was also no significant difference between the Hartstack trap counts and the number of males captured in the blacklight trap at both Rosemount and Le Sueur during 1995. However, the Hartstack trap detection of 50% peak moth night was delayed 4-15 d when compared with nearby blacklight traps.

Ben-Yakir, D., D. Efron, M. Chen and I. Glazer (1998). "Evaluation of entomopathogenic nematodes for biocontrol of the European corn borer, *Ostrinia nubilalis*, on sweet corn in Israel." *Phytoparasitica* 26(2): 101-108.

The potential of entomopathogenic nematodes for biological control of the European corn borer (ECB), *Ostrinia nubilalis* (Hubner), was evaluated under laboratory, greenhouse and field conditions. The 'All' and 'Mexican' strains of *Steinernema carpocapsae* (Weiser) and the 'HP88' strain of *Heterorhabditis bacteriophora* Poinar were compared in both dose response assays (5, 50 and 500 infective juveniles [IJ] per petri dish containing five 5th-instar ECB eggs; 72 h of incubation) and exposure time assays (3, 6 and 9 h of incubation). In the dose response assays the highest rates of ECB killing resulted from infestation with the Mexican strain of *S. carpocapsae*. In the exposure time assays there were no significant differences between the killing rates of the three nematode strains. Sweet corn plants (*Zea mays* var. *saccharata*) grown in a greenhouse, were infested with ECB neonates and 4 days later sprayed with a suspension of the Mexican strain of *S. carpocapsae* (50,000 IJ per plant). The number of ECB larvae found on treated corn plants after one week was significantly ($P=0.05$) lower (3- to 5-fold) than the number found on untreated plants. Similar treatment in the field significantly reduced the rate of economic ear damage from 20% to 5%.

Bruck, D. J. and L. C. Lewis (1998). "Influence of adjacent cornfield habitat, trap location, and trap height on capture numbers of predators and a parasitoid of the European corn borer (Lepidoptera : Pyralidae) in central Iowa." *Environmental Entomology* 27(6): 1557-1562.

The influence of adjacent habitats, trap location, and trap height on capture numbers of predators and a parasitoid were monitored in Iowa cornfields using insect traps (Gempler's(TM), AM No-Bait). Traps were fastened to a single wood lathe (122 by 3.8 by 1.3 cm) with wire ties at and 1 m above ground level. Traps at the 2 heights were placed in corn and their adjacent habitat. The adjacent habitat consisted of 1 of 3 types-herbaceous, wooded, and inter-mediate. Adjacent habitat did not significantly influence the number of *Macrocentrus grand Goidanich* (Hymenoptera: Braconidae) captured but did influence the capture of *Coleomegilla maculata* (De Geer) (Coleoptera: Coccinellidae), *Coccinella septempunctata* L. (Coleoptera: Coccinellidae), and *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) with increased captures from fields with the herbaceous and intermediate habitats. Distance that traps were placed in corn and trap height significantly influenced numbers of *M. grandii* and *C. maculata* captured. Significantly more *M. grandii* and *C. maculata* were captured from traps 11 m into corn than from traps 2.5 m into corn or in the adjacent habitat. Capture rates of *M. grandii* also were significantly higher on traps 1 m above ground. Data from this research indicate that *M. grandii* is synchronized with its host, *Ostrinia nubilalis* (Hubner), in central Iowa.

Cagan, L. (1998). "Spring behaviour of the European corn borer, *Ostrinia nubilalis* (Lepidoptera, Pyralidae) larvae in south-western Slovakia." *Biologia* 53(2): 223-230.

Spring behaviour of the European corn borer (ECB) larvae was observed in south-western Slovakia during 1989-1996. The number of larvae in maize stems covered with soil and in intact maize stems was compared. The first larvae of the ECB were found on the soil surface from 16 March to 23 April (depending upon the year). The highest spring movement of the ECB larvae was found in the second half of April. Soil temperature was the main factor influencing the movement of the larvae, which were active even at temperatures below 10 degrees C. High rainfall in the first half of April 1990 and in the second half of March 1992 forced some larvae to the soil surface. The time interval between spring movement of the ECB larvae and their pupation was nearly two months. The time of pupation did not correlate with the time of spring movement of larvae. Analysis of the remnants of maize stems covered with soil showed that all larvae abandoned their winter shelters during spring. The number of larvae in new shelters (made from corrugated paper) was almost half the number of larvae surviving in intact maize stems on the surface of the soil.

Cagan, L., J. Tancik and S. Hassan (1998). "Natural parasitism of the European corn borer eggs *Ostrinia nubilalis* Hbn. (Lep., Pyralidae) by *Trichogramma* in Slovakia - need for field releases of the natural enemy." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 122(6): 315-318.

Natural parasitism of the European corn borer (ECB) eggs by *Trichogramma* (Hym., Trichogrammatidae) was assessed in 1993 to 1996 in south-western Slovakia. No parasitized eggs were found in 1993. In 1994, parasitized ECB eggs were observed on July 7th, July 11th and July 13th. The average percentage of egg parasitism was 3.86 and 1.54 at two locations. Only one parasitized egg cluster was observed at the beginning of the ECB egg laying in 1995. At the end of the egg laying period (10th, 13th, 17th and 24th July) parasitism varied between 1.29 and 100% and averaged 4.15% at the location Nitra-Malanta. Parasitism was high in 1996 at the location Nitra-Malanta and reaching an average of 15.21%. Parasitized eggs were detected throughout the ECB egg laying period. At Nitra-Janikovce in the same year, average parasitism reached 2.46%. The authors assume that extremely dry weather probably reduced the egg parasitoid populations in 1993-1995. The egg parasitoid species was identified as *Trichogramma evanescens*. The study showed that the egg parasitoid appears sporadically in corn fields, was often absent but sometimes occurred in low numbers in spring early summer and increased towards the end of the season. Therefore, the release of mass reared *Trichogramma* can be recommended to insure predictable biological control of the pest.

Cordero, A., R. A. Malvar, A. Butron, P. Revilla, P. Velasco and A. Ordas (1998). "Population dynamics and life-cycle of corn borers in south Atlantic European coast." *Maydica* 43(1): 5-12.

Sesamia nonagrioides Lei. and *Ostrinia nubilalis* Hbn. are the main pests of maize in the mediterranean countries. Population fluctuations of both species were studied in NW Spain through 1990-1996. The abundance of both species varied greatly between and within locations. Their attacks were very intense in 1995 and 1996, reaching 100% of damaged plants in two plots, 30-50% in a third one and 7% in a Fourth plot. In several plots and years are found more than one larva per plant at harvest. The captures of adult moths made with pheromone traps indicate the existence of two generations, the first one flying in May and the second one in July-August. The larvae of first generation of both species rarely attack maize, but by September, most plants have been colonized by *S. nonagrioides* and, in a lesser degree, by *O. nubilalis* larvae. Larvae of both species overwinter inside the dead plants of maize, that are usually left in the fields after harvesting by most farmers. Given the mild winter temperatures of the South Atlantic coast, most of them survive until the next spring and produce the adults of first generation. Cultural methods (e.g. destruction of plant stems) and the use of resistant maize genotypes could improve the management of maize borers, diminishing their economic damages.

Hafez, M., H. S. Salama and A. Abdel-Rahman (1998). "Activity of *Bacillus thuringiensis* isolates on the corn borers, *Chilo agamemnon* Bles (Crambidae) and *Ostrinia nubilalis* Hbn (Pyraustidae)." *Anzeiger Fur Schadlingskunde Pflanzenschutz Umweltschutz* 71(6): 110-112.

The potential activity of different varieties of *Bacillus thuringiensis* was evaluated against the second instar larvae of the two lepidopterous corn borers *Chilo agamemnon* and *Ostrinia nubilalis*. Data on the LC50, slopes, 95% confidence limits and potencies of the tested varieties were determined. With *O. nubilalis*, Dipel 2X (*Bacillus thuringiensis* var, kurstaki HD-1) was the most potent and the LC50 was 2.68 µg/g diet. The LC50 for other varieties ranged between

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3.12 and 31.95 $\mu\text{g/g}$. In the case of *C. agamemnon*, the lowest LC50 was also determined with Dipel 2X bring 3.68 $\mu\text{g/g}$ diet; this ranged between 6.2-15.11 $\mu\text{g/g}$ for other tested varieties.

Harper, M. S., T. L. Hopkins and T. H. Czapla (1998). "Effect of wheat germ agglutinin on formation and structure of the peritrophic membrane in European corn borer (*Ostrinia nubilalis*) larvae." *Tissue & Cell* 30(2): 166-176.

European corn borer (ECB; *Ostrinia nubilalis* (Hubner)) larvae (third instar) fed 0.05% w/w wheat germ agglutinin (WGA) in their diet for 72 h showed very little increase in body weight, whereas weight of control larvae increased nearly fourfold. Light and transmission electron microscopy studies showed that the morphology of the peritrophic membrane (PM) changed within 24 h after ECB larvae fed on the WGA diet. Whereas the PM in the anterior region of the midgut was a thin membranous structure in control larvae, the WGA-fed larvae secreted a multiple-layered and unorganized PM that contained embedded food particles, bacteria, and pieces of disintegrated microvilli. Gold-labeled WGA was localized specifically in the PM and microvilli. The PM of WGA-fed larvae was inundated with dark-staining amorphous structures that, when incubated with anti-WGA, showed heavy WGA localization. The antibody label indicated that most of the ingested WGA was found in the PM, with lesser amounts on the microvillar surface and the least amount within the epithelium. After 72 h, the middle portion of the mesenteron revealed a thin, compact PM in the control larvae, whereas the PM of the WGA-fed larvae was multilayered and discontinuous, which allowed plant cell-wall fragments to penetrate into the microvilli of the epithelium. Scanning electron microscopy of PMs from fifth instar ECB larvae fed the WGA diet revealed a breakdown in the chitinous meshwork by 48 h after initiation of feeding. The endo-PM surface from control larvae was smooth and intact, whereas the PM of WGA-fed larvae showed disintegration of the meshwork and a reduced proteinaceous matrix. This allowed bacteria and food particles to penetrate through the PM into the ectoperitrophic space and directly contact the microvilli. Therefore, WGA, a protein inhibitor of larval growth, interferes with the formation and integrity of the PM, which exposes the brush border to ingested material. This, in turn, appears to stimulate secretion of additional PM layers, the concomitant disintegration of the microvilli, and cessation of feeding.

Hellmich, R. L., R. L. Pingel and W. R. Hansen (1998). "Influencing European corn borer (Lepidoptera : Crambidae) aggregation sites in small grain crops." *Environmental Entomology* 27(2): 253-259.

Reliable methods to attract European corn borer, *Ostrinia nubilalis* (Hubner), adults to small grain crops could be used to aggregate moths into small well-defined areas for control purposes or could be used in a resistance management program for delaying potential *O. nubilalis* resistance to transgenic corn. The objective of this research was to determine whether small-grain crops could be managed to influence *O. nubilalis* aggregation behavior. In farmer-managed oat, *Avena sativa* (L.), fields, more *O. nubilalis* adults were attracted to high-density patches of oat compared with standard patches of oat; no difference was found between patches of high-density oat and brome, *Bromus* spp. Numbers of *O. nubilalis* moths found in 6 barley, *Hordeum vulgare* (L.), and legume treatments (1995), and 4 oat/legume treatments (1996) were significantly different. The highest number of *O. nubilalis* adults were observed in barley planted with alfalfa, *Medicago sativa* (L.), followed by barley planted with crimson clover, *Trifolium incarnatum* (L.), barley planted with berseem, *Trifolium alexandrinum* (L.) barley planted with black medic, *Medicago lupulina* (L.), barley alone, and barley planted with Lespedeza, *Lespedeza stipulacea* (Maximowicz). Double-planted oat attracted the highest number of *O. nubilalis* adults followed by oat planted with crimson clover, oat planted with alfalfa, and single-planted oat. Each study suggests that there is a positive correlation between moth aggregation and canopy area. Suggestions are made that timing canopy closure of a small-grain crop with peak *O. nubilalis* night should maximize *O. nubilalis* aggregation and should thereby increase the efficacy of any control measures.

Klun, J. A., A. P. Khramian and J. E. Oliver (1998). "Evidence of pheromone catabolism via beta-oxidation in the European corn borer (Lepidoptera : Crambidae)." *Journal of Entomological Science* 33(4): 400-406.

Experiments were conducted using tritiated European corn borer, *Ostrinia nubilalis* (Hubner), pheromone, (Z)-[11,12-H-3(2)]-11-tetradecen-1-ol acetate, a tritiated fluorinated analog of the European corn borer pheromone, 2-fluoro-(Z)-[11,12-H-3(2)]-11-tetradecen-1-ol acetate, and methyl-4-bromocrotonate (MBC) to determine if pheromone catabolism proceeds on the moth's antennae via the beta-oxidation pathway of fatty acid degradation. When antennae were treated with tritiated natural pheromone plus MBC (a precursor of the known beta-oxidation inhibitor, 4-bromocrotonic acid), catabolism of the pheromone was significantly inhibited. When the 2-fluoro pheromone analog was applied alone to antennae, it was hydrolyzed to the corresponding alcohol but was not degraded. MBC had no effect on

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catabolism of the 2-fluoro analog, and 2-fluoro substitution inhibited entrance of the compound into beta-oxidation. These results demonstrate that beta-oxidation is the primary oxidative pathway by which pheromone is degraded on the antennae of European corn borer moths.

Kreps, R. C., R. K. Gumber, B. Schulz, D. Klein and A. E. Melchinger (1998). "Genetic variation in testcrosses of European maize inbreds for resistance to the European corn borer and relations to line per se performance." *Plant Breeding* 117(4): 319-327.

The European corn borer (ECB) *Ostrinia nubilalis* H. is a major pest in World maize *Zea mays* L. production. Objectives of this study were to (1) investigate the genotypic variance and covariance in testcrosses of European flint and dent inbreds for ECB resistance and agronomic traits, and (2) estimate the correlation between line per se and testcross performance for ECB resistance traits. A total of 16 flint and 24 dent inbreds and their testcrosses with two testers from the opposite germplasm pool were evaluated in four and three German environments, respectively. Using artificial infestation with ECB larvae, resistance was assessed by damage rating of stalks, tunnel length in dissected stalks, and relative yield of infested plots compared with protected plots. Yield losses due to ECB damage in testcross hybrids amounted to 40%. Significant genotypic variances between flint and dent lines and high heritabilities were found for damage rating of stalks for both line per se and testcross performance. Heritabilities were low or intermediate for tunnel length and relative grain yield. Correlations between line per se and testcross performance were tight for the damage rating of stalks and moderate for tunnel length and relative yield in both flint and dent germplasm. For damage rating of stalks, per se performance of lines tested in a few environments can be used to predict their testcross performance. In contrast, assessment of testcross performance for tunnel length and relative yield requires evaluating testcrosses with several testers in multi-environment trials.

Maas, J. L., J. M. Enns, S. C. Hokanson and R. L. Hellmich (1998). "Injury to strawberry crowns caused by European corn borer larvae." *Hortscience* 33(5): 866-867.

Larvae of several insects injure and kill strawberry (*Fragaria xananassa* Duchesne) plants by burrowing into and hollowing out plant crowns. Occasionally, these infestations are serious enough to cause heavy economic losses to fruit producers and nursery plant growers. In 1997 in Beltsville, Md., we observed wilting and dying mature plants and unrooted runner plants in two experimental strawberry plantings. Injury by larvae was extensive; large cavities occurred in crowns, and the central pith tissues were removed from stolons and leaf petioles. Often, insect frass was seen at entrance holes. Larvae removed from hollowed-out parts of injured plants were identified as the European corn borer (*Ostrinia nubilalis* Hubner) in their fifth instar stage. Their presence in this instance also was associated with a cover crop of millet [*Setaria italica* (L.) P. Beauv., 'German Strain R'] planted between the strawberry rows for weed suppression. This is the first published report of the European corn borer attacking strawberry. Although this insect may occur only sporadically in strawberry plantings, it may become important in the future. Growers and other professionals should become aware of this new strawberry pest and recognize that its management in strawberry will be different from management of other crown-boring insects.

Melchinger, A. E., R. Kreps, R. Spath, D. Klein and B. Schulz (1998). "Evaluation of early-maturing European maize inbreds for resistance to the European corn borer." *Euphytica* 99(2): 115-125.

The European corn borer (ECB) has become a serious pest for maize cultivation in Central and Western Europe. This study was conducted to evaluate resistance against ECB in a cross section of the European maize germplasm. A total of 115 flint and dent inbreds were evaluated for resistance under protected and artificial infestation conditions at two German sites in 1993. Resistance to ECB was assessed by damage rating before harvest, tunnel length in dissected stalks, and relative yield under infestation compared to protected control plots. Means for damage rating of stalks were significantly higher in flint lines than in dent lines. Artificial infestation reduced grain yield by 31% in flint lines and 20% in dent lines. Significant genotypic variances among lines and high genetic ratios (GR) were found in both flint and dent lines for all agronomic and ECB resistance traits. Exceptions were relative yield of stover in both germplasm groups and tunnel length in flint lines. Phenotypic correlations between agronomic and resistance traits were moderate to low. Damage rating was negatively correlated with days to silking and dry matter yield of stover in both germplasm groups. *in vitro* digestibility of stover was not associated with ECB resistance. Correlations of relative grain yield with tunnel length below the ear and damage rating were significantly negative, even though their magnitude was low. Our results indicate substantial genetic variation among European inbred lines for resistance to the univoltine ECB. Among all

resistance traits measured, damage rating of stalks is best suited for assessment of ECB resistance in breeding programs because of its easy recording and high genetic ratio.

Onstad, D. W. and F. Gould (1998). "Modeling the dynamics of adaptation to transgenic maize by European corn borer (Lepidoptera : Pyralidae)." *Journal of Economic Entomology* 91(3): 585-593.

A deterministic population dynamics model was modified to include single-locus, 2-allele genetics to simulate strategies for delaying resistance in the European corn borer, *Ostrinia nubilalis* (Hubner), population to transgenic maize. We evaluated seed mixtures of transgenic and nontransgenic maize, B-row strips of nontransgenic plants, adjacent but separate refuges of nontransgenic maize, and rotation of nontransgenic and transgenic maize. We studied how the choice of hybrid, planting time, and weather may influence the selection of a tactic for delaying resistance to transgenic maize. Our results indicate that separate refuges are superior to seed mixtures for delaying resistance. If a high toxin dose cannot be achieved and a small fraction of homozygous susceptible and heterozygous European corn borer neonates survive on transgenic maize, then resistance can develop in 10-33% of the time required under the assumption of a successful high dose that kills all heterozygous neonates. Planting e-row strips may be as good as separate refuges in delaying resistance, but their adoption carries greater risk because of the uncertainty surrounding movement and survival of neonates. The use of transgenic hybrids is the same whether or not they express the toxin gene in silks and kernels of maize ears. Toxin titer decline must be studied because our simulations indicate that development of resistance may be greatly hastened by this process.

Panouille, A., P. Anglade, A. Boyat, B. Gouesnard, J. C. Vible and M. Dupin (1998). "Assessment of 10 years of maize pedigree breeding for European corn borer tolerance and high-yielding combining ability." *Agronomie* 18(4): 299-308.

A multitrait pedigree breeding system including evaluation for European corn borer (*Ostrinia nubilalis* Hbn.) tolerance and other agronomic traits (yield, earliness, stalk lodging) was used for 16 years to create inbred lines from very different temperate germplasms. The ultimate evaluation of the 63 inbred lines was made in comparison with stable known references. The results allowed us to classify this material into three tolerance classes to the insect and demonstrated the efficacy of the method. High-yielding combining ability might be associated with earliness, lodging tolerance and good insect tolerance. The value of some early flint European materials and of Argentinian sources was discussed to improve European corn borer tolerance. ((C) Inra/Elsevier, Paris.)

Pavuk, D. M. and L. L. Hughes (1998). "The parasitoid complex of first generation *Ostrinia nubilalis* (Lepidoptera : Pyralidae) larvae in northwest Ohio." *Great Lakes Entomologist* 31(3-4): 169-172.

A survey of first generation European corn borer (*Ostrinia nubilalis*) larvae was conducted during 1997 in six cornfields located in northwestern Ohio in order to determine the larval parasitoid complex utilizing this host. Collected larvae were held under constant conditions until the larvae completed development or parasitoids emerged. The following species were recorded: *Eriborus terebrans* (Hymenoptera: Ichneumonidae), *Macrocentrus grandii* (Hymenoptera: Braconidae), *Sympiesis viridula* (Hymenoptera: Eulophidae), and *Lixophaga* sp. (Diptera: Tachinidae). Levels of parasitism in the different fields ranged from 14.3 to 83.3%. Future research will include surveys of additional fields and sampling of *O. nubilalis* over the entire season in the northwest Ohio region.

Pornkulwat, S., S. R. Skoda, G. D. Thomas and J. E. Foster (1998). "Random amplified polymorphic DNA used to identify genetic variation in ecotypes of the European corn borer (Lepidoptera : Pyralidae)." *Annals of the Entomological Society of America* 91(5): 719-725.

The European corn borer, *Ostrinia nubilalis* (Hubner), has 3 morphologically indistinguishable voltinism ecotypes. Random amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR) was used to discriminate ecotypes of the European corn borer. Genomic DNA samples from the European corn borer were screened with a total of 120 random primers. Ten of these primers yielded 21 clear and reproducible RAPD markers after agarose gel electrophoresis. Dendrograms constructed using the Nei and Li distance matrix of the phylogenetic relationships, among and within ecotypes, of the European corn borer showed the multivoltine ecotype to be genetically separated from univoltine and bivoltine ecotypes. The dendrogram of individual European corn borers correctly classified each insect. These results provide evidence of genetic variation at the molecular level among European corn borer ecotypes. The RAPD-PCR technique proved to be a powerful tool for identifying intraspecific variation in the European corn borer.

Cette veille bibliographique est réalisée par Nathalie Roullé et Nicolas Chatel-Launay, Pôle d'excellence en lutte intégrée (PELI).

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Riggs, D. I. M., M. P. Hoffmann and L. C. Thetford (1998). "Treatment thresholds for European corn borer (Lepidoptera : Pyralidae) infestations in early-season fresh market sweet corn." *Journal of Entomological Science* 33(4): 393-399.

We examined the effect of varying thresholds for treatment of first generation European corn borer, *Ostrinia nubilalis* (Hubner), infestations in early-season fresh market sweet corn in eastern New York over a 3-year period. Seven treatment thresholds were compared: (1) 15% infested plants at whorl stage, 5% infested plants at tassel and silk stage, (2) 15% at whorl stage, 15% at tassel and silk stage, (3) 30% at whorl stage, 5% at tassel and silk stage, (4) 30% at whorl stage, 15% at tassel and silk, (5) 5% at tassel and silk stage, (6) 15% at tassel and silk stage, and (7) control (untreated). When thresholds were reached, permethrin was applied using an air-blast sprayer. Results indicated little difference in percentage marketable ears whether plants were treated or not at whorl stage, and the tassel stage threshold could be raised to 15% infested plants with no significant effect on percentage marketable ears. We found no difference in marketable yield among plots treated from one side or both sides with an air-blast sprayer.

Shanklin, D. R., D. W. Johnson and L. H. Townsend (1998). "Survey of parasitoids of the European corn borer (Lepidoptera : Pyralidae) in southwestern Kentucky." *Journal of Entomological Science* 33(3): 256-260.

The European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae), is a major maize pest throughout the maize-growing regions of the U.S. A survey was conducted to determine the parasitoids of European corn borer in southwestern Kentucky, the major maize producing region in the state. Two species, *Lixophaga variabilis* (Coquillett) (Diptera: Tachinidae) and *Eriobus terebrans* Gravenhorst (Hymenoptera: Ichneumonidae), were found. The most abundant species was the native *L. variabilis*. Only one *E. terebrans* was collected.

Wang, B. and D. N. Ferro (1998). "Functional responses of *Trichogramma ostriniae* (Hymenoptera : Trichogrammatidae) to *Ostrinia nubilalis* (Lepidoptera : Pyralidae) under laboratory and field conditions." *Environmental Entomology* 27(3): 752-758.

Laboratory tests and field experiments were conducted to determine the functional response of *Trichogramma ostriniae* Pang & Chen to its host, eggs of the European corn borer, *Ostrinia nubilalis* (Hubner), under different conditions. Individual female wasps were offered different densities of host eggs for 16 h at 17, 20, and 27 degrees C. Field experiments were carried out in a sweet corn field that was divided into 6 plots of equal size (120 m²). Sentinel European corn borer egg masses were exposed to wasps for 3 d, from day 0 to 3 and day 4 to 7 after releasing wasps. Both the laboratory study and field experiments indicated that egg parasitism was positively correlated with egg density. However, this relationship differed significantly for the 3 temperatures in the laboratory study and varied considerably for the different days of exposures (days 0-3 versus days 4-7) and for different replicates (time of the year). The Gompertz equation and a modified disc equation were fitted to the laboratory data categorized based on temperatures. The results showed that female *T. ostriniae* might exhibit the type II or type III functional response depending on temperature. The field data suggested a type II functional response when data were pooled for all replicates.

Warnock, D. F. and D. W. Davis (1998). "Comparison of two visual scales for estimating European corn borer ear damage in maize." *Hortscience* 33(6): 1048-1049.

Some scales combine quantitative and qualitative components that inadvertently may skew damage estimates and eliminate potentially useful germplasm. Two visual evaluation scales to estimate European corn borer feeding damage were compared for their effectiveness in classifying sweet corn germplasm. Both the traditional 1 to 9 scale, combining ear feeding damage and damage location, and the alternative 1 to 5 scale, based solely on ear feeding damage, consistently separated sweet corn genotypes into resistant, marginally resistant, and susceptible classes. Inbred MN 3002, Hybrid MN 3004, 'Apache', and 'More' were classified as having marginally acceptable resistance levels. Inbred Mn 3003, Inbred W182E, and 'Jubilee' were susceptible to European corn borer. Individual genotype rankings varied by scale, but genotype classifications were consistent with regard to the degree of commercial acceptability. The combination of quantitative and qualitative components did not compromise genotypic characterization, as the previously untested hybrid, MN 3004, was placed in the marginally acceptable class by both scales. Plant breeders should carefully evaluate the efficacy of individual visual scales before incorporating them into a selection program.

Warnock, D. F., D. W. Davis and G. R. Gingera (1998). "Inheritance of ear resistance to European corn borer in 'Apache' sweet corn." *Crop Science* 38(6): 1451-1457.

European corn borer, *Ostrinia nubilalis* (Hubner), can severely affect commercial sweet corn (*Zea mays* L.) quality during years of heavy infestation. Greater ear resistance in sweet corn could reduce the need for insecticide application. A generation mean analysis was used to determine the inheritance of ear resistance and silk-channel length (SCL) in two crosses containing germplasm from the resistant sweet corn hybrid 'Apache'. Three inbred parents, F-1, F-2, and the first backcross populations were manually infested and visually evaluated in field experiments. For each cross, ear damage, SCL, and number of surviving larvae differed (P less than or equal to 0.05) among generations. The genetic effects affecting the variation for ear resistance ranged from epistatic (Cross 1) to additive-dominance (Cross 2). Silk-channel length was controlled by epistatic (Cross 1 and Cross 2) effects. Inheritance of these traits is complex, probably involving multiple genes. As the silk channel often is the point of larval entry, SCLs were hypothesized to be important in ear resistance. The low to moderate correlations (P less than or equal to 0.01) across generations within each cross between ear damage and SCL ($r = -0.18$ and -0.75), surviving larvae ($r = 0.78$ and 0.79), and number of larvae in each third of the ear ($r = 0.64$ - 0.84) suggest that extending the SCL is not the sole component responsible for ear resistance.

Anton, S., C. Lofstedt and B. S. Hansson (1997). "Central nervous processing of sex pheromones in two strains of the European corn borer *Ostrinia nubilalis* (Lepidoptera: Pyralidae)." *Journal of Experimental Biology* 200(7): 1073-1087.

Antennal lobe neurones were investigated in the pyralid moth *Ostrinia nubilalis* using intracellular recording and staining techniques. Response characteristics of antennal lobe neurones from males in the so-called E and Z strains, in F1 hybrids and in parental backcrosses were studied. The antennal lobe of a male *O. nubilalis* comprises approximately 30 ordinary glomeruli and three enlarged glomeruli making up the macroglomerular complex (MGC). Receptor neurones enter the antennal lobe via the antennal nerve and arborize in single glomeruli. Intracellularly stained, pheromone-responding projection neurones in both parental strains arborized in different glomeruli within the MGC, irrespective of their response characteristics. Neurones were grouped according to their specificity to single pheromone components and to pheromone blends. Component-specific, blend-specific and generalist neurones were found. Specificity only occurred at low stimulus concentrations and disappeared as concentrations increased. Although all neuronal types were present in both pheromone strains and crossings, differences in abundance and sensitivity were found. In the parental strains, neurones responding to the major pheromone component and to the respective strain-specific blend were more abundant than neurones responding to the minor component and the blend produced by the other strain. Neurones investigated in ZxE hybrids responded similarly to those of E-strain males, whereas neurones in EZxZ paternal backcrosses responded similarly to those of Z males. In the hybrids and paternal backcrosses, hybrid-blend-specific neurones were present that were not found in parental-strain males.

Bartels, D. W., W. D. Hutchison and S. Udayagiri (1997). "Pheromone trap monitoring of Z-strain European corn borer (Lepidoptera: Pyralidae): Optimum pheromone blend, comparison with blacklight traps, and trap number requirements." *Journal of Economic Entomology* 90(2): 449-457.

Commercial pheromone lures for monitoring European corn borer, *Ostrinia nubilalis* (Hubner), captured significantly fewer moths and indicated a delayed peak emergence compared with blacklight traps in Minnesota. Pheromone trap studies were therefore conducted during 1992-1994 at Rosemount and Le Sueur, MN, to determine the relative attractiveness of different ratios of (Z)- and (E)-11-tetradecenyl acetate isomers to *O. nubilalis* male moths. Isomer ratios in the pheromone lures tested ranged in percentage of concentration from 99.5:0.5 to 95.0:5.0 (Z:E). In addition to overall catch, the timing of *O. nubilalis* flights based on pheromone and blacklight traps catches was compared. The variance to mean relationship in pheromone trap catch data was used to estimate the optimum number of traps needed. Analysis of the proportion of total moths captured indicated that moths were highly attracted to lures with a ratio of isomers near 98:2 (Z:E). A significant decline in attractiveness occurred with lures in the 95:5 (Z:E) isomer range. Although the 1st moth catch in pheromone traps usually coincided with blacklight traps, the timing of 2nd-generation cumulative emergence (e.g., 50% peak catch) was significantly different between pheromone and blacklight traps. Despite an aggregated distribution of moth catches, the expected optimum trap number ranged from 2 to 5 at the 25% precision level. Results of this study confirm the increased response of *O. nubilalis* males to limited concentrations of (E) isomer (1-3%) in the pheromone blend. To ensure optimum performance of *O. nubilalis* pheromone lures, a renewed emphasis must be placed on quality control protocols during commercial pheromone lure preparation.

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Beeghly, H. H., J. G. Coors and M. Lee (1997). "Plant fiber composition and resistance to European corn borer in four maize populations." *Maydica* 42(3): 297-303.

Feeding activities of herbivorous insects are influenced by physical and nutritive characteristics of host plants. Improved resistance to insects resulting from either natural or artificial selection may be accompanied by changes in composition of plant fiber. The objectives of this study were to 1) determine heritabilities in each of four maize (*Zea mays* L.) populations (WFISIHI, WFISILO, BS9 cycle 2, and B73 x DE811) for fiber components, and 2) determine the relationship between second-generation European corn borer (ECB) [*Ostrinia nubilalis* (Hubner)] resistance and fiber composition within each population. One-hundred-fifty F-3 families from B73 x DE811 and 100 S-1 families from each of WFISIHI, WFISILO, and BS9 cycle 2 were evaluated for leaf-sheath and stalk concentrations of neutral and acid detergent fiber (NDF and ADF, respectively), and stalk concentrations of lignin. The same families from B73 x DE811 and subsets of 45, 49, and 49 S-1 families from WFISIHI, WFISILO, and BS9, respectively, were also evaluated for resistance to second-generation ECB in order to estimate generic variances and covariances for fiber components and ECB resistance. Significant phenotypic and genetic correlations were found between ECB tunneling and fiber components. Calculations of correlated response for fiber components predicted that with a selection intensity of 10% for increased second-generation ECB resistance, leaf-sheath NDF and ADF would increase by an average of 8 and 5 g kg⁻¹ cycle⁻¹, respectively, and stalk concentrations of NDF, ADF, and lignin would increase by 10, 8, and 2 g kg⁻¹ cycle⁻¹, respectively. These calculations are in approximate agreement with empirical observations over five cycles of S-1 selection for ECB resistance in BS9.

Bergvinson, D. J., J. T. Arnason and R. I. Hamilton (1997). "Phytochemical changes during recurrent selection for resistance to the European corn borer." *Crop Science* 37(5): 1567-1572.

Feeding performance of herbivorous insects is influenced by host plant nutritional quality which can be improved for insect resistance by artificial selection. This study was conducted to determine which biochemical constituents in maize (*Zea mays* L.) change during recurrent selection for resistance to first- and second-generation European corn borer (ECB) [*Ostrinia nubilalis* (Hubner)]. Four cycles of selection (C0, C2, C4, and C5) from the BS9 population were field grown, artificially and naturally infested with ECB, and the following tissues sampled for biochemical analysis: immature and mature leaf blade, leaf sheath, rind, node, and pith. Tissue was analyzed for percent protein, DIMBOA [2,4-dihydroxy-7-methoxy 2H-1,4-benzoxazin-3 (4H)-one], fiber, and cell wall-bound phenolics, which included p-coumaric acid (pCA), ferulic acid (FA), cyclobutane dimers (CBD), and diferulic acid (DFA). Leaf and stalk toughness were also determined and showed significant increases over cycles of selection. Protein content was lowest in stalk tissues with advanced cycles having lower levels, but leaf protein content did not differ significantly. DFA reached high levels in the rind (0.85 mg/g) and leaf sheath (1.35 mg/g) tissues, and increased significantly in immature leaf tissue (0.55-1.02 mg/g) over cycles of selection and may serve to fortify tender whorl tissue. Number of tunnels per stalk was negatively correlated with DFA content in the pith ($r = -0.77$, $P = 0.02$). Microspectrophotometer determinations of epidermal cell wall absorbance for leaf blade and rind tissue showed increased absorbances (23 and 27%, respectively) in the spectral region characteristic of phenolic acids over cycles of selection. Phenolic acids, in particular DFA, have increased over cycles of selection to render maize tissue more resistant through fortification of cell walls, especially in leaf and rind epidermal tissue.

Binder, B. F. and J. C. Robbins (1997). "Effect of terpenoids and related compounds on the oviposition behavior of the European corn borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae)." *Journal of Agricultural and Food Chemistry* 45(3): 980-984.

Twenty-eight volatile plant compounds and related analogs were evaluated in separate laboratory assays for mediation of oviposition behaviors of the female European corn borer, *Ostrinia nubilalis*. The compounds were acyclic and cyclic monoterpenes or sesquiterpenes or related compounds and possessed different functional groups, chain lengths, and molecular weights. The compounds varied in their effect on *O. nubilalis* oviposition behaviors, ranging from deterrents to stimulants. Cyclic sesquiterpenes generally stimulated oviposition by *O. nubilalis*, but several acyclic sesquiterpenes deterred oviposition. Individual compounds also may be used as cues for host finding by adult *O. nubilalis*. The compounds described in this study may serve as a guide for the creative design of safe, environmentally compatible control methods for the European corn borer, a destructive pest of many agricultural crops.

Clark, T. L., J. E. Foster, J. F. Witkowski, B. D. Siegfried and T. A. Spencer (1997). "Parasitoids recovered from European corn borer, *Ostrinia nubilalis* Hubner, (Lepidoptera : Pyralidae) larvae in Nebraska." *Journal of the Kansas Entomological Society* 70(4): 365-367.

Information about the current status of parasitoids attacking European corn borer *Ostrinia nubilalis* (Hubner), larvae is lacking in Nebraska. This study was conducted at multiple sites in 5 counties during 1995 and 1996 to determine the presence and prevalence of European corn borer parasitoids in Eastern Nebraska. The braconid, *Macrocentrus grandii* Goidanich, was recovered from 8.9 and 10.2% of collected 5th instar European corn borer larvae during 1995 and 1996, respectively. Recovery of this parasitoid had not been previously reported in Nebraska. Meanwhile, the ichneumonid, *Eriborus terebrans* (Gravenhorst), was recovered from 7.6 and 7.5% of collected larvae during the same period. A small number of the native tachinid parasitoid, *Lixophaga* spp., were recovered in three collections. Combined parasitoid recovery rates for all species was 16.6 and 17.7% during 1995 and 1996.

Davis, P. M. and S. B. Coleman (1997). "European corn borer (Lepidoptera: Pyralidae) feeding behavior and survival on transgenic corn containing CryIA(b) protein from *Bacillus thuringiensis*." *Journal of the Kansas Entomological Society* 70(1): 31-38.

The effect of short-term exposure of European corn borer (*Ostrinia nubilalis* (Hubner)) larvae to transgenic corn expressing cryIA(b) protein from *Bacillus thuringiensis* subsp. *kurstaki* (Btk) on leaf consumption and larval survival were compared to negative controls in laboratory bioassays. Neonates and fourth instars were allowed to feed for one of three time periods (1994 bioassays: 1, 4; or 24 hours; 1995 bioassays: 24, 48, or 72 hours) on leaf sections of either cryIA(b)-expressing or control leaf sections before being transferred to artificial diet. Field-grown plants of the transgenic corn lines MON802 and MON810 were used as the source of leaf material in 1994 and 1995, respectively (YieldGard(TM) genes, Monsanto). Leaf source and exposure time significantly affected consumption ratings of neonates with little feeding detected on cryIA(b) leaf material during the first 24 hours during 1994 or during the first 72 hours in 1995. In 1994, cryIA(b) content in leaves did not affect neonate survival at transfer (97%) or after 2 weeks on diet (87%). In contrast, only 35-40% of neonates were alive after 24 and 48 hour feeding periods and no larvae survived 72 hours in 1995. Of the live neonates transferred to diet, 53% and 26% died within 2 weeks for cryIA(b) and control leaves, respectively. For periods of 24 hours or more, at least 90% of the fourth instars initiated feeding, regardless of cryIA(b) content. Cumulative consumption ratings were 46-67% lower for larvae exposed to cryIA(b) expressing leaves; however, survival rates at transfer or after two weeks on diet were not affected by leaf source. Implications for resistance management are discussed.

Derridj, S., G. Touraud and A. Kollman (1997). Selection of egg-laying site by *Ostrinia nubilalis* (Hbn.) and canola glucosinolates.

Eculica, J. F., S. Becvar, Z. Mracek and P. Kindlmann (1997). "Laboratory evaluation of control of the European corn borer, *Ostrinia nubilalis* (Hb) (Lep, Pyralidae) by nematodes of the genus *Steinernema* (Nematoda, Steinernematidae) at low temperature." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 121(7): 407-409.

Cold active isolates #76, #102, and #D of *Steinernema kraussei* and the Czech isolate #B1 of *S. feltiae* preadapted for the parasitization of European corn borer, *Ostrinia nubilalis*, were used for the laboratory control of the European corn borer larvae and pupae at low temperature. The experiments performed in Petri dishes were divided into two alternatives, both at a constant temperature of 7 degrees C, exposition time 250 h with 200 infective juveniles and 10 insects per dish. In the first experiment the only non-ligatured *Ostrinia* larvae and Canadian isolates were tested, while in the second experiment the Canadian isolate #D and Czech isolate #B1 were compared when used against ligatured larvae of the pest. The average mortality of the pest larvae in the first experiment reached maximally 26% and the average number of adult nematodes recovered by dissection was 7.2 per insect in the best #D isolate. Low efficacy of steinernematids to pest larvae was probably significantly influenced by forming a cocoon by insect. In the second experiment the pest larvae were ligatured before nematode application and forming of the cocoon was blocked. Surprisingly, the #B1 isolate killed on average 88.3% of *Ostrinia* larvae while the cold active #D isolate killed only 48.3% of the pest larvae. Number of recovered adults per insect by dissection was 30.3 in the #B1 isolate and 10 in the #D isolate. The results were analysed by means of one-way analysis of variance and of t-test. The percentage of parasitization ($P < 0.01$) and number of recovered adults ($P < 0.05$) were statistically significant between *S. kraussei* #D and *S. feltiae* #B1. It is speculated that the adaptability of the #B1 isolate had more significant role for the parasitization than the cold activity of the #D isolate.

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Got, B., S. Piry, A. Migeon and J. M. Labatte (1997). "Comparison of different models for predicting development time of the European corn borer (Lepidoptera: Pyralidae)." *Environmental Entomology* 26(1): 46-60.

Nine nonlinear models (degree-day with a 10 degrees C base, degree-day model, polynomial, normal distribution, Stinner model, Sharpe and DeMichele model, Logan model with or without a base, Hilbert and Logan model) were tested to describe the relationship between development rate and temperature for the European corn borer, *Ostrinia nubilalis* Hubner. These models were calibrated with laboratory experiments based on destructive sampling under sinusoidal temperatures from 9 to 42 degrees C. They were then evaluated and compared with field experiments, at temperatures from 4 to 37 degrees C, carried out as artificial infestations in various areas. Laboratory development models with the smallest time shifts between predicted and observed molts were the Sharpe and DeMichele model, polynomial model, normal distribution,, and Stinner model. A classification with an adjusted coefficient of determination (taking into account the number of parameters in the model) slightly modified the results and the best models were the polynomial and the normal distribution, followed by the Stinner model and the degree-day model with a 10 degrees C base. The classification was almost reversed under field conditions. Large shifts occurred in all models in some experiments, thereby demonstrating that temperature was not the only factor involved. Models showing the smallest shifts under field conditions were the degree-day model and the Logan model. The experiments that showed the greater shifts corresponded to infestations on early or on late phenological stages of corn. Results confirmed that the experimental design and calibration method were adequate. The laboratory experiments provided a means of calibrating the models and of predicting results under field conditions from laboratory experiments. Future studies will focus on a precise quantitative analysis of factors affecting development other than temperature, notably infestation date, climatic factors, and phenological stage of corn.

Hanzlik, M. W., G. G. Kennedy, D. C. Sanders and D. W. Monks (1997). "Response of European corn borer (*Ostrinia nubilalis*, Hubner) to two potato hybrids selected for resistance to Colorado potato beetle." *Crop Protection* 16(5): 487-490.

The response of the European corn borer, *Ostrinia nubilalis* (Hubner) to K411-2 and NYL 235-4, fifth- and sixth-generation potato accessions derived from crosses between *Solanum tuberosum* L. and *S. berthaultii* (Hawkes) and selected for resistance to Colorado potato beetle (*Leptinotarsa decemlineata*, Say) and potato leafhopper (*Empoasca fabae*, Harris), was measured in field and greenhouse experiments. In one field test, which did not include NYL 235-4, the incidence of corn-borer damaged stems was eight times higher in the commercial potato varieties Atlantic, Superior and Norland than in K411-2. In a later field test, there were 11 times more European corn-borer damaged potato stems on Atlantic than on NYL 235-4. In a choice experiment, European corn-borer moths deposited significantly more egg masses on the susceptible Kennebec variety (72.9%) than on NYL 235-4 (27.1%), but in the absence of a choice, equal numbers of egg masses were deposited on both varieties. In a greenhouse experiment, fewer European corn-borer larvae (44%) were established on NYL 235-4 than on Kennebec plants. (C) 1997 Elsevier Science Ltd.

Harper, M. S. and T. L. Hopkins (1997). "Peritrophic membrane structure and secretion in European corn borer larvae (*Ostrinia nubilalis*)." *Tissue & Cell* 29(4): 463-475.

Peritrophic membrane (PM) secretion and formation occur primarily in the anterior region of the mesenteron in the European corn borer (*Ostrinia nubilalis*) as determined by light and electron microscopy, Nascent PM first became visible as fibrous linear chitin-containing structures stained with gold-labeled wheat germ agglutinin between and at the tips of the microvilli. No formed PM was visible at the foregut-midgut junction, but a thin single PM appeared first in the lumen between the stomodeal valves and the midgut epithelium. Just posterior to the stomodeal valves, multiple PMs were observed that became progressively thicker and more numerous in the mid and posterior regions of the mesenteron, The PM consists of an orthogonal chitin meshwork with openings slightly larger than the diameters of the microvilli. As it delaminates from the microvilli, the meshwork becomes embedded in proteinaceous matrix that greatly reduces the pore size of the PM.

Huang, F. N., R. A. Higgins and L. L. Buschman (1997). "Baseline susceptibility and changes in susceptibility to *Bacillus thuringiensis* subsp. *kurstaki* under selection pressure in European corn borer (Lepidoptera: Pyralidae)." *Journal of Economic Entomology* 90(5): 1137-1143.

Baseline susceptibility of European corn borer larvae, *Ostrinia nubilalis* (Hubner), to a commercial formulation of *Bacillus thuringiensis* Berliner Subsp. *kurstaki* (Dipel ES), was determined for colonies from 3 different geographic locations. The KS-NE colony, collected near Manhattan in northeast Kansas, was more tolerant to Dipel than those collected from near St. John in south central Kansas (KS-SC colony) and colonies provided by the USDA Corn Insects Laboratory in Ames, IA (Iowa colony). Five colonies of European corn borers were exposed to laboratory selection using a meridic diet incorporating Dipel ES. Decreasing susceptibility of European corn borer to Dipel ES was observed in each colony selected. In the colony collected in south central Kansas (KS-SC), the LC50 and survival of larvae at specific concentrations increased more rapidly than it did in the other colonies. After only 3 selected generations, the LC50 of this colony increased 35.8-fold, and after 7 selected generations, it reached 72.9-fold. The LC(50)s of the 3 Iowa colonies increased 25.0- to 35.2-fold after 9-14 selected generations. The LC(50)s of the colony collected in northeast Kansas increased 16.2-fold after 4 selected generations and it reached 35-fold after 6 selected generations. This indicates that European corn borer populations can respond rapidly to intense selection pressure with a commercial formulation of *Bacillus thuringiensis*. The LC(90)s of the 5 colonies also increased significantly in a pattern similar to that observed in the LC(50)s, but the increases in LC(90)s were not as large as the increases for the LC(50)s. The bioassay data suggest that a dose of approximate to 2.4 ml Dipel per kilogram of diet could be used as a preliminary discriminating dose. Neonates from field-collected insects could be placed on diets incorporating this concentration of Dipel to monitor for changes and regional differences in susceptibility among field populations of European corn borer. Studies on the genetic basis, the mechanism of action, and the stability over time (in the absence of selection pressure) of this change in susceptibility remain to be carried out.

Jansens, S., A. vanVliet, C. Dickburt, L. Buysse, C. Piens, B. Saey, A. DeWulf, V. Gossele, A. Paez, E. Gobel and M. Peferoen (1997). "Transgenic corn expressing a Cry9C insecticidal protein from *Bacillus thuringiensis* protected from European corn borer damage." *Crop Science* 37(5): 1616-1624.

The European corn borer, *Ostrinia nubilalis* (Hubner), is a devastating insect pest in the corn (*Zea mays* L.) growing regions of North America and Europe. Field evaluations in the USA and Belgium showed that transgenic corn events expressing Cry9C, an insecticidal crystal protein from *Bacillus thuringiensis* subsp. *tolworthi*, very effectively control both generations of the European corn borer. Second to fourth instar larvae fed with leaf material of event CBH351 expressing the Cry9C protein died within 4 d. Cry9C events, expressing high levels of the insecticidal protein, showed minimal stalk tunneling after heavy artificial infestations. Event CBH351 tested in plots containing only Cry9C transgenic plants had 0.14- and 0.09-cm tunneling per stalk compared with more than 30- and 23-cm tunneling per stalk for the negative controls, in the Belgium and Iowa field trial, respectively. In plots containing 30% non-transgenic plants the event CBH351, showed only 1.45-cm tunneling per stalk. Leaf, tassel, and pith tissue contained 39.0, 17.4, and 84.8 µg Cry9C protein mg⁻¹ soluble protein, respectively, in analyses conducted at harvest of the Belgium trial. The implications of Cry9C use for resistance management strategies are discussed.

Klun, J. A. and J. C. Graf (1997). "Contextual chemical ecology: Male to male interactions influence European corn borer (*Lepidoptera* : *Pyralidae*) male behavioral response to female sex pheromone in a flight tunnel." *Journal of Entomological Science* 32(4): 472-477.

The responses of European corn borer, *Ostrinia nubilalis* (Hubner), males in a flight tunnel to sex pheromone, [11-tetradecenyl acetate (97:3, Z:E)] was dependent upon the context in which the males were exposed to the stimulus. Males, held individually in isolation before being exposed to pheromone, flew upwind in the pheromone plume and landed on the pheromone source significantly more often than males caged with other males before exposure to the pheromone. When groups of males were simultaneously exposed to female sex pheromone, they responded, on a per-male basis, with significantly more upwind flights to pheromone and intense behavior near the pheromone source than did males exposed to the pheromone individually. Heightened intensity of male response in group flight was independent of whether the males were individually isolated or caged with other males before being exposed to the pheromone. The enhanced behavioral output of males responding to pheromone in groups may represent an evolutionary adaptive advantage in instances where several males are simultaneously pursuing a single calling female.

Klun, J. A., J. E. Oliver, A. P. Khimian, J. C. Dickens and W. J. E. Potts (1997). "Behavioral and electrophysiological activity of the racemate and enantiomers of a monofluorinated analog of European corn borer (Lepidoptera: Pyralidae) sex pheromone." *Journal of Entomological Science* 32(1): 37-49.

The racemate and individual enantiomers of 2-fluoro-Z-11-tetradecenyl acetate (2F-Z-11), analogs of a European corn borer moth, *Ostrinia nubilalis* (Hubner), female sex pheromone were compared with the natural pheromone, Z-11-tetradecenyl acetate, in field trapping experiments, flight tunnel studies, mating disruption assays and electrophysiological experiments. While the racemate and R-2F-Z-11 mimicked the natural female sex pheromone, they were not more biologically potent than the pheromone. The S-2F-Z-11 was largely ineffective in all assays and was, therefore, incompatible with the pheromone receptor system.

Labatte, J. M., S. Meusnier, A. Migeon, S. Piry and B. Got (1997). "Natural mortality of European corn borer (Lepidoptera: Pyralidae) larvae: Field study and modeling." *Journal of Economic Entomology* 90(3): 773-783.

Natural mortality of *Ostrinia nubilalis* (Hubner) larvae on corn was studied under 30 field-infestation conditions at 3 sites. High mortality occurred during the days immediately after egg hatching when >50% of hatched larvae died, followed by a lower and more stable mortality rate. Two models, one with constant mortality rate and the other with variable mortality rate, were proposed and tested to describe this pattern. These models described the time course of larval survival rate well. The 2nd model was used to compute the European corn borer survival rate at various dates in relation to larval development. The mean mortality rate was 74% during the 1st instar, then remained similar, then decreased by 13% during the 2nd and 3rd instars and 16% during the 4th instar. A high variability in survival rate between infestations was observed as early as the 1st instar. Multiple regressions were used to model relationships between larval survival rate and environmental factors (climatic factors and infestation conditions). Phenological stage of corn at the date of infestation was the primary factor influencing the larval survival rate. The relationship explained >45% of the variability.

Linn, C. E., M. S. Young, M. Gendle, T. J. Glover and W. L. Roelofs (1997). "Sex pheromone blend discrimination in two races and hybrids of the European corn borer moth, *Ostrinia nubilalis*." *Physiological Entomology* 22(3): 212-223.

The response specificity of males of two races, and hybrids, of the European corn borer moth, to a large series of doses/ratios of E- and Z-11-14:OAc, was determined in a sustained-flight tunnel. For both races an area of peak response was determined, which included the natural ratio eliciting peak levels of source contact, and other treatments eliciting response profiles over the behavioural sequence not significantly different from the peak. Consistent with studies on other moth species response specificity was controlled by two threshold effects, one affecting locking-on to odour plumes of lower doses and off-ratios containing lower proportions of the E or Z isomer than the natural blend, and the other resulting in arrestment of upwind flight to higher doses and off-ratios containing higher proportions of the E or Z isomer than the natural blend. A comparison of the size of the areas of peak response showed that males of the univoltine Z race (UZ) using a 3:97 E:Z mix displayed greater specificity and sensitivity than did males of the bivoltine E race (BE) responding to a 99:1 E:Z pheromone mix. At doses higher than these eliciting peak response (>100 µg) response specificity was lower for both races, but especially for the BE race, with increased levels of upwind flight and source contact occurring to off-ratios. Finally, consistent with a previous behaviour/genetic study on this species, F-1 hybrid males displayed peak levels of source contact not only to their natural isomer ratio (65:35 E:Z), but also to an expanded range of doses of ratios ranging from 2% to 98% E.

Mason, C. E., E. Y. Stromdahl and J. D. Pesek (1997). "Placement of pheromone traps within the vegetation canopy to enhance capture of male European corn borer (Lepidoptera: Pyralidae)." *Journal of Economic Entomology* 90(3): 795-800.

European corn borer, *Ostrinia nubilalis* (Hubner), pheromone traps are typically placed in the open or above vegetation to monitor adult presence and abundance in areas where moths are likely to aggregate. After noting in another study that more moths were captured in traps overgrown with vegetation than in traps above it, replicated field experiments were conducted at 2 locations in Delaware to determine if placement of traps within the vegetation was more effective than traps placed above the canopy. At Newark, 3.83 times more males were captured in traps baited with Z-pheromone lure when traps were placed just below the canopy top in mixed weedy vegetation compared with traps 3 m away with the pheromone source 50 cm above the plant canopy. At Laurel in a monoculture of developing wheat, 2.72 times more males were captured in traps baited with E pheromone lure which were placed below the top of the

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canopy versus trans above the canopy Greater variation in male moth captures was associated with greater diversity of the weedy sample location relative to samples in wheat monoculture. Also, traps placed within vegetation resulted in less variation in mean moth captures versus traps placed above the canopy. This indicates that a better estimate of the population may be obtained by placing traps within vegetation. Results suggest that males are more likely to respond to calling females within the vegetation as opposed to above the canopy Placement of pheromone traps with the pheromone source below the top of the canopy appears to be critical for maximizing their effective capture of European corn borer male moths. We suggest that enhancement of pheromone lures within vegetation may be caused by water vapor and volatiles associated with plants.

Orr, D. B. and D. A. Landis (1997). "Oviposition of European corn borer (Lepidoptera:Pyralidae) and impact of natural enemy populations in transgenic versus isogenic corn." *Journal of Economic Entomology* 90(4): 905-909.

In a 1994 field experiment, oviposition, predation, and parasitism of the European corn borer, *Ostrinia nubilalis* (Hubner), were recorded in transgenic and isogenic corn, *Zea mays* L. Plots of plants expressing the CryIA(b) protein of *Bacillus thuringiensis* Kurstaki and plots of isogenic plants both had end-generation *O. nubilalis* egg mass densities of approximate to 1.1 per plant, indicating a lack of antixenosis by transgenic plants. Distribution and size of egg masses on plants also was unaffected by corn type. Size of plants was the same in both treatments. Level of egg mass predation were 24.75 and 19.35%, respectively, but not significantly different between the transgenic and isogenic plots. Parasitism of egg masses was not significantly different between transgenic and isogenic plots, and was low at 6.31 and 4.41%, respectively. Percentage of eggs within masses which hatched was 10.2% lower in transgenic than in isogenic plots. However, neither predation, parasitism, or sloughing of eggs from plants were significantly different between the 2 treatments. Densities of *O. nubilalis* predators were not different between the 2 treatments throughout the *O. nubilalis* oviposition period. Parasitism of *O. nubilalis* larvae by *Eriborus terebrans* (Gravenhorst) and *Macrocentrus grandii* Goidanich was not significantly different between plots and ranged from 2.4 to 7.0%. Although most differences between transgenic and isogenic plants were nonsignificant, all observed differences in natural enemy population parameters under our conditions were in the direction opposite to that expected if transgenic plants had an adverse impact.

Ostrander, B. M. and J. G. Coors (1997). "Relationship between plant composition and European corn borer resistance in three maize populations." *Crop Science* 37(6): 1741-1745.

Breeders have selected for European corn borer [*Ostrinia nubilalis* (Huhner)] (ECB) resistance for many years and this may have led to higher concentrations of cell wall carbohydrates and lignin in stalks and leaf sheaths of maize (*Zea mays* L.). Our objectives were to evaluate the compositional changes accompanying divergent selection for cell wall constituents in three maize populations and to determine whether these changes were associated with changes in ECB resistance, Population BS9(CB) had undergone five cycles of SI family selection for increased first-and second-generation ECB resistance. Cycle 2 of BS9(CB) also underwent one cycle of divergent SI selection for neutral detergent fiber (NDF) and Lignin concentrations in the stalk and leaf sheath. Populations WFISILO and WFISIH I underwent two cycles of SI family selection, respectively, for low and high NDF, acid detergent fiber (ADF), and lignin. Whorl samples were collected at the time of first-generation infestation. Stalks, leaf sheaths, and leaf blades were sampled following second-generation infestation. Selection for increased ECB resistance in BS9(CB) increased NDF, ADF, and lignin concentrations in stalks and leaf sheaths, Selection for high NDF and lignin concentrations in BS9(CB) CZ produced materials with greater second-generation ECB resistance than did divergent selection for low concentrations. Selection for decreased NDF, ADF, and lignin in WFISILO decreased second-generation ECB resistance. Selection for increased NDF, ADF, and lignin in WFISIH I did not influence ECB resistance, however. In general, there was an association between plant cell wall composition and ECB resistance, but genetic background influenced the relationship.

Phoofolo, M. W. and J. J. Obrycki (1997). "Comparative prey suitability of *Ostrinia nubilalis* eggs and *Acyrtosiphon pisum* for *Coleomegilla maculata*." *Biological Control* 9(3): 167-172.

The effects of *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae) eggs and *Acyrtosiphon pisum* (Harris) (Homoptera: Aphididae), when provided as single prey species and in combination, on life history characteristics of *Coleomegilla maculata* DeGreer (Coleoptera: Coccinellidae) larvae and adults were quantified. Preimaginal development was not influenced by the larval prey regime; development at 26 +/- 1 degrees C was completed in approximately 13.5 days on

O. nubilalis eggs, *A. pisum*, or *A. pisum* alternated daily with *O. nubilalis* eggs. The resulting adults weighed 13.0, 10.7, and 12.5 mg when reared on *O. nubilalis* eggs, *A. pisum*, and *A. pisum* alternated daily with *O. nubilalis* eggs, respectively. Eighteen percent of the individuals died when reared on *A. pisum*, 28% died when reared on *O. nubilalis* eggs, and 22% died when fed *A. pisum* alternated daily with *O. nubilalis* eggs. Seven adult diet combinations, based on diet regimes of larvae and adults, did not cause significant differences in preoviposition period, interoviposition period, and the number of days on which eggs were laid. Total fecundity was influenced both by larval and adult diet. The diet that resulted in highly fecund females was *A. pisum* alternated daily with *O. nubilalis* eggs for larvae and *O. nubilalis* eggs for adults. Female *C. maculata* fed *O. nubilalis* eggs had the highest intrinsic rate of increase and net reproductive rate. (C) 1997 Academic Press.

Rice, M. E. and K. Ostlie (1997). "European corn borer management in field corn: A survey of perceptions and practices in Iowa and Minnesota." *Journal of Production Agriculture* 10(4): 628-634.

The European corn borer (*Ostrinia nubilalis* Hubner) is a major pest of field corn (*Zea mays* L.) in the midwestern states. In 1991, an outbreak of this insect caused yield losses as high as 32.6 bu/acre in Iowa and averaged 14 bu/acre in Minnesota. Following this pest outbreak, a questionnaire was developed to: (i) assess how farmers and agribusiness professionals perceive the crop production risks posed by European corn borer, and (ii) explore how these perceptions are reflected in management options they use or recommend. Farmers and agribusiness professionals completed 851 surveys. The survey results provided insights into yield loss perceptions, management tactics used, and research needs for European corn borer management. Economic yield losses caused by European corn borers during the first and second generations, respectively, were thought to occur only by 65 to 69% of farmers, 78 to 81% of ag-chemical professionals, 84 to 89% of crop consultants, and 68 to 70% of educator/agronomists. Respondents that perceived economic losses caused by European corn borers thought that the average loss was 15.3 to 16.6 bu/acre during the first generation and 15.2 to 18.1 bu/acre during the second generation. Although two-thirds of the farmers perceived the European corn borer as a serious pest, only 35% had ever scouted their fields and used economic thresholds, and only 28% had ever used an insecticide to control the pest. Farmers' primary and secondary options for managing the European corn borer or reducing yield losses were to harvest the fields early before ears drop onto the ground (63.4%) and to plant hybrids with known resistance (39.0%), respectively. In contrast, scouting and using economic thresholds was the primary recommendation from ag-chemical professionals (68.3%), crop consultants (88.5%), and educator/agronomists (54.0%). The second most common recommendation was using an insecticide by ag-chemical professionals (57.9%) and educator/agronomists (41.4%), whereas crop consultants were more likely to suggest early harvest to prevent ear droppage (73.8%). The survey results suggest that many farmers don't manage European corn borer because of historic inaction, hidden yield losses, reluctance to scout, logistical burnout, capital doubts, cultural competition, insecticide concerns, and a failure to recognize the problem. The results also suggest a strong need to educate farmers and agribusiness professionals regarding biology, crop damage, and management options for the European corn borer.

Schulz, B., R. Kreps, D. Klein, R. K. Gumber and A. E. Melchinger (1997). "Genetic variation among European maize inbreds for resistance to the European corn borer and relation to agronomic traits." *Plant Breeding* 116(5): 415-422.

The univoltine European corn borer (ECB) has become a major limiting factor for maize (*Zea mays* L.) production in central Europe. The objective of this study was to survey the genetic variation for ECB resistance in European elite maize germplasm. Eighteen flint and 23 dent inbreds were screened under artificial ECB infestation at two locations in 1993 and 1994. Resistance was assessed by damage rating of broken plants, measurement of tunnel length in dissected stalks, and yield reduction in infested plots relative to insecticide-protected control plots. Flint lines showed significantly greater means for damage rating than dent lines with grain yield reduction of 35% and 24%, respectively. Significant genotypic variances among lines and high heritabilities were found for agronomic traits and damage rating. Heritabilities were intermediate for tunnel length and relative grain yield. Significant associations of days to silking, ear dry matter content, and dry matter yield of the whole plant with damage rating and tunnel length suggested a better resistance in late-maturing, high-yielding inbreds. Genotypic correlations of relative grain yield with tunnel length and damage rating ranged between -0.46 and -0.72. Partial correlations, eliminating the effect of flowering time, confirmed these associations. Damage rating of stalks is the most suitable trait for evaluation of ECB damage owing to its high heritability and easy recording. Tunnel length below the primary ear is a useful trait for assessing antibiosis because it is

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not correlated with days to silking. Inbreds with extreme resistance and susceptibility were identified which can be used as parents for establishing breeding and QTL mapping populations.

Trisyono, A. and G. M. Chippendale (1997). "Effect of the nonsteroidal ecdysone agonists, methoxyfenozide and tebufenozide, on the European Corn Borer (Lepidoptera : Pyralidae)." *Journal of Economic Entomology* 90(6): 1486-1492.

The effect of 2 nonsteroidal ecdysone agonists, methoxyfenozide (proposed name For RH-2485) and tebufenozide (RH-5992), was examined on eggs and larvae of the European corn borer, *Ostrinia nubilalis* (Hubner). Both compounds were ovicides. More than 90% of eggs died when egg masses were dipped in a solution of 100 ppm methoxyfenozide or tebufenozide in acetone:distilled water (1:1). Although some eggs that were treated with 1 or 10 ppm methoxyfenozide or tebufenozide hatched, the survival rate was low. Test compounds were incorporated into an artificial diet to examine larvicidal effects. Using this technique, methoxyfenozide was 3-7 times more toxic to newly hatched larvae than was tebufenozide. Methoxyfenozide was 184-270 and 147-469 times more toxic to newly hatched larvae than were diflubenzuron and carbaryl, respectively, whereas tebufenozide was 41-68 and 22-75 times more toxic than were diflubenzuron and carbaryl, respectively. Methoxyfenozide was toxic to 3rd instars with tie LC50 value being approximate to 2 times higher than it was for neu lv hatched larvae. Methoxyfenozide (0.125 and 0.25 ppm) and tebufenozide (0.25 and 0.5 ppm) were lethal to newly hatched larvae, even after diets containing these compounds were held for 20 d under long days (16:8 [L:D] h) at 30 degrees C. Tebufenozide applied at 0.016 and 0.031 ppm to larvae inhibited larval growth, delayed pupation, and decreased adult emergence. Methoxyfenozide applied at 0.063, 0.125, 0.25, and 0.5 ppm to newly ecdysed 4th instars caused them to stop feeding approximate to 8 h after exposure and induced a premature and lethal molting cycle. Methoxyfenozide and tebufenozide are potential insect growth regulators for controlling *O. nubilalis*.

Udayagiri, S. and C. E. Mason (1997). "Epicuticular wax chemicals in *Zea mays* influence oviposition in *Ostrinia nubilalis*." *Journal of Chemical Ecology* 23(7): 1675-1687.

The chemical basis of oviposition elicitation in a generalist herbivore was determined by examination of oviposition responses in *Ostrinia nubilalis* to corn (*Zea mays*) chemicals in two-choice laboratory bioassays. A pentane extract of corn leaves stimulated oviposition and the activity persisted for three days, indicating that oviposition in *O. nubilalis* is elicited by low-volatility chemicals. Chemicals in the extract were fractionated by column chromatography on Florisil, using a sequence of solvents of increasing polarity. Bioassays of Florisil fractions indicated that the stimulants were eluted with nonpolar solvents. Positive bioassay results with an extract prepared by dipping corn leaves in pentane for 20 sec for extraction of leaf surface chemicals suggested that some of the active material was present in the leaf epicuticle. Gas chromatographic analyses and comparisons with retention times of standards suggested the presence of several n-alkanes in the dip extract. Five n-alkanes-hexacosane, heptacosane, octacosane, nonacosane, and tri-triacontane-known to be present in the epicuticle of corn leaves were bioassayed, and all five elicited oviposition responses. These results suggest that oviposition elicitation in *O. nubilalis* is influenced by the presence of n-alkanes in the host plant epicuticle.

Wang, B. D., D. N. Ferro and D. W. Hosmer (1997). "Importance of plant size, distribution of egg masses, and weather conditions on egg parasitism of the European corn borer, *Ostrinia nubilalis* by *Trichogramma ostriniae* in sweet corn." *Entomologia Experimentalis Et Applicata* 83(3): 337-345.

Trichogramma ostriniae (Hym: Trichogrammatidae), an egg parasitoid of the European corn borer, *Ostrinia nubilalis* (Lep: Pyralidae), were released into sweet corn (*Zea mays* L.) fields to study the effects of weather, plant size and distribution of egg masses on egg parasitism by the wasp. Sentinel European corn borer eggs were stapled onto leaves located in the upper, middle and lower third of sweet corn plants 5 to 35 meters away from the wasp release point in either a radial or grid manner. Weather conditions and plant architecture were monitored during the experiments. Logistic regression was used to analyze the data. The results indicated that percentage of eggs parasitized was negatively related to an increase in leaf area as well as an increase in distance eggs were located from the point of release of wasps. Eggs distributed on plants at different directions from the release point received different levels of parasitism. Eggs that were stapled onto leaves in the upper third of a corn plant received much less parasitism than those on the middle and lower third of the plant. Higher mean temperature adversely affected the level of parasitism during hotter times of the season and conversely, lower temperatures (< 17 degrees C) reduced the egg parasitism

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during cooler times of the season. The longer the exposure of eggs to wasps, the higher the level of egg parasitism. However, the levels of egg parasitism for 2 day's exposure were almost the same as that for 3 day's exposure due to the limited longevity and egg-laying behavior of the wasp. These results suggest that inundative releases of *T. ostrinae* should be made every two to three days, with multiple release points per hectare. In addition, weather conditions and plant architecture, especially temperature, plant height and leaf area must be taken into consideration to optimize levels of parasitism.

Warnock, D. F., W. D. Hutchison, T. J. Kurtti and D. W. Davis (1997). "Laboratory bioassays for evaluating sweet corn antibiosis on European corn borer (*Lepidoptera: Pyralidae*) larval development." *Journal of Entomological Science* 32(3): 342-357.

European corn borer (*Ostrinia nubilalis* Hubner) can severely affect commercial sweet corn quality during years of heavy infestation. The isolation and identification of allelochemicals in sweet corn which detrimentally affect *O. nubilalis* may enhance breeder selection for greater ear feeding resistance, thus reducing the need for insecticide application. Field selection techniques for improving plant resistance to *O. nubilalis* cannot easily distinguish between plant tolerance or antibiosis. A laboratory bioassay incorporating ear tissues from field resistant and susceptible sweet corn genotypes into a nutritionally complete *O. nubilalis* larval diet was developed as an initial step to facilitate the isolation and identification of potential chemical resistance factors in sweet corn. Neonates reared for 7 d on a meridic diet with limited fungal and bacterial contaminant control agents weighed more than larvae grown on a comparable diet with high levels of contaminant control (5.96 and 2.46 mg, respectively). Silk tissue from several sweet corn genotypes significantly reduced larval weight and increased total larval development time compared with kernel tissue. Silk tissues incorporated on a weight basis had volumes about 3 x that of an equal weight of kernel tissues. However, tissues incorporated into a specific diet volume on a weight or volume basis usually did not alter larval weight or time to pupation within a genotype. Incorporation on a weight basis was most time efficient. Future bioassays screening for antibiotic effects of sweet corn tissue on *O. nubilalis* development should utilize a diet with limited contaminant control agents, incorporate tissue on a weight basis, and focus on silk tissue.

Abedon, B. G. and W. F. Tracy (1996). "Corngress1 of maize (*Zea mays* L) delays development of adult plant resistance to common rust (*Puccinia sorghi* Schw) and European corn borer (*Ostrinia nubilalis* hubner)." *Journal of Heredity* 87(3): 219-223.

Based on morphological evidence, researchers have proposed that Corngress1 (Cg1) of maize (*Zea mays* L.) is a heterochronic mutation that prolongs the juvenile-vegetative phase because distal tissues display juvenile traits that normally occur only basally, Physiological or biochemical evidence in support of this hypothesis is lacking, Disease and insect resistance often depends on physiological, biochemical, and morphological factors and can vary during ontogeny, We evaluated resistance to common rust (*Puccinia sorghi* Schw,) and European corn borer (*Ostrinia nubilalis* Hubner) in cg1 and wild-type segregating families in order to test the hypothesis that Cg1 is a heterochronic mutation that extends the juvenile-vegetative phase, In backgrounds with high expression, Cg1 mid-whorl leaves had similar resistance as Cg1 and wild-type seedling leaves, whereas wild-type mid-whorl leaves differed in resistance from the other three leaf types, In the Mo17 background, which has reduced Cg1 expression, Cg1 mid-whorl leaves had resistance levels intermediate between wild-type seedling and mid-whorl levels, These results support the hypothesis that Cg1 prolongs the juvenile-vegetative phase and suggest that heterochrony may be among the factors responsible for disease and insect resistance in normal populations of maize.

Anglade, P., B. Gouesnard, A. Boyat and A. Panouille (1996). "Effects of multitrait recurrent selection for European corn borer tolerance and for agronomic traits in FS12 maize synthetic." *Maydica* 41(2): 97-104.

The European areas of early maize cultivation have normally one generation of the European corn borer (ECB) per year and sources of tolerance are needed. The evaluation of plant damage under artificial infestation may be considered as a convenient tool of selection for tolerance. Many European inbred lines were tested for ECB tolerance and a 38-line synthetic, designated FS12, was developed. Then two cycles of S1 recurrent multitrait selection were conducted by the independent culling levels method, both for tolerance and agronomic traits. The source (C0) and selected (C1 and C2) populations were evaluated per se and as testcrosses in several locations to determine their yield abilities in the absence of the borer. Furthermore, they were tested under ECB artificial infestation to estimate the tolerance ratings (from 1 = tolerant to 9 = susceptible) and the yield losses due to the borer. In the experimental network without ECB, the grain yield gain averaged 0.23 Mg ha⁻¹ per cycle on testcrosses. In the most accurate experiment under artificial

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infestation, the two cycles of selection decreased tolerance ratings from 3.8 to 2.9. The yield reductions decreased by 22.4% to 17.9%. Between C2 and C0 populations on testcrosses, the yield increase averaged 0.49 Mg ha⁻¹ for uninfested plots and 0.74 Mg ha⁻¹ for infested plots. It can be assumed that the difference corresponds to the gain in tolerance. Thus, the recurrent selection in FS12 led to valuable results in breeding for both agronomic performance and tolerance to ECB.

BenYakir, D. and C. Shochat (1996). "The fate of immunoglobulin G fed to larvae of *Ostrinia nubilalis*." *Entomologia Experimentalis Et Applicata* 81(1): 1-5.

Since plants can be transformed genetically to produce functional antibodies, an immunological approach may be developed for controlling their arthropod pests. Specific antibodies would protect plants from arthropods if they could gain access to the pest antigen in sufficient amounts such that the normal function of the antigen is disrupted. In order to study the fate of ingested antibodies in the body of the European corn borer (ECB), *Ostrinia nubilalis* (Hubner), (Lepidoptera: Pyralidae), we fed the larvae on serum-containing diet. When larvae were fed on the serum-containing diet for various lengths of time between 12 and 96 h, no significant differences were noted in the immunoglobulin G (IgG) concentration in their body. Immediately after the larvae stopped feeding, the concentrations of the IgG in their midgut was about one half that of the diet itself, but it decreased significantly after 6 h and again after 18 h (about 3 and 10 fold, respectively). Immediately after the larvae stopped feeding, the concentration of the IgG in their hemolymph was about 1/500 that in the diet. The concentration of IgG in the hemolymph of ECB larvae was influenced directly by the titer of antibodies in their diet. During the first 6 h after the larvae stop feeding the concentration of Ige in their hemolymph did not decrease significantly; however, it did so after 18 h (about 6 fold). The possibility that specific antibodies will gain access to antigens in the ECB body is discussed.

Bernardi, R. and S. Palmieri (1996). "Isolation and inhibition of a trypsin-like activity from larvae of corn borer (*Ostrinia nubilalis*) using reverse micelles." *Biotechnology Letters* 18(6): 663-666.

Endoproteinase(s) was isolated from a freeze-dried powder of larvae of *Ostrinia nubilalis* using reverse micellar, solutions. The inhibition of proteinase was studied in reverse micelles with commercial Bowman-Birk soybean trypsin inhibitor and three trypsin inhibitors recently isolated from ripe cruciferous seeds.

Bernardi, R., G. Tedeschi, S. Ronchi and S. Palmieri (1996). "Isolation and some molecular properties of a trypsin-like enzyme from larvae of European corn borer *Ostrinia nubilalis* Hubner (Lepidoptera:Pyralidae)." *Insect Biochemistry and Molecular Biology* 26(8-9): 883-889.

A one-step high-yielding procedure is presented for the purification of a trypsin-like proteinase from *Ostrinia nubilalis* larvae, consisting of benzamidine-sepharose affinity chromatography. The purified enzyme was homogeneous as judged by SDS-PAGE. The enzyme presents a molecular mass of 24 650 Da, a maximum pH activity profile of 9.5, a remarkable thermal stability and an optimum temperature of about 53 degrees C. K-m values determined using N alpha-benzoyl-DL-arginine-ethylester and N alpha-benzoyl-DL-arginine-p-nitro-anilide were 3.2x10⁻⁵ M and 4.1x10⁻⁴ M respectively, The proteinase was inhibited by some typical serine proteinase inhibitors such as N alpha-tosyl-L-lysine chloromethyl ketone, soybean trypsin inhibitors, benzamidine and phenylmethylsulfonyl fluoride. In particular, it,was competitively inhibited by benzamidine with a K, of 1.2x10⁻⁵ M, whereas it was not affected by cysteine proteinases inhibitors, Comparative analysis of the amino acid composition and N-terminal sequence of *O. nubilalis* proteinase confirmed that this enzyme is very similar to other serine proteinases from lepidopteran larvae. Copyright (C) 1996 Elsevier Science Ltd

Binder, B. F. and J. C. Robbins (1996). "Age- and density-related oviposition behavior of the European corn borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae)." *Journal of Insect Behavior* 9(5): 755-769.

Age-related oviposition patterns of *Ostrinia nubilalis* were studied at three population densities in the laboratory by releasing newly eclosed adults in wire-screened cages and analyzing their oviposition throughout the adult stage with digital analysis. Oviposition sequences of individual females depositing egg masses were documented on the third and seventh nights after eclosion with a video camcorder. During a sequence, a female produced an egg in an average time of 15 or 26 s on the third and seventh nights, respectively, and completed depositing an egg mass the size of 20-39 eggs in an average time of 316 and 525 s, respectively. Females were not easily disturbed during egg mass deposition

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and pulsated their abdomen before deposition of each egg. Females produced few egg masses the first night after eclosion. Oviposition increased on nights 2 and 3 but declined steadily thereafter as females matured. Females older than 6 nights produced fewer egg masses; the proportion of egg masses with fewer than 20 eggs increased gradually. By the end of the adults' lifetime, nearly 100% of the egg masses had fewer than 20 eggs. The data are fundamental to our research to define the role of phytochemicals in modifying oviposition behavior of the European corn borer.

Bolin, P. C., W. D. Hutchison and D. W. Davis (1996). "Resistant hybrids and *Bacillus thuringiensis* for management of European corn borer (Lepidoptera: Pyralidae) in sweet corn." *Journal of Economic Entomology* 89(1): 82-91.

Field studies were done in 1991 and 1992 to determine the potential for integrating host plant resistance and *Bacillus thuringiensis* Berliner variety *kurstaki* for control of the European corn borer, *Ostrinia nubilalis* (Hubner), in sweet corn. Three experimental hybrids resistant to ear feeding in 1991 and 5 in 1992 were treated with encapsulated *B. thuringiensis*, permethrin, or left unsprayed. The commercial hybrid 'Jubilee' was included as a susceptible control. In 1991, all resistant hybrids (with and without *B. thuringiensis*) controlled *O. nubilalis* larvae as well as or better than Jubilee + permethrin, a predominant management combination in the midwestern United States. In 1992, two untreated resistant hybrids, and 4 treated with *B. thuringiensis* controlled total larvae as well as Jubilee + permethrin. In addition, 2 of the hybrids treated with *B. thuringiensis* consistently provided >95% control of late instars (3rd-5th) in the corn ear. Based on fresh market standards (no larvae or damage in ear, husk, or silk), ear protection from 4 of 5 resistant hybrids treated with *B. thuringiensis* did not differ from Jubilee + permethrin. Based on processing marketability (no larvae or damage on ear kernels), all 5 resistant hybrids treated with *B. thuringiensis* were not different from the conventional management strategy. Population densities of generalist predators did not differ between the untreated plots and those treated with *B. thuringiensis*; however, predator density was lower in the plots treated with permethrin. Results from this study suggest that the integration of resistant hybrids and *B. thuringiensis* can provide a viable alternative to insecticide-based *O. nubilalis* management programs for sweet corn in the upper midwestern United States.

Ewete, F., R. W. Nicol, V. Hengsawad, P. Sukumalanand, C. Satasook, P. Wiriyaichitra, M. B. Isman, F. Duval, B. J. R. Philogene and J. T. Arnason (1996). "Insecticidal activity of *Aglaia odorata* extract and the active principle, rocaglamide, to the European corn borer, *Ostrinia nubilalis* Hubn (Lep, Pyralidae)." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 120(8): 483-488.

A standardized twig extract of the Asian shrub, *Aglaia odorata* Lour. (Meliaceae), and rocaglamide, a purified active principle of the extract, were evaluated for potential to control the European corn borer (*Ostrinia nubilalis* Hubn.), via incorporation into meridic diet fed to larvae. Life cycle bioassays using the extract revealed that it inhibited larval growth at all concentrations tested (12.5-100 p.p.m./fresh wt.) and delayed mean time to pupation from 24.1 days (control) to 83.8 days (50 ppm). Other effects include reduced pupal and adult weights and an increase in the frequency of deformed pupae. Investigation of consumption rates and dietary utilization in larvae feeding on diet containing the extract suggested that it acts via a combination of antifeedant and postingestive (toxic) actions. Life cycle bioassays using rocaglamide demonstrated that this compound is an extremely potent inhibitor of larval growth, with concentration dependent activity observed at dietary concentrations from 0.05-0.02 ppm. Effects at these levels include severe reductions in growth and pupal weight, and increases in larval mortality and time to pupation. Rocaglamide appears to be as, or even more active, than the very effective botanical pesticide azadirachtin from the neem tree.

Ewete, F. K., J. T. Arnason, J. Larson and B. J. R. Philogene (1996). "Biological activities of extracts from traditionally used Nigerian plants against the European corn borer, *Ostrinia nubilalis*." *Entomologia Experimentalis Et Applicata* 80(3): 531-536.

Preliminary investigations with ethanolic (EtOH) extracts from five Nigerian plants show that extracts of *Piper guineense* Schum and Thonn (Piperaceae), *Cedrela odorata* L. (Meliaceae), *Dennettia tripetala* G Baker (Annonaceae) and *Aframomum melegueta* (Rosch) K. Schum (Zingiberaceae) in artificial diets significantly reduced larval growth of European corn borer (ECB), *Ostrinia nubilalis* Hubner, at a concentration of 1000 ppm (0.1%). An extract of *Xylopia aethiopica* (Dunal) A. Rich (Annonaceae) was ineffective. When the extracts were subsequently incorporated into artificial diets at 300 ppm and offered to neonates, larval mortality increased in the order *A. melegueta* (13%), *D. tripetala* (13%), *P. guineense* (27%), and *C. odorata* (48%). Larval and adult emergence periods increased with increasing concentration of *P. guineense*, *C. odorata* and *D. tripetala* indicating a toxic response. Nutritional indices for habituated

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third instar larvae with the two most promising plant extracts, *P. guineense* and *C. odorata*, showed that the efficiencies of conversion of digested food (ECD) was significantly reduced at 300 ppm suggesting a postdigestive toxicity of the extracts. *P. guineense* and *C. odorata* extracts show the best potential for development as botanical insecticides.

Frolov, A. N., D. S. Trishkin, K. D. Dyatlova and M. A. Chumakov (1996). "Spatial distribution of corn borer (*Ostrinia nubilalis*) in area of developing two generations." *Zoologichesky Zhurnal* 75(11): 1644-1652.

Spatial distribution of European corn borer adults was studied during the flying of the overwintered and the first generation in Krasnodar Territory and in Rostov district. Adults of the overwintered generation aggregated on small plots ("action sites") of 200-1000 m² located nearby corn fields which were protected by forest shelterbelts and were covered with plants attractive for insects. The first generation adults were usually concentrated in the action sites, located at the borders of corn fields, which were covered with not high but dense weed vegetation. A high correlation was found between the density of overwintered adults and the area of corn fields ($r = 0,99$). Precocity of plants influenced the density of adults to a less degree.

GarnierGeoffroy, F., P. Robert, N. Hawlitzky and B. Frerot (1996). "Oviposition behaviour in *Ostrinia nubilalis* (Lep: Pyralidae) and consequences on host location and oviposition in *Trichogramma brassicae* (Hym: Trichogrammatidae)." *Entomophaga* 41(2): 287-299.

Before oviposition, *Ostrinia nubilalis* Hubner females sweep the surface of the plant with their abdominal tip extruded. The consequences of such behaviour were studied on host searching and oviposition behaviours of the parasitoid *Trichogramma brassicae* Bezdenko. Egg-masses of *O. nubilalis*, associated or not with sweeping, were submitted to *T. brassicae* females. The behaviour of *T. brassicae* females appeared to be very different between the two situations. The parasitoid in the vicinity of an egg-mass associated with sweeping spent more time on the corn leaf. Ninety percent of females located the egg-mass with sweeping, whereas only 40% located the egg-mass without sweeping. Eighty three percent of *T. brassicae* females parasitized egg-masses with sweeping, but only 10% in the case without sweeping. Although no deposit was visible, a chemical trail was probably left behind and was found to arrest the parasitoid, to promote host recognition and to trigger oviposition. The amount of the scales left behind on the corn leaf during the sweeping behaviour was also taken into account but did not appear to constitute the trail. The passage over the trail followed by the egg-mass examination constituted behavioural steps which seemed necessary for oviposition in the *T. brassicae* female.

Got, B., J. M. Labatte and S. Piry (1996). "European corn borer (Lepidoptera: Pyralidae) development time model." *Environmental Entomology* 25(2): 310-320.

A nonlinear model for describing the larval development of the European corn borer, *Ostrinia nubilalis* (Hubner), was calibrated because previous work had revealed limitations of the degree-day model. The model proposed by Logan et al. in 1976 was used as a starting point. Experimental design was based on destructive sampling in order to record a large number of larvae, and on variable temperatures in order to fit the nonlinear model with few experiments and to avoid artifacts caused by constant temperatures. A calibration method was also proposed. The Logan model and the normal distributions describing the timing of the moult could be calibrated with the proposed method for temperatures ranging between 9 and 42 degrees C. The model was validated under field conditions. Validation revealed that at least 1 environmental variable, probably maize phenology, that was not taken into account by the temperature model had a strong effect on the development rate. Leasing out the infestation where this effect was maximum (infestation during the early whorl stage), the model predicted the 2nd moult with a 48-h accuracy, and the last moult with an accuracy of better than 5 d. However, predictions were only half a day better than those obtained by the degree-day model. Nevertheless, this work helped to determine precisely the range of validity for the degree-day concept. Further investigations are along 2 directions: testing other mathematical formulations of the relationship between development rate and temperature to determine the possible limitations of the Logan formulation, and analyzing the influence of other environmental variables once the influence of temperature has been taken into account.

Labatte, J. M., S. Meusnier, A. Migeon, J. Chaufaux, Y. Couteaudier, G. Riba and B. Got (1996). "Field evaluation of and modeling the impact of three control methods on the larval dynamics of *Ostrinia nubilalis* (Lepidoptera: Pyralidae)." *Journal of Economic Entomology* 89(4): 852-862.

Impact of 3 control methods on larval European corn borer, *Ostrinia nubilalis* Hubner, dynamics on corn, Zee mays (L.), was evaluated under field conditions at Versailles, France. The control methods studied were a chemical insecticide, *Beauveria bassiana* Vuillemin (Deuteromycotina: Hyphomycete), and a transgenic corn hybrid. The experimental study showed that *B. bassiana* control was similar to chemical control. The transgenic hybrid control was always very high throughout the corn cycle studied. A substantial decrease of *B. bassiana* and chemical control efficacy was observed with an increase in the delay between treatment and infestation. The complementary studies of *B. bassiana* persistence, control impact, and pathogen contact showed control-larval behavior interactions, which could explain this decrease in efficacy. To take into account the main factors that condition control efficacy, a modular and mechanistic model was proposed to describe larval dynamic and control impact. The proposed control model made it possible to integrate *O. nubilalis* dynamics, and thus to describe the time response of control.

Lewis, L. C., E. D. Berry, J. J. Obrycki and L. A. Bing (1996). "Aptness of insecticides (*Bacillus thuringiensis* and carbofuran) with endophytic *Beauveria bassiana*, in suppressing larval populations of the European corn borer." *Agriculture Ecosystems & Environment* 57(1): 27-34.

Research was conducted in 1989 and 1990 to determine if *Beauveria bassiana* in combination with *Bacillus thuringiensis* or carbofuran is an effective tactic for season-long management of the European corn borer, *Ostrinia nubilalis*. A granular formulation of *Beauveria bassiana* was applied to corn at whorl stage (V6) and/or at pollen-shed stage (R1) corn. *Bacillus thuringiensis* or carbofuran was then applied to the same plants. *Beauveria bassiana* reduced larval populations of *O. nubilalis* when the fungus was applied to corn during both the whorl stage and the pollen-shed stage. When either *Bacillus thuringiensis* or carbofuran was added to plants treated with *Beauveria bassiana*, there was increased mortality of *O. nubilalis*. Although *Beauveria bassiana* alone reduced *O. nubilalis* tunneling, mostly damage was further reduced when *Bacillus thuringiensis* or carbofuran was applied to whorl-stage corn. When applied to pollen-shedding corn, *Beauveria bassiana* reduced tunneling but had no significant effect on yield, unless *Bacillus thuringiensis* was added. Although *Beauveria bassiana*, *Bacillus thuringiensis*, and carbofuran reduced tunneling by first generation *O. nubilalis*, increased yields did not always result. Tunneling by second-generation *O. nubilalis* was significantly reduced by *Beauveria bassiana* in both years of all experiments. Even so, yields were variable in all experiments which indicated that a number of abiotic and biotic factors, aside from insects, affected yields. This study is the first to document compatibility of *Beauveria bassiana* with a chemical insecticide. Yield data indicate that endophytic *Beauveria bassiana* is not a plant pathogen.

Nault, B. A., N. M. French and G. G. Kennedy (1996). "Influence of European corn borer (Lepidoptera: Pyralidae) damage to potato and foliage availability on overwinter survival of first-generation Colorado potato beetle adults (Coleoptera: Chrysomelidae) in North Carolina." *Journal of Economic Entomology* 89(1): 124-130.

Survival of 1st-generation Colorado potato beetle, *Leptinotarsa decemlineata* (Say), adults following harvest of the Irish potato, *Solanum tuberosum* L., crop in late June was investigated in eastern North Carolina. First-generation adults that emerge before harvest may have access to postbloom-stage potato plants injured by European corn borer, *Ostrinia nubilalis* (Hubner), whereas beetles that emerge after harvest may have access only to cull tubers. We tested the hypotheses that adult overwinter survival is positively correlated with the period 1st-generation adult beetles had fed on potato foliage and that feeding on corn borer-damaged plants affect overwinter survival of 1st-generation adults. Therefore, overwinter survival was examined after beetles were presented a continuous supply of potato tubers as the only source of food or were fed for 3, 7, 11-12, or 17 d on potato plants that were either damaged by the European corn borer or undamaged, and then were provided tubers. Feeding on corn borer-damaged plants did not affect overwinter survival of 1st-generation potato beetle adults (survival in 1993: damaged, 15% and undamaged, 14%; 1994: damaged, 11% and undamaged, 9%). First-generation adults that had access to potato foliage in late June and early July had a significantly better chance of surviving overwinter and reproducing the following year compared with beetles that had access only to tubers. Overwinter survival of 1st-generation beetles that had only tubers as a host was 0 and 0.5% in 1993 and 1994, respectively.

Nault, B. A. and G. G. Kennedy (1996). "Sequential sampling plans for use in timing insecticide applications for control of European corn borer (Lepidoptera: Pyralidae) in potato." *Journal of Economic Entomology* 89(6): 1468-1476.

Sequential sampling plans were developed for use in recommending control of European corn borer, *Ostrinia nubilalis* (Hubner), in potato, *Solanum tuberosum* L., fields based on the distribution of damaged stems. Likelihood ratio tests indicated that the beta-binomial distribution (aggregated) provided a better fit than the binomial (random) when the mean percentage of damaged stems in a field was greater than or equal to 6%, but not when damage was <6%. Similarly, variance-ratio (D) and C(alpha) tests indicated that damage was aggregated generally at damage levels greater than or equal to 6%. Because the slope (b) +/- SEM of the binary form of the Taylor power law (1.15 +/- 0.05) (total of 41 fields) revealed moderate overdispersion, and a weak linear relationship existed between the index of aggregation (theta) and p, sequential sampling plans were evaluated under various degrees of aggregation. The precision and practicality of the sequential sampling plans were evaluated through calculation of operational characteristics and average sample number functions for both simulated binomial and beta-binomial distributions. Precision of the sequential sampling plans decreased as the aggregation of *O. nubilalis* damage increased, especially when the proportion of damaged stems was near threshold. However, precision increased dramatically if fields near threshold were sampled more than once. Because, in practice, potato fields near threshold are sampled repeatedly, the sampling plans were considered acceptable. A comparison between the sequential sampling plan and the conventional sampling plan revealed that control decisions made using the sequential plan agreed closely with those made by the conventional plan, and averaged 57% fewer samples needed to make the decision.

Nault, B. A. and G. G. Kennedy (1996). "Timing insecticide applications for managing European corn borer (Lepidoptera: Pyralidae) infestations in potato." *Crop Protection* 15(5): 465-471.

European corn borer, *Ostrinia nubilalis* (Hubner), management using insecticides was investigated in Irish potato, *Solanum tuberosum* L., in eastern North Carolina. Additionally, activity of corn borer larvae on untreated 'Kennebec' potato plants was evaluated. Corn borer larvae produced new tunnels at the same rate throughout their development and ultimately produced 4.7 +/- 0.4 (mean +/- SEM) tunnels per plant per larva. Thus, for any given corn borer infestation level, estimates of damage to the crop will increase as the season progresses. Application timing of carbofuran, methamidophos and esfenvalerate were evaluated for control of corn borer damage in 'Atlantic' potato. The type and rate of insecticide and the level of corn borer damage at the time of application affected the level of damage at the end of the season. The greatest reduction in damage occurred when the insecticide was applied when many neonates were observed penetrating the plant. A single application of either carbofuran (1.12 kg a.i. ha(-1)) or methamidophos (0.84 or 1.12 kg a.i. ha(-1)) when approximate to 20-40% of the stems are damaged in early May should improve European corn borer management in potato. Copyright (C) 1995 Elsevier Science Ltd.

Nault, B. A. and G. G. Kennedy (1996). "Evaluation of Colorado potato beetle (Coleoptera: Chrysomelidae) defoliation with concomitant European corn borer (Lepidoptera: Pyralidae) damage on potato yield." *Journal of Economic Entomology* 89(2): 475-480.

The relationship between Irish potato, *Solanum tuberosum* L., yield and Colorado potato beetle, *Leptinotarsa decemlineata* (Say), defoliation has been established in many regions but rarely has been considered coincident damage by other pests. In eastern North Carolina, the Colorado potato beetle and the European corn borer, *Ostrinia nubilalis* (Hubner), attack potato each spring, and the potential exists for reduced potato yields caused by a combination of potato beetle and corn borer damage. Yields from potatoes damaged by both pests were evaluated in small-plot experiments for 3 yr. Plant damage was achieved by manipulating pest densities with insecticides and by augmenting plots with notate beetles from nearby commercial fields. Yields were measured at the end of each growing season in late June to early July. Defoliation caused by Colorado potato beetle during bloom significantly reduced yields of U.S. No. 1 tubers in 'Atlantic' each year, whereas European corn borer damage did not. Absence of an interaction effect between corn borer damage and defoliation on potato yield indicated that the yield/damage relationship for each pest can be defined independently.

Onstad, D. W. and E. F. Brewer (1996). "Modeling induction of diapause in North American *Ostrinia nubilalis* (Lepidoptera: Pyralidae) populations." *Environmental Entomology* 25(5): 1140-1146.

A general model for predicting diapause induction in most North American populations of European corn borer, *Ostrinia nubilalis* (Hubner), was created by statistically testing the influence of scotophase, civil twilight (the period before sunrise or after sunset when the sun is 6 degrees below the horizon), temperature, and latitude in equations calibrated with and validated against laboratory and field data. The best equation includes scotophase as hours of darkness per day, mean temperature, and latitude in decimal degrees. To predict diapause induction in the field, a larval maturation model and a function for determining the response of different larval instars must be calculated along with the basic equation. In the field, scotophase should be calculated by subtracting daylength and civil twilight from 24 h. The overall model explained about half the variability in the independent data for European corn borer populations in North America between 30 and 50 degrees N latitude.

Orr, D. B. and J. M. Pleasants (1996). "The potential of native prairie plant species to enhance the effectiveness of the *Ostrinia nubilalis* parasitoid *Macrocentrus grandii*." *Journal of the Kansas Entomological Society* 69(2): 133-143.

Over 600,000 acres of roadside rights-of-way laid out in a grid-like pattern across Iowa have been targeted for restorative planting of flowering native prairie plants. These plantings may benefit agriculture if native plant species provide resources for insects that parasitize crop pests. We examined a number of prairie plant species to determine whether they provided nectar resources that could be used by *Macrocentrus grandii*, a wasp parasitoid of the European corn borer, *Ostrinia nubilalis* (Hubner). Individual wasps were caged with particular prairie species and wasp lifespan was measured. Of 11 plant species tested, 8 significantly increased *M. grandii* longevity and three had no effect. The flowers of species which did not increase longevity either produced little nectar or had very deep corolla tubes, making the nectar inaccessible to the short mouthparts of this wasp. The data suggest that plant species which have flowers with very short corolla tubes or no corolla tube (cup-shaped flowers) have the greatest potential to be of benefit to *M. grandii*. *M. grandii* has two generations in Iowa, synchronized with the two generations of *Ostrinia nubilalis*. Only plant species that bloom during these two flight periods could potentially be used by *M. grandii*. A phenology data base was compiled on all Iowa prairie plant species, based on literature sources and our monitoring of two prairie sites in central Iowa. This database also includes information on corolla depth, type of pollinator that visits the species, and whether the species is planted along roadsides. Two subsets of this database were extracted for central Iowa species, one for the first flight period and the other for the second. These data sets show what plant species could be beneficial to the wasp during the time when it is searching for prey.

Phelan, P. L., K. H. Norris and J. F. Mason (1996). "Soil-management history and host preference by *Ostrinia nubilalis*: Evidence for plant mineral balance mediating insect-plant interactions." *Environmental Entomology* 25(6): 1329-1336.

Organic-farming practitioners have long suggested that maximizing soil biotic activity results in crops of reduced susceptibility to pests. In the current study, we examined the ovipositional preference of *Ostrinia nubilalis* (Hubner), the European corn borer, on sweet corn grown in the greenhouse using soils from neighboring organic and conventional farms and fertilized with NH_4NO_3 , cow-manure compost, or left unamended. In addition to ovipositional preference, we compared photosynthetic potential, leaf-mineral profiles, and biochemical profiles measured by near-infrared (NIR) spectroscopy. Significant variation in *O. nubilalis* oviposition among fertilizer treatments was measured for plants in conventional soil, but not for those in organic soil. Photosynthetic parameters, notably net photosynthesis and stomatal conductance, correlated strongly with plant biomass accumulation, but no correlations with *O. nubilalis* preference were detected. In contrast, a quadratic model of 3 leaf-mineral levels (Zn, Al, and N) showed a strong relationship with *O. nubilalis* oviposition (adjusted $r^2 = 0.71$); plant growth was best described by a quadratic model of N alone (adjusted $r^2 = 0.69$). The greatest differences in NIR spectra were caused by protein, and soil-fertilizer combinations producing the lowest protein levels were those whose plants received the greatest number of *O. nubilalis* eggs. We suggest that differences in corn acceptability to *O. nubilalis* is at least in part mediated by plant mineral balance, which incorporates both absolute levels and ratios of minerals, and that an optimal balance of these minerals is more likely to occur in organically managed soil because of an inherent property of reducing variation in mineral availability in those soils.

Ragsdale, D. W. and C. T. Oien (1996). An environmental risk assessment for release of an exotic microsporidium for European corn borer control in North America.

The European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae), is the most destructive pest of field and sweet corn in the mid-western US. In Minnesota alone, the average annual yield loss is \$113 million. In an effort to

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establish biological control of the European corn borer, 24 exotic parasitoids have been released over the past 70 years. Only a few species have become widely established and parasitism rates are often low. In Minnesota average cumulative parasitism by the four known established exotic species was only 6.1% in a 4-year study. A microsporidium, *Nosema pyrausta* (Paillot) (Microspora: Nosematidae), is the most frequently encountered natural enemy of the European corn borer and it plays a significant role in regulating European corn borer populations in North America. An exotic microsporidium, *N. furnacalis* Wen and Sun, whose normal host is the Asian corn borer, *O. furnacalis* (Guenee), is a candidate biological control agent for the European corn borer. Using *N. furnacalis* as a classical biological control agent offers great potential for consistent, reliable control of the European corn borer. However, *N. pyrausta* and *N. furnacalis* cannot be distinguished morphologically using light microscopy. The inability to determine which microsporidian is infecting the European corn borer has curtailed interest in employing *N. furnacalis* as a classical biological control agent. We developed a species-specific immunoassay that can discriminate between *N. pyrausta* and *N. furnacalis*. Using this immunoassay has enabled the laboratory host range of *N. furnacalis* to be studied. Our data indicate that no generalist predator is a host for this exotic microsporidium. However, the European corn borer parasitoid, *Macrocentrus grandii* Goidanich, can be infected with *N. furnacalis*. The fact that *N. furnacalis* infects *M. grandii* is not surprising. Many lepidopteran-infecting *Nosema* spp. are known to infect parasitoids. Further study is needed to determine the extent to which *M. grandii* and other corn borer parasitoids are affected by *N. furnacalis*. Once these data are available a decision whether or not to release *N. furnacalis* over a wide geographic area can be made.

Ridgway, R. L., V. L. Illum, R. R. Farrar, D. D. Calvin, S. J. Fleischer and M. N. Inscoc (1996). "Granular matrix formulation of *Bacillus thuringiensis* for control of the European corn borer (Lepidoptera: Pyralidae)." *Journal of Economic Entomology* 89(5): 1088-1094.

A low-cost, granular matrix formulation of *Bacillus thuringiensis* Berliner var. *kurstaki*, composed primarily of corn flour and containing a feeding stimulant composed of cottonseed flour and sugars, was developed for use against the European corn borer, *Ostrinia nubilalis* (Hubner), on whorl-stage corn. Laboratory experiments indicated that a corn flour agricultural commodity product was a suitable carrier, that the feeding stimulant enhanced the activity of *B. thuringiensis*, and that the granular matrix protected *B. thuringiensis* from photodegradation. Results of a greenhouse test showed higher mortality of the European corn borer on corn plants treated with the granular matrix than on plants treated with a standard commercial granular formulation of *B. thuringiensis*. Mortality with either treatment was increased by application of simulated rainfall. In a field test, the granular matrix applied at a rate of 5.5 kg/ha gave control comparable with that achieved by the commercial standard applied at a rate of 11 kg/ha. Results indicated that increased efficacy or reduction in costs of management of the European corn borer with *B. thuringiensis* should be possible through the use of the granular matrix formulation.

Schaafsma, A. W., F. Meloche and R. E. Pitblado (1996). "Effect of mowing corn stalks and tillage on overwintering mortality of European corn borer (Lepidoptera: Pyralidae) in field corn." *Journal of Economic Entomology* 89(6): 1587-1592.

Studies were conducted to determine the distribution of overwintering larvae of the European corn borer, *Ostrinia nubilalis* (Hubner), in corn stalks, and to examine the effect of primary tillage and flail mowing of corn stalks on mortality of the overwintering population. Approximately 78% of the overwintering population was found in corn stalks within 30 cm of the soil surface, and 25% within 7.5 cm. Most larvae found in stalks below the mower blades survived mowing. About 75% of the larvae in the stalks >7.5 cm were killed by the flail mower. Mowing corn stalks after corn harvest reduced overwintering populations of European corn borer up to 85%. Primary tillage such as moldboard plowing or chisel plowing in the fall reduced overwintering populations. Mowing corn stalks combined with primary tillage improved mortality. The highest mortality was achieved by mowing corn stalks after harvest followed by moldboard plowing in the fall or chisel plowing in the spring. Mowing the stalks close to the ground (within 3 cm) resulted in the greatest benefit. Moldboard plowing alone in the fall resulted in mortality of between 29 and 80% depending on whether plow slices were left standing or flipped over. Mowing before moldboard plowing added up to 10% mortality. Chisel plowing in the fall resulted in mortality of up to 75%, whereas mowing before fall chisel plowing added up to 13% mortality. However, if mowing in the fall preceded chisel plowing in the spring, >95% mortality was achieved.

Zhu, J. W., C. Lofstedt and B. O. Bengtsson (1996). "Genetic variation in the strongly canalized sex pheromone communication system of the European corn borer, *Ostrinia nubilalis* Hubner (Lepidoptera; Pyralidae)." *Genetics* 144(2): 757-766.

The major difference in pheromone production between the so-called E and Z strains of the European corn borer *Ostrinia nubilalis* is controlled by two alleles at a single autosomal locus. E-strain females produce an (E)-11-tetradecenyl acetate pheromone with 1-3% of the Z isomer, whereas Z-strain females produce the opposite blend. In laboratory-reared insects we found that F-1 females produced, on average, a 71:29 E/Z ratio, but the distribution was clearly bimodal. The variability in pheromone blend produced by heterozygous females could be explained by the existence of two different alleles in the Z strain which in combination with the E-strain allele for the major production locus cause the production of a component mixture either high or low in the E isomer. In addition, evidence was found for an independently inherited factor, existing in the E strain, with a dominant effect on the amount of E isomer produced by females homozygous for Z-alleles at the major production locus. Thus, the low variability normally found in the pheromone mixture produced by *O. nubilalis* and other moth females may, by canalization, hide a considerable amount of underlying genetic variation.

Zhu, J. W., C. H. Zhao, F. Lu, M. Bengtsson and C. Lofstedt (1996). "Reductase specificity and the ratio regulation of E/Z isomers in pheromone biosynthesis of the European corn borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae)." *Insect Biochemistry and Molecular Biology* 26(2): 171-176.

Species specificity of moth sex pheromones is in many cases achieved by means of specific blends rather than by specific components. Two pheromone strains of the European corn borer, *Ostrinia nubilalis*, use (E)- and (Z)-11-tetradecenyl acetate in different ratios as their pheromone, but show the same ratio of the pheromone precursors (70:30 E/Z-11-tetradecenoic acid). The hypothesis that the ratio of the pheromone components in the two strains and their hybrids is controlled by the specificity of the reductase system, responsible for conversion of acid to the corresponding alcohol precursors, was tested. Deuterium-labeled alcohols, aldehydes and fatty acids corresponding to the two pheromone components were topically applied to the pheromone glands in different ratios and their selective incorporation into pheromone components was determined by gas chromatography with mass selective detection. Acetylation of the (E)- and (Z)-11-tetradecenols was unselective, whereas the corresponding aldehydes and acids were selectively incorporated into the pheromone components. Z strain females selectively metabolized the Z-isomers whereas E strain females converted the E-isomers. The E strain being the most selective of the two strains, Hybrids converted both geometric isomers. The relative conversion rate of both E- and Z-isomers of all tetradecenoic acids with the double bond in positions from 7-12, was also determined. In addition to the Delta 11-isomers, the E strain females converted (E)-8-tetradecenoic acid into acetate and the Z strain females converted (E)-12-tetradecenoic acid. None of these substrates occur naturally in the pheromone gland, but (E)-12-tetradecenyl acetate is a pheromone component of the Asian corn borer *O. furnacalis*. Thus the possibility for conversion of (E)-12-tetradecenoic acid to acetate in the Z strain, as well as the earlier reported conversion of (Z)-11-tetradecenoic acid to acetate in *O. furnacalis*, suggests that *O. furnacalis* is closest related to the Z strain of *O. nubilalis*.

Abel, C. A., R. L. Wilson and J. C. Robbins (1995). "EVALUATION OF PERUVIAN MAIZE FOR RESISTANCE TO EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) LEAF FEEDING AND OVIPOSITIONAL PREFERENCE." *Journal of Economic Entomology* 88(4): 1044-1048.

Partial control of the European corn borer, *Ostrinia nubilalis* (Hubner), in maize, *Zea mays* L., has been achieved through germplasm resistant to leaf feeding that was incorporated into breeding populations. Leaf-feeding resistance to European corn borer in maize had generally been attributed to presence of the chemical 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA). New sources of resistance, other than that mediated by DIMBOA, are desirable for developing new resistant cultivars. From 1990 to 1992, 1,601 accessions of Peruvian maize maintained in the U.S. National Plant Germplasm System were evaluated for leaf-feeding resistance to European corn borer. Eleven resistant accessions were identified, all of which originated from Peru's north coast. The 11 resistant accessions were then analyzed for 6-methoxybenzoxazolinone (MBOA), the degradation product of DIMBOA and an indicator of DIMBOA levels present in the plant. All 11 resistant accessions contained low MBOA concentrations, equivalent to that found in the susceptible inbred WF9, indicating that DIMBOA is not the basis of this resistance. The factor(s) underlying this source of host plant resistance remains to be determined. Six morphologically diverse Peruvian maize races were

evaluated in the greenhouse for ovipositional nonpreference by the European corn borer. Some differences were noted, but morphological factors could not be confirmed as causing the differences.

Andow, D. A., G. C. Klacan, D. Bach and T. C. Leahy (1995). "LIMITATIONS OF TRICHOGRAMMA-NUBILALE (HYMENOPTERA, TRICHOGRAMMATIDAE) AS AN INUNDATIVE BIOLOGICAL-CONTROL OF OSTRINIA-NUBILALIS (LEPIDOPTERA, CRAMBIDAE)." *Environmental Entomology* 24(5): 1352-1357.

Previous work indicated that *Trichogramma nubilale* Ertle & Davis could potentially be used as an inundative biological control of *Ostrinia nubilalis* in sweet corn, *Zea mays* L., in Minnesota. We expand on these observations to evaluate some of the factors that might limit the utility of 2 nubilale in sweet corn and report on releases in green snap bean, *Phaseolus vulgaris* L. We conducted 3 releases in sweet corn and 2 releases in beans at LeSueur, MN, from 1990 to 1992. Between 11.8 and 60.0 females per square meter of plant surface were released. Two-day egg parasitism varied between 2 and 60% in corn and 15 and 60% in beans. A meta-analysis of these results and several published experimental releases indicated that the major limitation in using *T. nubilale* is high variability in the relation between release rates and egg mass parasitism rates. This analysis also indicated that the relation between egg mass parasitism and larval population reduction was very strong, and that there was no evidence of density-dependent larval mortality. Thus, future work should focus on elucidating the factors causing variability in parasitism rates to improve the reliability of *T. nubilale*.

Armstrong, C. L., G. B. Parker, J. C. Pershing, S. M. Brown, P. R. Sanders, D. R. Duncan, T. Stone, D. A. Dean, D. L. Deboer, J. Hart, A. R. Howe, F. M. Morrish, M. E. Pajeau, W. L. Petersen, B. J. Reich, R. Rodriguez, C. G. Santino, S. J. Sate, W. Schuler, S. R. Sims, S. Stehling, L. J. Tarochione and M. E. Fromm (1995). "FIELD-EVALUATION OF EUROPEAN CORN-BORER CONTROL IN PROGENY OF 173 TRANSGENIC CORN EVENTS EXPRESSING AN INSECTICIDAL PROTEIN FROM BACILLUS-THURINGIENSIS." *Crop Science* 35(2): 550-557.

The European corn borer [ECB; *Ostrinia nubilalis* (Hubner)] is an economically significant pest of corn (*Zea mays* L.). The ability to routinely transform corn has broadened the control options available to include the introduction of resistance genes from sexually incompatible species. In this study, microprojectile bombardment was used to introduce synthetic versions of cryIA insecticidal protein genes from *Bacillus thuringiensis* subsp. *kurstaki* (Btk) into embryogenic tissue of the Hi-II (A188/B73 derivative) genotype of corn. Of 715 independent transgenic calli produced, 314 (44%) had insecticidal activity against tobacco hornworm (*Manduca sexta* L.) larvae. Plants were regenerated, self-pollinated when possible, and crossed to B73. First-generation progeny of 173 independent Btk-protein expressing calli were evaluated under field conditions with artificial ECB infestations in 1992 or 1993. Approximately half (89/173) segregated in a single-gene manner for resistance to first-generation ECB leaf-feeding damage. All of the 89 lines evaluated in 1992 or 1993 for resistance to second-generation ECB exhibited less stalk tunneling damage than the non-transgenic controls. In 1993, 44% (34/77) of the lines tested had less than or equal to 2.5 cm of tunneling, compared to severe damage (mean = 45.7 cm) in the B73 X Hi-II controls. Experiments are in progress to evaluate the effect of the introduced genes on yield and other agronomic properties.

Bartels, D. W. and W. D. Hutchison (1995). "ON-FARM EFFICACY OF AERIALY APPLIED BACILLUS-THURINGIENSIS FOR EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) AND CORN-EARWORM (LEPIDOPTERA, NOCTUIDAE) CONTROL IN SWEET CORN." *Journal of Economic Entomology* 88(2): 380-386.

Aerial applications of *Bacillus thuringiensis* subsp. *kurstaki* and tank-mixes with synthetic insecticides were evaluated for control of *Ostrinia nubilalis* (Hubner) and *Helicoverpa zea* (Boddie) in Minnesota sweet corn during 1990-1992. In addition to natural infestations, sweet corn was manually infested with first-instar *O. nubilalis* to investigate optimum timing of applications relative to larval hatch. Efficacy of *B. thuringiensis* was significantly enhanced when applied 2 d before larval hatch, compared with 2 d after hatch. Treatments with low-rate permethrin + *B. thuringiensis* or full-rate permethrin followed by *B. thuringiensis* provided control of *O. nubilalis* equal to full rates of permethrin or micro-encapsulated methyl parathion. Of the *B. thuringiensis* treatments, only the tank-mix of low-rate permethrin + Dipel ES significantly reduced *H. lea* larval infestations and yielded more marketable ears than the untreated check. Based on active ingredient per hectare, low-rate permethrin + *B. thuringiensis* reduced synthetic insecticide use 66%, compared with full-rate permethrin, or 92% compared with full-rate methyl parathion. Using a four-application program, permethrin followed by three *B. thuringiensis* applications reduced synthetic insecticide use 75% compared with full-

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rate permethrin, or 94% compared with full-rate methyl parathion. Disadvantages of the use of *B. thuringiensis* for late-season insect management in sweet corn include application timing, incidence of *H. zea*, and potential for increased risk of larval contaminants in marketable product.

Bartels, D. W., W. D. Hutchison, V. A. Fritz and G. R. Klacan (1995). "Effect of *Bacillus thuringiensis* application interval on European corn borer (Lepidoptera: Pyralidae) control in sweet corn." *Journal of Entomological Science* 30(3): 374-389.

Ground-applied treatments of two commercial *Bacillus thuringiensis* subsp. *kurstaki* formulations (MVP and Dipel ES) and tank mixes with a pyrethroid (Ambush 2E) were evaluated for control of European corn borer, *Ostrinia nubilalis* (Hubner), larvae in sweet corn. Treatments were applied at average intervals of 3.4, 5, 7, and 10 days to determine field persistence. Manual infestations of first-instar *O. nubilalis* were used to augment natural populations. During both years, there were no significant interactions between application interval and treatment for all dependent variables tested, including late instars per ear, percent marketability, yield, and predator density. Regardless of application interval, MVP provided greater larval control than Dipel ES. However, the decline in efficacy of the encapsulated MVP formulation occurred at the same rate as that of the nonencapsulated Dipel ES formulation over the 3.4 to 10-d intervals. Tank-mixes of *B. thuringiensis* + low-rate permethrin provided no additional control compared with low-rate permethrin alone. Given the infestation levels present in this test, neither *B. thuringiensis* formulation provided control sufficient to maintain current processor standards of 5-10% infested ears at harvest.

Benyakir, D., D. Nestel, H. Benherzel, M. Grossman, H. Benyaminy and M. Chen (1995). "POSTDIAPOUSE DEVELOPMENT AND SPRING EMERGENCE OF THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS*, IN ISRAEL." *Phytoparasitica* 23(3): 205-215.

The European corn borer (ECB), *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae), is the major pest of corn (*Zea mays* L.) in Israel. We investigated the temporal patterns of pupation and emergence of various overwintering ECB populations in Israel during 1992-94. The association between Julian date (JD) or cumulative degree-days (DD) and the rates of either pupation or emergence was studied using simple linear regression models. Differences between populations in JDs required to reach 50% pupation amounted to 5%, whereas for DD differences amounted to 26%. Similarly, at 50% emergence, differences between populations were up to 3% for JD and to 12% for DD. Two different forecasting models are proposed for either pupation or emergence. Based on these models, both pupation and emergence develop over a period of 4 to 5 weeks, and they are expected to occur between the following JDs: onset of pupation, 66-70 (March 7-11); 50% pupation, 96-102 (April 6-12); onset of emergence, 85-94 (March 26-April 4); and 50% emergence, 115-121 (April 25-May 1). Pupal development required 160 DD (confidence interval [C.I.] 141-179 DD) and it is expected to take ca 16 days (C.I. 14-18 days). The simple linear regression models obtained in this study are suggested as preliminary phenological models for the temporal prediction of postdiapause pupation and emergence of ECB.

Bergvinson, D. J., R. I. Hamilton and J. T. Arnason (1995). "LEAF PROFILE OF MAIZE RESISTANCE FACTORS TO EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS*." *Journal of Chemical Ecology* 21(3): 343-354.

The feeding preference of European corn borer larvae for immature whorl tissue of maize was examined by conducting leaf bioassays and quantifying resistance factors along the length of mid-whorl leaves from the maize synthetic BS9(C4) developed by recurrent selection for resistance. Potential resistance factors that were quantified included percent foliar nitrogen, gravimetric determination of soluble metabolites and fiber, soluble phenolics and hydroxamic acids, cell-wall-bound phenolics, leaf toughness, and UV absorbance of the epidermal cell wall determined by microspectrophotometry. Larvae consumed immature tissue at a higher rate than more mature tissue outside of the whorl, despite higher levels of DIMBOA in immature tissue. Consumption rate was highly negatively correlated with epidermal cell wall absorbance and leaf toughness. Fiber content and phenolic fortification of cell walls are proposed as the major resistance components that influence European corn borer feeding preference within the resistant synthetic BS9(C4).

Bergvinson, D. J., J. S. Larsen and J. T. Arnason (1995). "EFFECT OF LIGHT ON CHANGES IN MAIZE RESISTANCE AGAINST THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (HUBNER)." *Canadian Entomologist* 127(1): 111-122.

The herbivore-resistant synthetic maize BS9 (C4) was grown in three environments, namely, greenhouse with reduced UV light, greenhouse with supplemental UV light, and outside, and leaves at the three-, five-, seven-, nine-, and 10-leaf

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stages of development were fed to the European corn borer, *Ostrinia nubilalis* (Hubner). Larvae preferred younger leaves, and leaves grown under reduced UV light, in spite of the high levels of the defence compound 2,4-dihydroxy-7-methoxy-2H-1,4 benzoxazin-3 (4H)-one (DIMBOA). The low level of feeding on leaves from plants grown outside was associated with increased toughness and increased photochemically derived phenolic dimers that cross-link hemicellulose. Tender young maize plants have a low level of cell wall phenolics and depend on a toxin (DIMBOA) for defence. In older plants, DIMBOA levels are low, leaves are tough, and resistance is largely structure-based.

Binder, B. F., J. C. Robbins and R. L. Wilson (1995). "CHEMICALLY MEDIATED OVIPOSITIONAL BEHAVIORS OF THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (LEPIDOPTERA, PYRALIDAE)." *Journal of Chemical Ecology* 21(9): 1315-1327.

The volatile plant sesquiterpenoids farnesene, nerolidol, and farnesol were tested to determine their effect on European corn borer, *Ostrinia nubilalis*, oviposition during the first six nights of the adult stage. Adult European corn borers were released into cages designed to encourage oviposition on eight glass plates randomly arranged on top of the cage: four coated with either 80 $\mu\text{g}/\text{cm}^2$ farnesene, nerolidol, or farnesol, and four coated with the solvent methylene chloride. The setup was used as a binary choice test. Farnesene was preferred by females because they deposited significantly more egg masses on plates coated with the compound. Nerolidol had no effect, Farnesol, by contrast, deterred oviposition: the number of egg masses was significantly lower on plates covered with that compound. These data show that structural modification at a single terminal functional group in these compounds affects the ovipositional behavior of European corn borer females.

Briggs, C. J. and H. C. J. Godfray (1995). "Models of intermediate complexity in insect-pathogen interactions: Population dynamics of the microsporidian pathogen, *Nosema pyrausta*, of the European corn borer, *Ostrinia nubilalis*." *Parasitology* 111: S71-S89.

Nosema pyrausta is an important microsporidian pathogen of the European corn-borer, *Ostrinia nubilalis* (Pyralidae), a major pest of corn (maize). The population dynamics of the interaction between the moth and its pathogen have been studied previously using simple models phrased as coupled differential equations, and using large simulation models containing over 150 000 coupled equations. A middle approach is adopted here and the interaction studied using an age-structured model written as a system of delay-differential equations. Although the model contains twenty four parameters, estimates for twenty of these were available in the literature. Our model provides a good qualitative match to observed within and between season dynamics and suggests which aspects of the interaction are most important in determining the nature of the system's population dynamics. More generally, we argue that in the absence of better data on insect-disease interactions in natural habitats, valuable insights can be gained by studying equivalent systems in agro-ecosystems. We also argue that models of intermediate complexity that incorporate considerable detail about the natural history of individual interactions, but which are derived from the classical models of animal ecology and epidemiology, offer the most profitable way of modelling insect-pathogen interactions in the wild.

Burgio, G. and S. Maini (1995). "CONTROL OF EUROPEAN CORN-BORER IN SWEET CORN BY *TRICHOGRAMMA-BRASSICAE* BEZD (HYM, TRICHOGRAMMATIDAE)." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 119(1): 83-87.

The biological control effectiveness of the indigenous egg parasitoid *Trichogramma brassicae* Bezd, reared continuously on *Ostrinia nubilalis* (Hb.) (ECB) eggs, was tested against ECB in sweet corn in 1991 (2 ha release plot) and 1992 (3.5 ha release plot). *T. brassicae* was reared for three-four generations on the factitious host *Ephesttia kuehniella* Zell. and then released on the crop; a 0.5 ha plot situated at 300-400m from the test plots was used as control in both years. Four releases, each totalling 250-300 000 individuals, were made the first year and three at the same rate per ha the second. ECB adult emergence was monitored using traps baited with sex pheromone and phenylacetaldehyde food attractant. The parasitoid activity was monitored via sentinel egg masses following each release. The parasitization rates of the sentinel egg masses was always higher in the release plot vs, control. The parasitization of natural egg masses sampled in both years before harvest was: 12.5 and 10.86% in control as against 87.5 and 68.58% in *T. brassicae* plots in the respective years. ECB damage was calculated on crop ear samples. The rate (%) of sentinel egg mass predation by wild predators showed no significant difference between control and release plots for both years. The low level of ECB damage to crop ears evinced the good search capacity, parasitization and control effectiveness of *T. brassicae*.

Cosse, A. A., M. G. Campbell, T. J. Glover, C. E. Linn, J. L. Todd, T. C. Baker and W. L. Roelofs (1995). "PHEROMONE BEHAVIORAL-RESPONSES IN UNUSUAL MALE EUROPEAN CORN-BORER HYBRID PROGENY NOT CORRELATED TO ELECTROPHYSIOLOGICAL PHENOTYPES OF THEIR PHEROMONE-SPECIFIC ANTENNAL NEURONS." *Experientia* 51(8): 809-816.

In genetic studies on the sex pheromone communication system of two races of European corn borer, which use opposite pheromone blends of the E and Z compounds, it was found that antennal olfactory cell response amplitudes to the two compounds were controlled by an autosomal factor, whereas behavioral responses to the blends were controlled by a sex-linked locus. Because of the difference in genetic controls, it was postulated that some unusual males would be produced in F-2 crosses between these two races. These unusual males would have antennal olfactory cells that respond as the Z-race males, but would respond behaviorally to the E blend. The present studies combined behavioral studies in a flight tunnel and single cell electrophysiological studies to show that these unusual males do indeed exist. These findings show that the spike amplitude of peripheral olfactory cells is not important in regulating species- or race-specific pheromone responses, as compared to some central nervous system factor assesses the spike frequencies from different pheromone-component-specific cells on the antenna. This factor seems to be essential in governing the pheromone-blend specific behavioral responses of male moths.

Dornan, A. P. and J. G. Stewart (1995). "The location of egg masses of *Ostrinia nubilalis* Lepidoptera: Pyralidae on potato plants." *Phytoprotection* 76(3): 123-126.

The location of egg masses of the European corn borer, *Ostrinia nubilalis*, was studied on potatoes (*Solanum tuberosum*) 'Russet Burbank' grown on Prince Edward Island, Canada, from 1990 to 1992. The within-plant positions of 315 egg masses were characterized by the examination of approximately 3700 plants. Ninety-two percent of the egg masses were found on the bottom two-thirds of the plants and 95% were found on the underside of the leaflets and on the stalks. In total, 88% of the egg masses were found on the bottom two-thirds of the plants on both the stalks and the underside of the leaflets. Sampling time can be optimized if the people engaged in scouting programs concentrate their efforts on the bottom two-thirds of the stalks alone, which represents only 3.7% of the total surface area of the haulm but contains 50% of the egg masses.

Dornan, A. P. and J. G. Stewart (1995). "POPULATION-DYNAMICS OF THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (HUBNER)(LEPIDOPTERA, PYRALIDAE) ATTACKING POTATOES IN PRINCE-EDWARD-ISLAND." *Canadian Entomologist* 127(2): 255-262.

The population dynamics of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae), were documented on potatoes grown in Prince Edward Island (P.E.I.) from 1990 to 1992. By comparing degree-day accumulations above 10 degrees C, both first occurrence and peak flights of male adults occurred earlier than elsewhere in North America. Because potatoes in P.E.I. are attacked earlier and over a longer period of time than potatoes grown in other regions, the insect is an important pest of potatoes in P.E.I. The correlation between peak numbers of male adults caught in pheromone traps and egg masses on potato plants was not significant ($p = 0.22$). However, the correlation between egg masses per potato stalk and larvae per potato stalk was significant ($p = 0.003$). Trapping adults and monitoring potato plants for the presence of egg masses during the period from 250 to 500 degree-days appears to be a reliable way to determine the presence of adults and the potential impact of larvae on yield of potatoes.

Durant, J. A., H. W. Fescemyer, C. E. Mason and S. Udayagiri (1995). "EFFECTIVENESS OF 4 BLENDS OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) SEX-PHEROMONE ISOMERS AT 3 LOCATIONS IN SOUTH-CAROLINA." *Journal of Agricultural Entomology* 12(4): 241-253.

A field study was conducted at Florence, Newberry, and Clemson, South Carolina, to determine the relative attractiveness of four isomeric blends of 11-tetradecenyl acetate to male moths of the European corn borer (ECB), *Ostrinia nubilalis* (Hubner). The E and Z isomers were formulated in E:Z ratios of 99:1, 97:3, 65:35, and 3:97. Trap capture data indicated that the E pheromone strain of the ECB was predominant at Florence and the Z strain was predominant at Clemson. Both strains appeared to occur sympatrically at Newberry. Pheromone analysis of 46 ECB female moths at Florence indicated that 43 were the E strain and 3 were hybrids. The 99E:1Z pheromone blend captured over four times as many male moths as the 97E:3Z blend at Florence. The 65E:35Z blend captured 5%, 11%, and 12% of the moths at Florence, Newberry, and Clemson, respectively, indicating the possible presence of hybrid moths. The superior

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performance of the 99E:1Z blend of 11-tetradecenyl acetate should enhance the development of a more effective lure for the E strain of the ECB.

Gelman, D. B. and R. A. Bell (1995). "LOW-MOLECULAR-WEIGHT ECDYSIOTROPINS IN THE HEMOLYMPH OF 5TH INSTARS OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE), AND THE GYPSY-MOTH, LYMANTRIA-DISPAR (LEPIDOPTERA, LYMANTRIIDAE)." *European Journal of Entomology* 92(1): 131-141.

Fluctuations of low molecular weight (500-1,500 daltons) ecdysiotropin titers in the hemolymph of the European corn borer, *Ostrinia nubilalis*, and of the gypsy moth, *Lymantria dispar*, were measured. For hemolymph from nondiapauser-bound European corn borer 5th instars, dose/response curves suggest that there exist at least two ecdysiotropins capable of stimulating prothoracic glands to produce ecdysteroid, one (ECTR I) with maximum activity at 0.5 μ l hemolymph/25 μ l drop of incubation medium and one (ECTR II) with maximum activity at 4 μ l hemolymph/25 μ l drop of incubation medium. ECTR I was detected on days 2, 3 and 4 of the 5th instar while ECTR II was detected throughout the 5th instar and also in the hemolymph of pharate pupae and day-1 pupae. Hemolymph of diapauser-bound 5th instars also possessed ecdysiotropic activity. Considerably more ecdysiotropin was detected on days 1 through 5 of these diapauser-bound 5th instars than on days 7 through 24. Dose/response curves for hemolymph from fifth instar *L. dispar* also suggest that there are at least two ecdysiotropins present. Extracts of hindguts (proctodaea) of *O. nubilalis* and of *L. dispar* have been reported to contain low molecular weight ecdysiotropins that stimulate the *in vitro* production of ecdysteroid by prothoracic glands. It is possible that the source of one or both of the newly discovered hemolymph ecdysiotropins is the proctodaeum.

Gelman, D. B., R. A. Bell, A. B. Demilo and J. P. Kochansky (1995). "EFFECT OF KK-42 ON GROWTH, DEVELOPMENT, MOLTING, AND METAMORPHOSIS OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS (HUBNER)." *Archives of Insect Biochemistry and Physiology* 28(1): 1-15.

KK-42 (1-benzyl-5-[(E)-2,6-dimethyl-1,5-heptadienyl]imidazole), administered by feeding, delayed the growth and development of nondiapauser-bound and diapauser-bound *Ostrinia nubilalis* larvae and increased the length of the instar. At doses of 80-240 ppm, 62-100% of nondiapauser-bound fourth instars precociously pupated or remained as fourth instars, while 52-100% of diapauser-bound fourth instars did not molt to the fifth instar. Injection of these nondiapauser- and diapauser-bound KK-42-fed fourth instars with ecdysone elicited a molt and resulted in the production of larval-pupal intermediates. When mature fourth instar controls were similarly injected, they molted into normal fifth instars. These results support the view that KK-42 delays/inhibits ecdysteroid production. Both eupyrene and apyrene spermiogenesis were prematurely initiated in nondiapauser-bound fourth instars that were fed on medium containing 160 ppm KK-42. Fenoxycarb, a potent juvenile hormone mimic, rescued nondiapauser-bound fourth instars from precocious pupation. All fenoxycarbtreated larvae either molted to the fifth instar or remained as fourth instars and eventually died. These results support the view that treatment with KK-42 inhibits JH production. When KK-42 treatment was begun in the third instar a considerable number of nondiapauser-bound and some diapauser-bound third instars precociously molted to the fifth instar. There was a correlation between weight and the incidence of precocious molting in that third instars destined to skip the fourth instar attained a weight, as pharate fifth instars, of two to three times more than pharate fourth instar controls. Similarly, fourth instars that were destined to undergo precocious pupation attained a weight, as pharate pupae, that was approximately two times more than pharate fifth instar controls. More potent analogues of KK-42 may prove useful in controlling populations of *O. nubilalis* by interfering with their growth, development, and metamorphosis. (C) 1995 Wiley-Liss, Inc.

Hoard, M. W. and M. J. Weiss (1995). "INFLUENCE OF POSTDIAPAUSE DEVELOPMENT ON THE VOLTINISM OF THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) IN NORTH-DAKOTA." *Environmental Entomology* 24(3): 564-570.

The postdiapauser developmental rates of the European corn borer, *Ostrinia nubilalis* (Hubner), were investigated using collections of larvae from several selected sites in North Dakota from 1990 to 1992. Significant differences in days to pupation for postdiapausing larvae were found between different geographic locations, and between bivoltine and univoltine populations of the European corn borer in North Dakota. The differences in the time required for postdiapauser development is believed to be the major contributing factor responsible for voltinism of the European corn borer population in North Dakota. Larvae from most of the sites had some degree of similarity to the bivoltine population, as measured by the proportion of the larvae pupating at less than or equal to 220 DD. Retention of the

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bivoltine trait allows a mechanism for the expression of a second generation in populations that had been considered univoltine. Retention of the bivoltine trait supports the importance of local adaptations in determining the voltinism of European corn borer populations in the northern Great Plains.

Hoffmam, M. P., D. L. Walker and A. M. Shelton (1995). "Biology of *Trichogramma ostriniae* (Hym.: Trichogrammatidae) reared on *Ostrinia nubilalis* (Lep.: Pyralidae) and survey for additional hosts." *Entomophaga* 40(3-4): 387-402.

Trichogramma ostriniae has been identified as a candidate for biological control of *Ostrinia nubilalis*. As little was known about the biology of this parasitoid when reared on *O. nubilalis*, we undertook experiments to quantify biological parameters important to mass-rearing and use of *T. ostriniae*. When reared continuously on *O. nubilalis*, female *T. ostriniae* on average lived 2.7 days and produced 24 progeny. Continuous access to honey resulted in a four-fold increase in longevity and fecundity and a significant increase in the percentage of females parasitizing eggs. Rates of fecundity and parasitism decreased with age of female. Likewise, emergence rates and percentage of female progeny decreased with age of parental female. *T. ostriniae* successfully parasitized *O. nubilalis* eggs until the blackhead stage. Most parasitism of eggs and eclosion of adults occurred during the first half of photophase. Eggs of 13 Lepidoptera were parasitized by *T. ostriniae*. Eggs of the Noctuidae, Pyralidae, and Plutellidae experienced higher levels of parasitism than others tested. *T. ostriniae* appears to be similar to other species of *Trichogramma* in several respects and does not possess any characteristics that limit its potential for mass rearing and use for augmentative biological control of *O. nubilalis*.

Houseman, J. G. and P. S. Chin (1995). "DISTRIBUTION OF DIGESTIVE PROTEINASES IN THE ALIMENTARY-TRACT OF THE EUROPEAN CORN-BORER *OSTRINIA-NUBILALIS* (LEPIDOPTERA, PYRALIDAE)." *Archives of Insect Biochemistry and Physiology* 28(2): 103-111.

The distribution of digestive proteinases in either the anterior and posterior midgut or between the midgut epithelium and ectoperitrophic and endoperitrophic spaces in the midgut were examined in the European corn borer, *Ostrinia nubilalis*. Trypsin, chymotrypsin, elastase, and aminopeptidase activities were the same in the anterior and posterior halves of the midgut. Of the total aminopeptidase activity, 95% was located in the midgut epithelium, and 90% of the trypsin, 97% of chymotrypsin, and 93% of the elastase activity were found in the midgut lumen. Trypsin, measured by hydrolysis of benzoyl-L-arginine ethyl ester, and chymotrypsin levels were significantly higher in the ectoperitrophic space compared to the endoperitrophic space. Digestion in the midgut is proposed to be sequential with tryptic digestion occurring in the endoperitrophic space. Ingested protein is digested further in the ectoperitrophic space by the action of elastase, chymotrypsin, and a second trypsin. Final digestion occurs by an intracellular aminopeptidase. (C) 1995 Wiley-Liss, Inc.

Joyce, M. S. and D. W. Davis (1995). "TRANSMITTIBILITY OF EAR RESISTANCE TO EUROPEAN CORN-BORER IN SWEET CORN TESTCROSSES AND RESISTANCE STABILITY." *Journal of the American Society for Horticultural Science* 120(1): 107-111.

Concern over insecticide usage for control of European corn borer (*Ostrinia nubilalis* Hubner) in sweet corn (*Zea mays* L.) in recent years has increased the need for genetic control. Our objectives were to determine the degree of ear feeding resistance transmitted by resistant breeding lines to testcrosses and to investigate the-relationship between resistance and both ear silk channel length, and infestation level. Testcrosses averaged 35% acceptable ears compared to 7% for two commercial control hybrids and 45% for the lines *pei se* when artificially infested at the ear tip at mid-silk at two locations. Generally, resistance in the testcrosses was closer to the resistance level of the resistant parent, indicating good combining ability for resistance. Heterosis above the resistant parent was found in 8 of 12 testcrosses. Across entries, ears having relatively longer silk channel length tended to have less damage but the relationship was not strong ($r(2) = 0.24$, $P < 0.01$). When silk channels were artificially shortened at infestation, resistance levels were lower, but five of seven lines had a higher proportion of acceptable ears than did the control hybrid. Across increasing levels of infestation from 50 to 200 neonate larvae per ear eight of nine lines had higher resistance ($P < 0.05$) than the control.

Losey, E., S. J. Fleischer, D. D. Calvin, C. L. Harkness and T. Leahy (1995). "EVALUATION OF TRICHOGRAMMA-NUBILALIS AND BACILLUS-THURINGIENSIS IN MANAGEMENT OF OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE) IN SWEET CORN." *Environmental Entomology* 24(2): 436-445.

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A biological control program for European corn borer, *Ostrinia nubilalis* (Hubner), using *Trichogramma nubilalis* Ertle & Davis and *Bacillus thuringiensis* var. *kurstaki* was tested in plots of sweet corn 1990 and 1991. *Trichogramma* were released during the egg mass recruitment period of *O. nubilalis* to bracket the peak egg mass deposition period. One or two *B. thuringiensis* applications were targeted against host larvae that escaped *T. nubilalis* parasitism in the egg stage. The European corn borer phenology model adequately predicted the timing and shape of the adult flight and egg recruitment periods in 1990 and 1991. The released *Trichogramma* parasitized 70 and 56% of the European corn borer eggs in 1990 and 1991, respectively. In both years, <20% of the host eggs hatched in the *Trichogramma* release plots, compared with 38-56% in the control plots. Total mortality of European corn borer from egg deposition to sweet corn harvest was 94 and 92% in 1990 and 1991, respectively. The stage structure of the European corn borer population at sweet corn harvest in 1991 did not differ between the *Trichogramma* release and no release plots. The proportion of sweet corn ears free of European corn borer larvae varied with position of the plots relative to nearby sudangrass, and ranged between 0.7 and 0.9 in the release plots, compared with 0.6-0.65 in control plots in 1990 and 1991, respectively.

Ma, P. W. K. and W. L. Roelofs (1995). "ANATOMY OF THE NEUROSECRETORY-CELLS IN THE CEREBRAL AND SUBESOPHAGEAL GANGLIA OF THE FEMALE EUROPEAN CORN-BORER MOTH, *OSTRINIA-NUBILALIS* (HUBNER) (LEPIDOPTERA, PYRALIDAE)." *International Journal of Insect Morphology & Embryology* 24(3): 343-359.

The anatomy of the neurosecretory cells in the brain-subesophageal ganglion complex of female European corn borer moth *Ostrinia nubilalis* (Lepidoptera: Pyralidae) was studied using histological and cobalt backfilling techniques. Histological staining revealed the presence of 2 median and one lateral neurosecretory cell groups in the brain. These brain neurosecretory cells are made up of mainly type A cells with a few type B cells in the median group. Three type C neurosecretory cell clusters occupy the apparent mandibular, maxillary, and labial neuromeres at the ventral median aspect of the subesophageal ganglion. Axonal pathways of the neurosecretory cell groups were delineated by retrograde cobalt filling from the corpora cardiaca. Fibers of the 3 brain neurosecretory cell groups merged to form a distinct axonal tract that exits the brain via the fused *nervi corporis cardiaci-1+2*. Cobalt backfilling from the corpora cardiaca filled 4 groups of cell bodies in the subesophageal ganglion. The presence in the subesophageal ganglion of extensive dendritic arborizations derived from the brain suggests interactions between neurosecretory cell groups in the 2 head ganglia.

Ma, P. W. K. and W. L. Roelofs (1995). "CALCIUM INVOLVEMENT IN THE STIMULATION OF SEX-PHEROMONE PRODUCTION BY PBAN IN THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (LEPIDOPTERA, PYRALIDAE)." *Insect Biochemistry and Molecular Biology* 25(4): 467-473.

An in vitro assay was used to study the stimulation of sex pheromone production by pheromone biosynthesis activating neuropeptide (PBAN) in female European corn borer (ECB), *Ostrinia nubilalis*. Synthetic Bom-PBAN was active at 0.25 nM and maximally stimulated in vitro pheromone production at 2.5 nM. With 2.5 nM Bom-PBAN, maximum pheromone production was reached within 90 min of incubation. The calcium ionophore, A23187, stimulated pheromone production independent of PBAN. Both Bom-PBAN-stimulated and ionophore-stimulated pheromone production are dependent on the presence of calcium in the incubation medium. A calcium-free incubation medium and a medium with calcium replaced by 5 mM magnesium did not support Bom-PBAN-stimulated and ionophore-stimulated pheromone production. Furthermore, a potent calcium blocker, lanthanum, inhibits Bom-PBAN stimulated pheromone production at 0.5 mM. These results suggest that the activation of sex pheromone production by PBAN in ECB is mediated, in part, by calcium ion.

Ma, P. W. K. and W. L. Roelofs (1995). "SITES OF SYNTHESIS AND RELEASE OF PBAN-LIKE FACTOR IN THE FEMALE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS*." *Journal of Insect Physiology* 41(4): 339-350.

Sex-pheromone production in female European corn borer moths, *Ostrinia nubilalis*, is regulated by PBAN(pheromone biosynthesis activating neuropeptide)-like factors, Using a decapitated-moth bioassay, three discrete sets of neurosecretory cells were identified in the subesophageal ganglion of female *O. nubilalis* that contained PBAN-like biological activity. Immunocytochemical studies with a polyclonal antiserum raised against a synthetic-truncated Hez-PBAN revealed the presence of PBAN-like immunoreactivity throughout the entire ventral nervous system. The corpora cardiaca also exhibited PBAN-like biological activity and immunoreactivity. Corpora cardiacectomized-allatectomized females produced significantly less pheromone than sham-operated females, Cobalt anterograde/retrograde filling

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studies did not show direct neural connections between the terminal abdominal ganglion and the sex-pheromone gland. Transection of the ventral nerve cord did not impair pheromone production. Removal of the entire abdominal ventral nerve cord did not affect the response of the operated females to exogenous PBAN. Results of the present investigation show that PBAN-like factors in female *O. nubilalis* moth are synthesized in three sets of neurosecretory cells in the subesophageal ganglion, and that release of these factors from the corpora cardiaca plays a more important role in pheromone production than does the ventral nerve cord.

Mertz, B. P., S. J. Fleischer, D. D. Calvin and R. L. Ridgway (1995). "FIELD ASSESSMENT OF TRICHOGRAMMA-BRASSICAE (HYMENOPTERA, TRICHOGRAMMATIDAE) AND BACILLUS-THURINGIENSIS FOR CONTROL OF OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE) IN SWEET CORN." *Journal of Economic Entomology* 88(6): 1616-1625.

Field studies conducted in 1992 and 1993 tested the efficacy of using commercially available *Trichogramma brassicae* Bezdenko and *Bacillus thuringiensis* to control *Ostrinia nubilalis* (Hubner) in sweet corn. Shipped *T. brassicae* displayed good biotic fitness (emergence rates, sex ratios, longevity, and fecundity) in 1992 and 1993, but release rates and emergence profiles of the parasitoids differed in the 2 yr. In 1992, a total of 429,120 female parasitoids per hectare was released over 10 release dates. In 1993, a total of 163,680 female parasitoids per hectare was released over 10 release dates. Parasitoids dramatically affected the fate of *O. nubilalis* egg masses in both 1992 and 1993. *O. nubilalis* egg mass survival decreased by at least 45% in *T. brassicae* plots in both years. When all insect damage was considered, field releases of *T. brassicae* significantly improved ear quality in 1993 and in plots augmented with *O. nubilalis* egg masses in 1992. When an effect caused by *T. brassicae* was observed, the increase in percentage clear ears ranged from 9 to 17%. There was no significant interaction between *B. thuringiensis* and *T. brassicae* treatments in 1992 and 1993. *B. thuringiensis* treatments alone had a significant impact on ear quality only when high *O. nubilalis* populations were present in 1992. The integration of *B. thuringiensis* and *T. brassicae* did not result in additional insect control.

Phelan, P. L., J. F. Mason and B. R. Stinner (1995). "Soil-fertility management and host preference by European corn borer, *Ostrinia nubilalis* (Hubner), on *Zea mays* L: A comparison of organic and conventional chemical farming." *Agriculture Ecosystems & Environment* 56(1): 1-8.

It has long been argued by proponents of organic agriculture that crop losses to insects and diseases are reduced by this farming method, and that reduced susceptibility to pests is a reflection of differences in plant health, as mediated by soil-fertility management. These reports although widespread are mostly anecdotal and largely without experimental foundation. In this study, the effects of two parameters of soil fertility on the host-preference behavior of an insect pest were measured: (1) the immediate effect of organic vs. inorganic fertilizers and (2) the long-term effect of soil-management history. Soils were collected from three pairs of neighbouring farms, each pair matched for soil type and comprising organic and conventional chemical production systems. Each soil was potted and amended with mineral fertilizers, animal manures, or left amended. After planting the amended soils with maize (*Zea mays* L.) in a greenhouse, European corn borer females (ECB), *Ostrinia nubilalis* (Hubner), were released to determine egg-laying preferences. For each of the three farm comparisons, there was a significantly higher level of ECB oviposition on plants in conventional soil. In two comparisons, there was also a significant amendment effect; however, the specific fertilizers leading to greater egg laying were not consistent among farm comparisons. Thus, the form of the fertilizer did not have consistent effects on maize susceptibility to ECB, but soil-management history did. Moreover, there was significant variation in egg laying among fertilizer treatments within the conventionally managed soil, but for plants in the organic soils, egg laying was uniformly low. Pooling results across all three comparisons, variance in egg laying was about 18 times higher among plants in conventional soil than among plants in organic soil. It is suggested that this difference is evidence for a form of biological buffering characteristic of organically managed soils. Also significant, ECB ovipositional preference did not correlate with plant biomass. Thus, these results suggest that soil-management practices can significantly affect the susceptibility of crops to pests, and do so without adversely affecting plant productivity.

Rahal, Y., M. Renou, A. Derrien and N. Hawlitzky (1995). "Reproductive characteristics of *Pseudoperichaeta nigrolineata* (Dipt., Tachinidae), parasitoid of *Ostrinia nubilalis* (Lep., Pyralidae)." *Entomophaga* 40(3-4): 329-340.

The ovolarviparous tachinid fly *Pseudoperichaeta nigrolineata* Walker is a larval parasitoid of the European corn borer, *Ostrinia nubilalis* Hubner. A study of the behaviours of gravid females and the kairomones that influence these behaviours led us to quantify several biological characteristics of these females. The females were observed from the

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moment they became gravid. They were placed in the presence of a corn-caterpillar complex that was changed three times per 24-hour period. Parasitoids lived an average of 8.5 more days. From emergence, the mean longevity was 24 days and the maximum, 39 days. The ovolarviposition period of the sample lasted a total of 12 days. However, the actual number of days of ovolarviposition per female averaged 6.9. The number of days between the end of ovolarviposition and death varies, but 69% of females laid eggs until their death. All the females ovolarviposited; some laid eggs regularly (59%) and others with interruptions (41%). Total mean ovolarviposition per female was 83 maggots, with extremes of 15 and 231 maggots. Thirty percent of the females laid eggs between 30 and 60 planidia. Variability was high for all characteristics studied. Results obtained are discussed with reference to other tachinids and the experimental conditions used.

Rinkleff, J. H., W. D. Hutchison, C. D. Campbell, P. C. Bolin and D. W. Bartels (1995). "INSECTICIDE TOXICITY IN EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) - OVICIDAL ACTIVITY AND RESIDUAL MORTALITY TO NEONATES." *Journal of Economic Entomology* 88(2): 246-253.

Field and laboratory studies were conducted using selected carbamate, organophosphate, and pyrethroid insecticides to quantify their toxicity to European corn borer, *Ostrinia nubilalis* (Hubner), eggs and residual mortality to neonates. Field studies included most insecticides currently registered for *O. nubilalis* on vegetable crops, as well as recently developed pyrethroids. Insecticides with the greatest ovicidal activity in field trials, in decreasing order, included methomyl, encapsulated methyl parathion, permethrin, thiodicarb, zeta-cypermethrin, and lambda-cyhalothrin. With the exception of methomyl, significant larval mortality was also observed for each material. Of all materials tested, only methomyl previously was assumed to have ovicidal activity on *O. nubilalis*. Laboratory bioassays were conducted to estimate the LC(50) for insecticides showing the greatest ovicidal activity in the field. Insecticides with the greatest ovicidal activity included, in decreasing order, zeta-cypermethrin, lambda-cyhalothrin, permethrin, methyl parathion, esfenvalerate, and methomyl. With the exception of methomyl, all insecticides demonstrated high levels of residual toxicity to neonates. Ovicidal activity of methomyl in the field but low inherent toxicity to eggs in the laboratory bioassay was partially explained by the use of a higher field rate relative to the pyrethroids. Results from this study will be useful for improving the timing of insecticide applications against *O. nubilalis* and necessary for refinement of an *O. nubilalis* management model.

Saleh, M. M. E., L. C. Lewis and J. J. Obyrcki (1995). "SELECTION OF NOSEMA-PYRAUSTA (MICROSPORIDIA, NOSEMATIDAE)-INFECTED OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE) EGGS FOR PARASITIZATION BY TRICHOGRAMMA-NUBILALE (HYMENOPTERA, TRICHOGRAMMATIDAE)." *Crop Protection* 14(4): 327-330.

Trichogramma nubilale Ertie and Davis females were offered a choice between egg masses of the European corn borer, *Ostrinia nubilalis* (Hubner), infected with the microsporidium *Nosema pyrausta* (Paillot) and non-infected egg masses. *Nosema pyrausta*-infected *O. nubilalis* eggs were smaller (weight) than non-infected host eggs. *Trichogramma nubilale* females did not discriminate between infected and *N. pyrausta*-free egg masses. This microsporidian infection did not significantly affect the sex ratio of emerging wasps. Significantly fewer and smaller adult parasitoids emerged from infected host eggs than from noninfected eggs.

Showers, W. B., M. J. Weiss, M. E. Derrick and W. H. Hendrix (1995). "POTENTIAL MOVEMENT ON SURFACE AIR-FLOW OF A BIVOLTINE POPULATION OF EUROPEAN CORN-BORER (PYRALIDAE, LEPIDOPTERA) INTO A HISTORICALLY UNIVOLTINE HABITAT." *Environmental Entomology* 24(4): 835-840.

Larval collections of European corn borer, *Ostrinia nubilalis* (Hubner), were made in and surrounding a seed corn nursery at Johnstown, ND, a year before and each of 3 yr during a test for hybrid resistance to this insect. Johnstown is in an area known to maintain a univoltine population of *O. nubilalis*. The 30,000 inbred corn plants tested for resistance, however, were infested each year with a bivoltine population of *O. nubilalis*. Each sample site collection was maintained as a separate population, and the 2nd laboratory-reared generation was tested for diapause frequency in growth chambers programmed to force most univoltine individuals to enter larval diapause and allow a minimum of 50% of bivoltine individuals to continue development. These results illustrate that bivoltine populations dispersed at least 32 km/yr. The results indicate further that light southerly or easterly surface winds (under 8 km/h) were the essential transport mechanisms for this dispersal. It is probable that bivoltine *O. nubilalis* have been invading the historically univoltine areas of northwestern Minnesota, North Dakota, and the Canadian prairie provinces from the south for years.

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Siegfried, B. D., P. Marcon, J. F. Witkowski, R. J. Wright and G. W. Warren (1995). "SUSCEPTIBILITY OF FIELD POPULATIONS OF THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (HUBNER) (LEPIDOPTERA, PYRALIDAE), TO *BACILLUS-THURINGIENSIS* (BERLINER)." *Journal of Agricultural Entomology* 12(4): 267-273.

Susceptibility to the CryIA(b) protein from *Bacillus thuringiensis* (Berliner) was determined for five field-collected populations and one laboratory colony of the European corn borer, *Ostrinia nubilalis* (Hubner). Field-collected larvae were reared for two generations in the laboratory, and susceptibility of neonate larvae was determined with feeding bioassays where increasing concentrations of the CryIA(b) toxin were applied to the surface of artificial diet. In general, the response to *B. thuringiensis* among the populations was similar based on the slopes of the dose mortality curves. However, significant differences in susceptibility (greater than 5 fold) based on LC(50) values were observed. Repeated and prolonged exposure to *B. thuringiensis* is not known to have occurred in the populations tested indicating that the observed tolerance was due simply to natural variability among geographically distinct populations and unrelated to selective pressures associated with insecticide exposure.

Sorenson, C. E., J. W. Vanduyne, G. C. Kennedy, J. R. Bradley, C. S. Eckel and G. C. J. Fernandez (1995). "EVALUATION OF A SEQUENTIAL EGG MASS SAMPLING SYSTEM FOR PREDICTING 2ND-GENERATION DAMAGE BY EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) IN-FIELD CORN IN NORTH-CAROLINA." *Journal of Economic Entomology* 88(5): 1316-1323.

A sequential egg mass sampling plan was developed for prediction of stalk tunneling damage by end-generation European corn borer, *Ostrinia nubilalis* (Hubner), in field corn in eastern North Carolina. The plan was based on a critical density constructed from a linear relationship between egg mass numbers and subsequent stalk tunnel numbers; the sampling unit consisted of 5 leaves on 10 consecutive plants, Decision lines were constructed using the mean crowding-mean method developed by Iwao (1975). The plan was evaluated through computer simulations and comparison with field data. Average sample number and operating characteristic curves for a range of thresholds are estimated. The expected costs and feasibility of scouting for European corn borer under various economic conditions are examined.

Tomasino, S. F., R. T. Leister, M. B. Dimock, R. M. Beach and J. L. Kelly (1995). "FIELD PERFORMANCE OF *CLAVIBACTER-XYLII* SUBSP *CYNODONTIS* EXPRESSING THE INSECTICIDAL PROTEIN GENE *CRYIA(C)* OF *BACILLUS-THURINGIENSIS* AGAINST EUROPEAN CORN-BORER IN-FIELD CORN." *Biological Control* 5(3): 442-448.

The field efficacy of the endophytic bacterium *Clavibacter xyli* subsp. *cynodontis* (Cxc) expressing the cry-IA(c) insecticidal protein gene of *Bacillus thuringiensis* (Bt) was evaluated against European corn borer (*Ostrinia nubilalis*) (ECB) in field corn during 1990 in Maryland and during 1991-1993 in Nebraska. The engineered strains, referred to as Cxc/Bt, were introduced into corn seedlings using a wound inoculation technique or into corn seed via a pressure infiltration technique. Two Cxc/Bt strains (MDR1.586, MDR1.1413) were evaluated in the pedigree LH119 x LH82. Plants were artificially infested near pollen shed with neonate ECB larvae and later dissected to determine the amount of ECB tunneling. In 1993, plots were machine-harvested to obtain yield data. Both Cxc/Bt strains significantly reduced ECB damage compared with plants colonized by wild-type Cxc and/or uncolonized control plants. In 1990, strain MDR1.586 reduced the number of tunnels by 64.0%. Field efficacy of strain MDR1.586 was further demonstrated in 1991 and 1992 as treated plants exhibited 57.1 and 65.0% fewer tunnels, respectively. Strain MDR1.1413 reduced the number of tunnels by 79.0% in 1992 and by 68.7% in 1993. Despite the significant control of ECB by strain MDR1.1413 in 1993, grain yield from Cxc/Bt-inoculated plants was not significantly different from the uninoculated control. (C) 1995 Academic Press, Inc.

Udayagiri, S. and C. E. Mason (1995). "HOST-PLANT CONSTITUENTS AS OVIPOSITION STIMULANTS FOR A GENERALIST HERBIVORE - EUROPEAN CORN-BORER." *Entomologia Experimentalis Et Applicata* 76(1): 59-65.

Oviposition response of the polyphagous European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera:Pyralidae), to chemical constituents in host plants was investigated in the laboratory using two-choice bioassays. Foliar extracts of corn (*Zea mays* L.), pepper (*Capsicum annuum* L.) and potato (*Solanum tuberosum* L.) were prepared using the solvents pentane, acetone and methanol. In all three host plants, chemicals soluble in pentane stimulated oviposition. In potato, chemicals extractable in acetone also elicited a positive oviposition response. When presented with a choice between pentane extracts of corn and pepper, females preferred corn. No preferences were exhibited between pentane extracts

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of corn and potato or pepper and potato. Pentane extracts of corn husks, tassels, silk, and corn leaves from plants at early whorl and tassel (pre-pollen shed) stages of development also stimulated oviposition. Similar extracts from plants at 2-leaf and blister (when kernels resemble blisters) stages were not stimulatory. This indicates that plant phenology affects chemically mediated oviposition response in European corn borer. The potential use of plant chemicals for management of *O. nubilalis* in the field is suggested.

Uzun, S. (1995). The natural efficiency of *Trichogramma brassicae* Bezd (Hym: Trichogrammatidae) on the eggs of *Ostrinia nubilalis* Hbn (Lep: Pyralidae) in the corn fields in Cine Aydin, Turkey. *Trichogramma and Other Egg Parasitoids*. E. Wajnberg: 207-210.

Warthen, J. D., J. A. Klun, M. Schwarz and N. Wakabayashi (1995). "Structure-activity relationship observations for European corn borer moth pheromone and fluoro analogs via computer molecular modeling." *Journal of Chemical Ecology* 21(12): 1921-1930. Structure-activity relationship (SAR) observations were made for the Z-type European corn borer moth pheromone, (Z)-11-tetradecen-1-ol acetate, and a series of analogs with fluorination in the alcohol portion of the molecule. The attractiveness of these analogs and the pheromone was compared to the electrostatic potential map of the molecular mechanics (MM) minimized lowest energy conformation for each compound. A critical range of electrostatic potential on the protons of the double-bond appears to be essential for optimal acceptor fit and attractiveness.

Welty, C. (1995). "MONITORING AND CONTROL OF EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (LEPIDOPTERA-PYRALIDAE), ON BELL PEPPERS IN OHIO." *Journal of Agricultural Entomology* 12(2-3): 145-161.

Field studies were undertaken to document pod infestation by European corn borer (*Ostrinia nubilalis*) during the harvest season, to evaluate timings of insecticide applications, and to evaluate whether monitoring populations in traps is an appropriate basis for timing insecticide applications. Over a three year period at several locations, acephate was sprayed on 5-d to 14-d schedules, and pepper pods were evaluated during periodic harvests. Damage by *O. nubilalis* was usually highest in the first two harvests, when as few as 36% of the pods were undamaged in untreated plots. Later harvests were less affected by *O. nubilalis* but were sometimes infested by fall armyworm (*Spodoptera frugiperda*) or corn earworm (*Helicoverpa zea*). In 1990, when *O. nubilalis* populations were moderate in size, fewer infested pods and higher yields were found in plots treated on a 7-d schedule than on a 14-d schedule. In 1991, when populations were exceptionally high, damage was high even in plots sprayed every 7 d. In 1992, when populations were low to moderate, damage was light and no yield advantage resulted from a variable 5- to 10-d schedule versus a 7-d schedule. A 7-d schedule was suitable in years with average *O. nubilalis* activity, starting when blacklight traps consistently caught one or more moths per night. Pheromone traps appear to be an acceptable alternative to blacklight traps, but a pheromone-based threshold has not yet been tested. Management of European corn borer on peppers in Ohio must be supplemented in the later part of the season by management of fall armyworm and corn earworm.

Wilson, R. L., C. A. Abel, B. R. Wiseman, F. M. Davis, W. P. Williams, B. D. Barry and W. H. White (1995). "EVALUATION FOR MULTIPLE PEST RESISTANCE IN EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS*, RESISTANT MAIZE ACCESSIONS FROM PERU." *Journal of the Kansas Entomological Society* 68(3): 326-331.

Eleven maize, *Zea mays* L., accessions from Peru previously found resistant to leaf feeding by first generation European corn borer (ECB1), *Ostrinia nubilalis* (Hubner), were evaluated for resistance to stalk boring by second generation European corn borer (ECB2), southwestern corn borer (SWCB), *Diatraea grandiosella* Dyar, fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), western corn rootworm (WCRW), *Diabrotica virgifera virgifera* LeConte, corn earworm (CEW), *Helicoverpa zea* (Boddie), and sugarcane borer (SCB), *Diatraea saccharalis* (Fab.). Four accessions were resistant to 2 pests in addition to ECB1: PI 503720 was resistant to WCRW and ECB2, whereas PI 503728, PI 503849, and A-10623 were resistant to CEW and ECB2. Accession PI 503720 also had intermediate resistance to CEW and SCB. Accessions PI 503728 and PI 503849 had intermediate resistance to WCRW and SCB. Accession A-10623 had intermediate resistance to CEW larval weight and days to pupation and to SCB. Multiple pest resistance in maize, such as that detected in this study, would be useful in pest management, especially in sustainable agriculture systems.

Barry, D., D. Alfaro and L. L. Darrah (1994). "RELATION OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) LEAF-FEEDING RESISTANCE AND DIMBOA CONTENT IN MAIZE." *Environmental Entomology* 23(1): 177-182.

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European corn borer, *Ostrinia nubilalis* (Hubner), is a major insect pest of maize, *Zea mays* L., in the northern Corn Belt, which affects production through physiological yield reduction and harvest losses. Four maize inbreds (two resistant [CI31A and B75] and two susceptible [C103 and CI21E]) to first-generation European corn borer along with all possible F1s [6 each] and F2s [6 each] plus the double crosses [15 each] from the F1s) were evaluated for resistance to leaf feeding by the European corn borer and 2, 4-dihydroxy-7-methoxy-1, 4-benzoxazin-3-one (DIMBOA) concentration in the leaf tissue. The two objectives of our study were: (1) to compare the traditional visual leaf feeding rating scale to a chemical analysis of the concentration of DIMBOA and (2) to determine the concentration and persistence of DIMBOA among these genotypes in relation to resistance. The leaf-feeding resistant inbreds, CI31A and B75, had initial ratings of 1.0 on a scale of 1-9 (1 highly resistant to 9, highly susceptible) and they had a concentration of DIMBOA of 704 and 433 µg/g, respectively. The susceptible inbreds, C103 and CI21E, had ratings of 7.5 and 3.8 and DIMBOA concentrations of 91 and 70 µg/g, respectively. The resistant ratings of the F1s and F2s were generally related to their parentage. The resistant genotypes had higher levels of DIMBOA and this trait was expressed in the various crosses in an additive manner indicating that DIMBOA concentration is genetically determined. The leaf feeding ratings became higher and DIMBOA concentrations lower as the plant matured. The correlation of leaf feeding rating and DIMBOA concentration was $r = -0.40$ 62 d after planting, but 10 d later it dropped to $r = -0.34$; both are significant negative correlations. No resistance was found by the time the inbreds and crosses were flowering.

Bergvinson, D. J., J. T. Arnason, R. I. Hamilton, J. A. Mihm and D. C. Jewell (1994). "DETERMINING LEAF TOUGHNESS AND ITS ROLE IN MAIZE RESISTANCE TO THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Journal of Economic Entomology* 87(6): 1743-1748.

An instron technique was developed for determining leaf toughness of maize (*Zea mays* L.) and its relation to maize resistance to the European corn borer, *Ostrinia nubilalis* (Hubner). Leaf tissue of field-grown maize was mounted onto a stainless steel plate, and the force required to puncture the leaf was determined using an instron. A rounded cylindrical probe attached to the instron gave consistent leaf-toughness readings. Significant negative correlations were found between leaf toughness and leaf-damage ratings taken at midwhorl and plant tasseling for five different groups of maize germplasm that included multiple borer-resistant cultivars and inbreds, Mexican landraces, BS9 selection cycles, and North American inbreds. Leaf toughness appears to be an important defense mechanism in maize across diverse groups of germplasm. Instron measurements of leaf toughness can be used to monitor leaf toughness in resistance breeding programs and as a tool to better understand phytochemical contributions to leaf toughness and behavioral ecology of lepidopteran folivores feeding on maize.

Bergvinson, D. J., J. T. Arnason, R. I. Hamilton, S. Tachibana and G. H. N. Towers (1994). "PUTATIVE ROLE OF PHOTODIMERIZED PHENOLIC-ACIDS IN MAIZE RESISTANCE TO OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE)." *Environmental Entomology* 23(6): 1516-1523.

Five genotypes of maize were grown under three light regimes in the field. Artificial infestation with European corn borer, *Ostrinia nubilalis* (Hubner), egg masses resulted in greater leaf feeding damage for plants grown under a UV absorbing plastic (UV-) than for the same genotypes grown under UV transmitting (UV+) plastic or in the open. Leaf bioassays performed on tissue from the three different light regimes showed similar trends. Foliar nitrogen content was reduced as much as 15% for UV- plants. 2,4-dihydroxy-7-methoxy-2H-1,4-benzoxazin-3-one levels were consistently higher in UV- plants as were the levels of cell-wall-bound hydroxycinnamic acids (HCA). Light-activated dimers of HCA called truxillic and truxinic acids were lower in UV- plants. These results indicate that cell-wall-bound truxillic and truxinic acids are an additional resistance mechanism that provide an explanation for increased susceptibility of greenhouse grown plants to folivores.

Bergvinson, D. J., J. T. Arnason and L. N. Pietrzak (1994). "LOCALIZATION AND QUANTIFICATION OF CELL-WALL PHENOLICS IN EUROPEAN CORN-BORER RESISTANT AND SUSCEPTIBLE MAIZE INBREDS." *Canadian Journal of Botany-Revue Canadienne De Botanique* 72(9): 1243-1249.

Three maize inbreds (MBR 6796-15, B86, and CI31A) resistant to leaf feeding by the European corn borer *Ostrinia nubilalis*, and one susceptible inbred (MS72), were evaluated for insect resistance and phytochemical composition to gain a better understanding of maize-resistance mechanisms. Insect resistance was evaluated using laboratory bioassays that demonstrated that immature leaf tissue is the preferred feeding substrate. Phytochemical analyses were

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conducted for leaf protein, hydroxamic acid content, and hydroxycinnamic acids bound to the cell wall for both immature and mature leaf tissue. Hydroxycinnamic acid distribution in cell walls was examined using five stains, autofluorescence, and microspectrophotometry. Phloroglucinol, azure B, diazotized salts of p-nitroaniline and sulfanilic acid, and chlorine sulfite allowed visualization of phenolic localization but were not quantitative. Microspectrophotometer readings of epidermal, phloem, and xylem cell walls confirmed staining results, showing extremely low cell wall hydroxycinnamic acid levels in epidermal cell walls of immature leaf tissue. Foliar nitrogen content was not related to insect feeding preference. Hydroxycinnamic acid fortification of epidermal cell walls appears to correlate best with corn borer feeding preference, accounting for differential resistance between inbred lines and between tissue maturities. Microspectrophotometry may be useful as a technique for monitoring phytochemical resistance mechanisms in breeding programs.

Calvin, D. D. and P. Z. Song (1994). "VARIABILITY IN POSTDIAPAUSE DEVELOPMENT PERIODS OF GEOGRAPHICALLY SEPARATE OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE) POPULATIONS IN PENNSYLVANIA." *Environmental Entomology* 23(2): 431-436.

Postdiapause developmental periods of overwintering European corn borer, *Ostrinia nubilalis* (Hubner), larvae collected at five geographically separate locations in Pennsylvania (Bradford, Centre, Lancaster, Lycoming, and Mercer counties) were compared. Larvae were reared under constant 25-degrees-C and 16-h light conditions in growth chambers after collection, and the days for each individual larva to complete the larval stage were recorded. Degree-days (DD) from 1 January to pupation were calculated. The Mercer and Lancaster populations completed the postdiapause developmental period within 450 DD; whereas the Centre and Lycoming populations required 650 DD, and the Bradford population required more than 900 DD. Although the termination day of a population's pupation period varied greatly between geographic locations, the degree-days for initiation of spring pupation among populations were very similar. The study results suggested that a mixture of univoltine and bivoltine individuals coexist in Centre, Lycoming, and Bradford counties, leading to a prolonged postdiapause developmental period and continual emergence over the growing season. The data also suggested that postdiapause developmental periods may be correlated with length of growing season.

Ebora, R. V., M. M. Ebora and M. B. Sticklen (1994). "TRANSGENIC POTATO EXPRESSING THE BACILLUS-THURINGIENSIS CRYIA(C) GENE EFFECTS ON THE SURVIVAL AND FOOD-CONSUMPTION OF PHTHORIMEA-OPERCULELLA (LEPIDOPTERA, GELECHIIDAE) AND OSTRINIA-NUBILALIS (LEPIDOPTERA, NOCHUIDAE)." *Journal of Economic Entomology* 87(4): 1122-1127.

Second generation transgenic potatoes were grown from tubers of transgenic plants expressing the *Bacillus thuringiensis* CryIA(c) gene. Leaf disks from transgenic and untransformed potato plants were tested against the tuber moth *Phthorimea operculella* (Zeller), a major pest of potato, and European corn borer, *Ostrinia nubilalis* (Hubner), which can use potato as an alternative host. Ten percentage of mortality of first-instar *P. operculella* was observed after 48 h of feeding on leaf disks from transgenic plants. Bioassays also showed that second-instar *P. operculella* is slightly less capable of surviving on leaf disks from transgenic plants than on untransformed plants after 240 h of feeding. The amount of feeding of *P. operculella* larvae was also less, as indicated by lighter weight of the dried frass. Bioassay showed that second-instar European corn borer is less capable of surviving on leaf disks from transgenic plants than those from untransformed plants. Preference tests showed that leaf disks from transgenic plants were less preferred than those from untransformed plants by third-instar corn borer after 24 h of exposure. Prolonged exposure showed that leaf disks from transgenic and untransformed plants were equally preferred by corn borer larvae. These transgenic plants can be used together with untransformed plants or transgenic plants (or both) expressing high quantity of *B. thuringiensis* insecticidal protein to devise insect resistance management strategies.

Foster, S. P. and B. Frerot (1994). "SEX PHEROMONE-MEDIATED FLIGHT AND LANDING BEHAVIORS OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS (HUBNER)." *Journal of Chemical Ecology* 20(9): 2323-2343.

The pheromone-mediated flight and landing behaviors of male *Ostrinia nubilalis* were studied in a wind tunnel. The pheromone source was placed in the middle of an 18 x 18-cm horizontal surface, and a smaller surface placed 4, 18, or 36 cm downwind. The smaller surface did not appear to affect significantly the flight tracks or position of landing of males on the upwind surface, and it allowed the positions and altitudes of males as they passed over the downwind surface to be estimated. The flight altitude and position of males as they passed over the downwind surface related to

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where males landed on the upwind surface. Regardless of the downwind position of the downwind surface, most males flew over its center (i.e., in line with the source) and landed in line with the source on the upwind surface. When a small 2.5 x 10-cm vertical object was placed on the upwind surface, just upwind and to one side of the source, males flew over the downwind surface in positions skewed toward the vertical object and in broader distributions than for the comparable situation without an object; males landed on the upwind surface on positions skewed toward, or on, the object and with a broader distribution (laterally). Flight altitude also corresponded with landing position. Thus, when there was no vertical object, most males flew just above the downwind surface and landed on the downwind edge of the upwind surface. In contrast, with the vertical object, males flew significantly higher and tended to land past the downwind edge of the upwind surface. With a taller object (20 cm), males flew even higher, past the downwind edge and most landed on the vertical object. These data show the close relationship between flight and landing behaviors of male *O. nubilalis* and suggest that flight maneuvers that determine track and altitude largely govern where a male lands.

Frolov, A. N. (1994). "REGULARITIES OF THE RACE FORMATION IN PHYTOPHAGOUS INSECTS - OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE), A MODEL." *Zhurnal Obshchei Biologii* 55(4-5): 464-476.

Analysis of original data on *Ostrinia nubilalis* along with published ones on various species of Lepidoptera, Homoptera, and Diptera indicates that formation of new races in phytophagous insects is determined by changes of limiting effects of ecological factors. The latter act as the most important factors influencing on population density, especially during critical phases of the life cycle. Among these factors the affecting are climatic characteristics and trophic connections. Due to their interrelation, specific set of ecological races in a given region reflects regional climatic conditions.

Frolov, A. N. (1994). "FORMATION OF REPRODUCTIVE ISOLATION BARRIERS IN THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS - DIFFERENCES IN HOST-PLANT EXPLOITATION STRATEGIES." *Zhurnal Obshchei Biologii* 55(2): 189-197.

Ethological reproductive isolation barriers between populations feeding on corns (*Ostrinia nubilalis*, *O. persica*) and on dicotyledonous host plants (*O. nubilalis*, *O. narynensis*, *O. nubilalis* x *narynensis*, *O. scapularis*) were tested in lab using pair mating analysis. The corn dwelling populations of *O. nubilalis* were shown to form two groups according to their ability to breed with dicotyledon dwellers. In one group, populations which crossbred freely were clustered; another group contained populations with lower fertility rate. Formation of the reproductive barrier was correlated with caterpillars adaptations to feed upon corn leaves at whorl stage, which is peculiar to northern populations. Contrary to this, in the south where caterpillars used to feed upon leaves after their tasseling, there was no sign of barriers. It is supposed that differentiation of the *O. nubilalis* populations is caused by their selecting one of two possible strategies of the fodder plants. One of these is species-generalized and ontogenetic stage-specialized strategy implying feeding on a wide score of plant species but at flowering stage only. Another is species-specialized and ontogenetic stage-generalized strategy, feeding occurring on few plant species but at different stages, including those when antibiotic mechanisms are in effect.

Gelman, D. B. and R. A. Bell (1994). PHOTOPERIODIC INFLUENCES ON ECDYSIOTROPIN LEVELS IN THE HINDGUT OF PREPUPAE OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS.

Gillespie, R. L., M. R. McGuire and B. S. Shasha (1994). "PALATABILITY OF FLOUR GRANULAR FORMULATIONS TO EUROPEAN CORN-BORER LARVAE (LEPIDOPTERA, PYRALIDAE)." *Journal of Economic Entomology* 87(2): 452-457.

Newly developed techniques for producing starch and flour granule formulations encapsulating *Bacillus thuringiensis* Berliner have led to a large number of potentially effective baits for *Ostrinia nubilalis* (Hubner). One aspect of these formulations that must be considered is their palatability to corn borer larvae. Experiments were conducted to determine palatability of several formulations in two-choice preference tests. Corn borer larvae preferred flour granules containing cotton leaves or a commercially available feeding stimulant, Coax, or both. Larvae rejected granules formulated with CaCl₂. Granules made with molasses were intermediate in palatability. When the granules were formulated with 1,600 International Units (IU) *B. thuringiensis* per mg granules and 20 mg of granules were sprinkled on cotton leaves, several formulations killed >70% of the corn borer larvae that fed on treated leaves; other formulations killed <40% of the test insects. Mortality was reduced when larvae were exposed to cotton leaves sprinkled with granules formulated with CaCl₂ when compared with those formulated with cotton leaves or Coax, or both. The dose of

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B. thuringiensis could be reduced by 3/4 (i.e., to 400 IU/mg) without affecting the level of larval mortality if the pathogen was entrapped in granules containing cotton leaf tissue + Coax or only cotton leaf tissue.

Got, B., S. Meusnier, L. Peypelut and F. Fleury (1994). "1ST STEP IN EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) DIAPAUSE MECHANISTIC MODELING - WING DISKS DEVELOPMENT MODEL." *Environmental Entomology* 23(4): 955-964.

Taking into account the limits of previous models proposed to predict European corn borer, *Ostrinia nubilalis* (Hubner) infestation time, complementary research in physiology, population dynamic, and modeling was used to propose a mechanistic model to describe this phenomenon. Diapause is the main process that determines infestation time in this pest. Recent work on diapause has demonstrated the heterogeneity of this development phase. This model describes the first phase of the diapause process, wing disk development. The model proposed consists of two parts; the first component takes into account the influence of temperature as a nonlinear function and the second (normal distributions) represents the variability in development time among a population for each stage. This model has been estimated by maximum likelihood from laboratory data obtained with a destructive sampling under three variable sinusoidal temperature regimes 9-21, 12-34, and 18-42-degrees-C with a photoperiod of 12:12 (L:D) h allowing diapause induction. This unique model describes the development under these different temperature ranges with a 2% precision (0.5 d) and has been validated under field conditions. The development of populations ending their development before winter is correctly represented (10% precision). The model is not adapted to describe the population ending their development after winter. The estimated model correctly predicts diapause development for temperatures above 4-degrees-C. This report presents novel data in modeling research and demonstrates a convincing correlation between laboratory and field collected data.

Hallberg, E., B. S. Hansson and R. A. Steinbrecht (1994). "MORPHOLOGICAL-CHARACTERISTICS OF ANTENNAL SENSILLA IN THE EUROPEAN CORNBORER OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE)." *Tissue & Cell* 26(4): 489-502.

The European cornborer antenna is filiform in both sexes, but exhibits a substantially larger diameter in the males. On the antenna of both sexes, the following sensillum types were characterized: sensilla trichodea, *s. basiconica*, *s. auricillica*, *s. cocloconica*, *s. chaetica* and *s. styloconica*. Long dorsal bristles were of a chaetic type. An intermediate trichoid/basiconic type was found in low numbers on the ventral part of the antenna. In the male, three different morphological types of *s. trichodea* were observed, having one, two or three sensory cells, correlated with different dimensions of the hair. The *s. trichodea* with three sensory cells are most common in the basal part of the antenna, while sensilla with two cells are mainly found distally. Trichodca with one sensory cell are more evenly distributed over the length of the antenna. All cells present in the different *s. trichodea* respond to sex pheromone components or to a behavioural antagonist in electrophysiological sensillum recordings. *S. basiconica* and *s. auricillica* had 2-3 sensory cells, and a probable olfactory function. Sensilla *cocloconica*, also with a putative olfactory function, contained 3-5 sensory cells. *S. chaetica* of the taste/tactile type possessed 4 + 1 sensory cells. *S. styloconica* comprised three sensory cells with possible functions as thermo- and hygrosensors.

Hansson, B. S., E. Hallberg, C. Lofstedt and R. A. Steinbrecht (1994). "CORRELATION BETWEEN DENDRITE DIAMETER AND ACTION-POTENTIAL AMPLITUDE IN SEX-PHEROMONE SPECIFIC RECEPTOR NEURONS IN MALE OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE)." *Tissue & Cell* 26(4): 503-512.

Outer dendritic segments of olfactory receptor neurons tuned to sex pheromone components were measured morphometrically on the antenna of male European corn borers, *Ostrinia nubilalis*, to determine if a correlation exists between the diameter of the outer dendritic segment and the spike amplitude. The olfactory sensilla investigated each contained three receptor cells. Two cells were each specific for one of the two pheromone components, (Z)-11-tetradecenyl acetate (Z11-14:OAc) and (E)-11-tetradecenyl acetate (E11-14:OAc). Two strains of cornborers (Z and E) differ as to which of the two pheromone components is the main one. In both strains a large difference could be observed between the spike amplitudes elicited in the receptor cells by the two pheromone components, the main component always eliciting the large spike. In F1-hybrids (EZ) of these two strains, producing both pheromone components in similar quantities, the spike amplitudes were equal in the two pheromone-specific receptor cells. The third cell responded specifically to a behavioural antagonist, (Z)-9-tetradecenyl acetate (Z9-14:OAc) in both the parental and hybrid strains, and always showed the smallest spike amplitude. In a morphometric study, the outer dendritic segments were shown to differ more in diameter between the largest and second largest cell in the two parental strains

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than in the hybrid strain, while the smallest diameter cell did not differ between the different strains. These results imply that receptor cells with larger diameter produce spikes with greater amplitude. The data also show that all three types of receptor neurons display outer dendritic segments with strong variation in the diameter along the length of the segment, and with a pronounced taper towards the tip.

Hawltzky, N., F. M. Dorville and J. Vaillant (1994). "STATISTICAL STUDY OF TRICHOGRAMMA-BRASSICAE EFFICIENCY IN RELATION WITH CHARACTERISTICS OF THE EUROPEAN CORN-BORER EGG MASSES." *Researches on Population Ecology* 36(1): 79-85.

The efficiency of *Trichogramma brassicae* inundative releases in biological control of the European corn borer *Ostrinia nubilalis* was analyzed in seven plots of 504 plants, each situated in a corn field naturally infested by the European corn borer. Different strategies of *Trichogramma* releases were defined on the seven plots. These inundative releases were concluded to be highly efficient even on plots where there were either no parasitoid release or only one parasitoid release at the beginning of the egg mass laying period.

Hoskovec, M., D. Saman and B. Koutek (1994). "SYNTHESIS OF (Z)-14-HEPTADECEN-4-OLIDE AND (Z)-11-PENTADECEN-4-OLIDE, SEX-PHEROMONE ANALOGS OF OSTRINIA-NUBILALIS AND CYDIA-MOLESTA." *Collection of Czechoslovak Chemical Communications* 59(5): 1211-1218.

The key step in the preparation of racemic (Z)-14-heptadecen-4-olide (VIa) and (Z)-11-pentadecen-4-olide (VIb), sex pheromone analogues of *Ostrinia nubilalis* and *Cydia molesta*, was efficient cross-coupling reaction of 3-methoxycarbonylpropanoyl chloride with corresponding (Z)-alkenylmagnesium bromides. The methyl 4-oxo-(Z)-14-heptadecenoate (Va) and methyl 4-oxo-(Z)-11-pentadecenoate (Vb) prepared in this way were converted by one-pot reaction using sodium borohydride in an ethanolic solution to the required (Z)-alken-4-olides (VIa, VIb).

Kalinova, B., A. Minaif and L. Kotera (1994). "SEX-PHEROMONE CHARACTERIZATION AND FIELD TRAPPING OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE), IN SOUTH MORAVIA AND SLOVAKIA." *European Journal of Entomology* 91(2): 197-203.

The analysis of pheromone glands from individual females of the European corn borer, *Ostrinia nubilalis* (Hubner), originating in South Moravia and Slovakia showed that this population utilizes the "Z" pheromone system. The ratio of (Z)- and (E)-11-tetradecenyl acetates was found in the range of 98.5:1.5-99.5:0.5. Field experiments confirmed the identity of the local population as being predominantly of the Z strain. Individuals responding to E and hybrid blends were detected.

Leahy, T. C. and D. A. Andow (1994). "EGG WEIGHT, FECUNDITY, AND LONGEVITY ARE INCREASED BY ADULT FEEDING IN OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE)." *Annals of the Entomological Society of America* 87(3): 342-349.

Two experiments were conducted to assess the influence of sugar and protein foods for adult *Ostrinia nubilalis* (Hubner) females on selected reproductive parameters. Individuals were fed diets of sugar plus protein (fructose-egg-agar) in all possible combinations and diets with one of three sugars (glucose-agar, fructose-agar, sucrose-agar). Free water served as a control in both experiments. Diets with sugars significantly increased oviposition period, fecundity, and adult longevity. Total numbers of eggs and egg masses oviposited were significantly higher in females that received sugar diets. Weight of individual eggs remained constant for females that received a sugar diet but decreased by the 3rd d of oviposition for females that did not receive sugar. Adult nutrition may be an important factor in the population ecology of *O. nubilalis*.

Mason, C. E., R. F. Romig, L. E. Wendel and L. A. Wood (1994). "DISTRIBUTION AND ABUNDANCE OF LARVAL PARASITOIDS OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) IN THE EAST CENTRAL UNITED-STATES." *Environmental Entomology* 23(2): 521-531.

Overwintering *Ostrinia nubilalis* (Hubner) fifth instars were systematically collected at 621 sample sites on a grid interval of 40 km encompassing New York, Pennsylvania, Ohio, Delaware, Maryland, Virginia, West Virginia, and North Carolina and were evaluated for parasitoids. The study was focused on the extent of dispersal of *Lydella thompsoni* Herting from its presumed reestablishment in Delaware during the mid-1970s and the level of parasitism of overwintering *O. nubilalis* larvae. The bulk of the study was conducted in 1986 and 1987 with some additional samples taken in 1988 and

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1989 from outlier locations. *L. thompsoni*, *Macrocentrus grandii* Goidanich, and *Eriborus terebrans* Gravenhorst were the only exotic species recovered. All three of these parasitoids were found in all states surveyed. Parasitism by these three species combined was 5.4% in 1986 and 7.5% in 1987 for the entire areas surveyed. The areas of most abundance for each species were in North Carolina for *L. thompsoni*, a band from northeastern Pennsylvania to eastern Virginia for *M. grandii*, and in Ohio for *E. terebrans*. All three exotic parasitoids species were retrieved at less than 3% of the sample sites. Data suggest that the dispersal rate of *L. thompsoni* from Delaware was about 50 km per year. An uncommon native *Lixophaga* sp. was found in Western Ohio and Western North Carolina. The three exotic parasitoid species appear to be well established in their respective foci of abundance.

McGuire, M. R., R. L. Gillespie and B. S. Shasha (1994). "SURVIVAL OF OSTRINIA-NUBILALIS (HUBNER) AFTER EXPOSURE TO BACILLUS-THURINGIENSIS BERLINER ENCAPSULATED IN FLOUR MATRICES." *Journal of Entomological Science* 29(4): 496-508.

Two types of pregelatinized corn flour were used to produce granules containing *Bacillus thuringiensis* Berliner subsp. *kurstaki* and various additives for control of the European corn borer, *Ostrinia nubilalis* (Hubner), in the whorl of corn plants. Laboratory-reared larvae were applied to corn whorls in the greenhouse and field, and a high natural infestation occurred at one field site (Champaign). In the greenhouse and at all three field sites, five of these formulations were just as effective as Dipel 10G, a commercially available *B. thuringiensis* product, for control of European corn borer larvae. In all greenhouse studies and at one of the three field sites (Champaign), the dose of *B. thuringiensis* could be reduced by as much as 75% when a phagostimulant was added to flour granules without significant loss of corn borer control. The phagostimulant dose response was not observed at the other two field sites in which larval infestations were relatively low. Flour type had no significant effect on European corn borer control under greenhouse and field conditions. Greenhouse evaluations provided results significantly similar to results from two of the field sites indicating the usefulness of the technique. The data presented highlight the versatility and potential for using novel formulation techniques for enhancing the efficacy of *B. thuringiensis*.

Orr, D. B., L. C. Lewis and J. J. Obyrcki (1994). "BEHAVIOR AND SURVIVAL IN CORN PLANTS IN OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE) LARVAE WHEN INFECTED WITH NOSEMA-PYRAUSTA (MICROSPORA, NOSEMATIDAE) AND PARASITIZED BY MACROCENTRUS-GRANDII (HYMENOPTERA, BRACONIDAE)." *Environmental Entomology* 23(4): 1020-1024.

To clarify the interaction among the European corn borer, *Ostrinia nubilalis*, the parasitic wasp, *Macrocentrus grandii*, and the entomopathogen *Nosema pyrausta*, we examined behavior and survival in corn stems of *O. nubilalis* larvae infected with *N. pyrausta* and parasitized by *M. grandii*. Fifty-four percent of heavily infected, parasitized *O. nubilalis* larvae emigrated from their tunnels before emergence of parasitoid larvae and did not reestablish on corn plants. One-third as many heavily infected host larvae as noninfected larvae remained in tunnels until parasitoid larval emergence. The tunnels bored by infected, parasitized *O. nubilalis* larvae did not differ in length from those of noninfected parasitized larvae, suggesting that emigration behavioral changes occur after feeding. Parasitoid larval and pupal mortalities were greater in infected *O. nubilalis* hosts than in noninfected hosts. Greater than 46% of heavily infected *M. grandii* broods wandered instead of remaining clustered around host carcasses and pupating. This behavior accounted for almost almost-equal-to 40% of the observed mortality in infected parasitoids. Wandering was attributed to decreased production of cocoons by hosts, causing parasitoid larvae to search for suitable substrates on which to spin their own cocoons. Percentage emergence of *M. grandii* adults from corn stalks was significantly lower in *N. pyrausta*-infected treatments, but the sex ratio of the parasitoid was unaffected by the level of host infection. The mean number of *M. grandii* adults per brood was reduced from 39.8 in the noninfected treatment to 10.5 in heavily infected larvae.

Ozpinar, A. and S. Kornosor (1994). THE EFFECTIVENESS OF THE RELEASED TRICHOGRAMMA-EVANESCENS WESTWOOD (HYMENOPTERA, TRICHOGRAMMATIDAE) ON THE EGG POPULATION OF OSTRINIA-NUBILALIS HUBNER (LEPIDOPTERA, PYRALIDAE).

Sayers, A. C., R. H. Johnson, D. J. Arndt and M. K. Bergman (1994). "DEVELOPMENT OF ECONOMIC INJURY LEVELS FOR EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) ON CORN GROWN FOR SEED." *Journal of Economic Entomology* 87(2): 458-464.

Experiments were conducted to quantify the relationship between the percentage of plants infested with European corn borer, *Ostrinia nubilalis* (Hubner), larvae and yield to establish economic injury levels (EILs) for corn (*Zea mays* L.) grown

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for seed. In 1988 and 1989, three inbred genotypes were infested manually with neonates at the mid-whorl or flowering stages of corn development to simulate natural infestations by first- or second-generation *O. nubilalis*, respectively. Infestation levels ranged from 0 to 84% of plants with larvae. Susceptibilities of the inbreds to infestations of European corn borer ranged from relatively susceptible to moderately tolerant, based on visual injury scores. Yields of salable seed decreased as the percentage of plants infested increased, with infestations at either stage of crop development. Observed yield losses were converted to potentially preventable monetary losses based on variable field production costs of \$10 and \$20 per 80,000-kernel unit of salable seed. EILs were calculated using current insecticide and application costs and levels of control that might be expected with timely insecticide application(s). The EIL for whorl-stage infestation of European corn borer would be exceeded when >2-3% of the plants have larvae present in the whorl, and the EIL for flowering-stage infestation would be exceeded when >10-17% of the plants have larvae in leaf axils.

Stewart, J. G. (1994). "MONITORING ADULT EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) IN POTATOES ON PRINCE-EDWARD-ISLAND." *Environmental Entomology* 23(5): 1124-1128.

Experiments to determine the effectiveness and time required to sample for males of the European corn borer, *Ostrinia nubilalis* (Hubner), with blacklight, water-pan, Heliiothis-cone, and delta-wing traps, along with sweep-net samples of grassy areas near potato fields were conducted at four sites in 1990 and 1991 on Prince Edward Island. Compared with the blacklight trap, the water-pan trap caught 1.72 times more males in 1990 and 1.97 times more males in 1991. The Heliiothis-cone and delta-wing traps, and sweep-net samples were ineffective for male European corn borer. Blacklight traps required significantly more time to sample than any of the pheromone-based traps. A water-pan trap is an effective tool to monitor adult males of the European corn borer in potatoes on Prince Edward Island. In 1992, the mean number of males per pan trap per week was 7.4 for the Iowa strain, 1.1 for the New York strain, 0.6 for the hybrid strain, and 1.1 for an unbaited trap. This suggests that the Iowa strain predominates in the population of European corn borer on Prince Edward Island.

Yu, D. S. and J. R. Byers (1994). "INUNDATIVE RELEASE OF TRICHOGRAMMA-BRASSICAE BEZDENKO (HYMENOPTERA, TRICHOGRAMMATIDAE) FOR CONTROL OF EUROPEAN CORN-BORER IN SWEET CORN." *Canadian Entomologist* 126(2): 291-301.

Inundative release of *Trichogramma brassicae* Bezdenko for control of European corn borer was tested in experimental plots in 1991 and 1992 in southern Alberta, Canada, to determine its effectiveness as a potential method of control in sweet corn. The tests were conducted in 1-ha plots, in three different fields of irrigated sweet corn each year, at a release level of about 196 000 wasps per ha. The reduction in European corn borer damage in the release plots ranged from 85 to 87% in 1991 and from 45 to 95% in 1992. The reduction in damage was not significantly different in fields with 25 and 49 release points. General area degree-day accumulation for postdiapause development was not adequate to determine the timing of release for individual fields because European corn borer phenology varied among fields. Total moth catch in pheromone traps, however, was directly related to the number of plants damaged by European corn borer, and releases near the time of peak trap catch produced the greatest reduction in damage.

Abouzaid, M. M., C. W. Beninger, J. T. Arnason and C. Nozzolillo (1993). "THE EFFECT OF ONE FLAVONE, 2 CATECHINS AND 4 FLAVONOLS ON MORTALITY AND GROWTH OF THE EUROPEAN CORN-BORER (*OSTRINIA-NUBILALIS* HUBNER)." *Biochemical Systematics and Ecology* 21(4): 415-420.

Seven compounds incorporated into an artificial diet at concentrations of 1, 10 and 100 mg g⁻¹ were evaluated for their effect on growth and mortality of the European corn borer *Ostrinia nubilalis* (Hubner). At all three concentrations the flavanone pinocembrin, two flavan-3-ols, catechin and epicatechin, and the flavonols, quercetin, rhamnetin, quercitrin and rutin significantly reduced the growth of larvae after only eight days of feeding. By day 18, only larvae fed pinocembrin had a survival rate in excess of 50% at all concentrations. Flavonols were the most toxic. EC50 (effective concentration to reduce growth relative to controls by 50%) values evaluated on day 8 ranged from 0.17 to 7.4 mg g⁻¹; estimated LC50 (lethal concentration resulting in 50% larval mortality evaluated on day 18) values ranged from 0.16 to 12 mg g⁻¹. The results suggest the potential of flavonoids for reducing the growth and survivorship of the European corn borer.

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Beninger, C. W., P. Ndayiragije and J. T. Arnason (1993). "DITERPENE 3-EPICARYOPTIN AFFECTS GROWTH AND DEVELOPMENT OF THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Journal of Economic Entomology* 86(5): 1599-1602.

The diterpene 3-epicaryoptin reduced growth and increased mortality of *Ostrinia nubilalis* (Hubner) (European corn borer) larvae when incorporated into artificial diet at concentrations of 0.1, 0.3, 1.0, 3.0 and 10.0 ppm. Pupal deformities and time to pupation also increased in a dose-dependent manner. 3-epicaryoptin and other diterpenes show potential as plant-derived compounds for protection of commercial plants.

Bing, L. A. and L. C. Lewis (1993). "OCCURRENCE OF THE ENTOMOPATHOGEN *BEAUVERIA-BASSIANA* (BALSAMO) VUILLEMIN IN DIFFERENT TILLAGE REGIMES AND IN ZEA-MAYS L AND VIRULENCE TOWARDS *OSTRINIA-NUBILALIS* (HUBNER)." *Agriculture Ecosystems & Environment* 45(1-2): 147-156.

The entomopathogen, *Beauveria bassiana* (Balsamo) Vuillemin, is an important component in the corn (*Zea mays* L.) agroecosystem; this pathogen was found in soil, living corn plants, and field corn residue. *Beauveria bassiana* occurs naturally in the soil within different tillage systems (plow, chisel, no-tillage), with an average of 51-74 colony forming units g⁻¹ of soil. The natural inoculum was present in the crop residue from the different tillage systems, killing up to 84% of European corn borer larvae (*Ostrinia nubilalis* (Hubner), Lepidoptera: Pyralidae) overwintering in the no-tillage regime. Of the larvae collected from corn late in the season, 100% of those killed by *Beauveria bassiana* were from plants colonized by *Beauveria bassiana* applied foliarly at the whorl-stage ($\chi^2 = 19.1$, $P < 0.01$). However, the lack of mycosis in the total *O. nubilalis* population may have been a function of low concentrations of the fungus in the plants. Fungal samples isolated from internodal and nodal tissue of those plants maintained virulence, killing from 23-100% of exposed larvae. *Beauveria bassiana* has potential for environmentally safe insect suppression, in that it occurs naturally and can also be applied to field corn. Understanding the unique relationship between the soil, *Beauveria bassiana*, and *Z. mays* will be invaluable in furthering development and utilization of such fungi to manage insect pests of food plants.

Chaika, V. N., A. M. Cherny and R. M. Panteleichuk (1993). "STUDY OF COMPETITION OF NATURAL AND ARTIFICIAL PHEROMONES ON THE CHEMOSENSORY LEVEL IN *OSTRINIA-NUBILALIS* (LEPIDOPTERA, PYRALIDAE)." *Zoologicheskyy Zhurnal* 72(1): 54-62.

Sensitivity of physiological reactions of males to the female pheromone and to its synthetic analog is statistically comparable. This can be explained by the existence of population and species specific reaction norm to the pheromone in the butterflies. However olfactory importance of different pheromone signals is specific for individual males. Apparently this is connected both with the individual specificity of olfactory perception and with heterogeneity of females by parameters of a pheromone signal. Synthetic pheromones of lepidopterans got included in the natural channels of chemocommunication on the condition of competition and this determines the degree of their influence on a population of phytophagous insects. All this should be taken into account creating new preparative forms of synthetic pheromones and elaborating methods of their practical use.

Denolf, P., S. Jansens, M. Peferoen, D. Degheele and J. Vanrie (1993). "2 DIFFERENT *BACILLUS-THURINGIENSIS* DELTA-ENDOTOXIN RECEPTORS IN THE MIDGUT BRUSH-BORDER MEMBRANE OF THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (HUBNER) (LEPIDOPTERA, PYRALIDAE)." *Applied and Environmental Microbiology* 59(6): 1828-1837.

Binding of three *Bacillus thuringiensis* insecticidal crystal proteins (ICPs) to the midgut epithelium of *Ostrinia nubilalis* larvae was characterized by performing binding experiments with both isolated brush border membrane vesicles and gut tissue sections. Our results demonstrate that two independent ICP receptors are present in the brush border of *O. nubilalis* gut epithelium. From competition binding experiments performed with I-125-labeled and native ICPs it was concluded that CryIA(b) and CryIA(c) are recognized by the same receptor. An 11-fold-higher binding affinity of CryIA(b) for this receptor correlated with a 10-fold-higher toxicity of this ICP compared with CryIA(c). The CryIB toxin did not compete for the binding site of CryIA(b) and CryIA(c). Immunological detection of ingested *B. thuringiensis* ICPs on gut sections of *O. nubilalis* larvae revealed binding only along the epithelial brush border membrane. CryID and CryIE, two ICPs that are not toxic to *O. nubilalis*, were not bound to the apical microvilli of gut epithelial cells. In vitro binding experiments performed with native and biotinylated ICPs on tissue sections confirmed the correlation between ICP binding and toxicity. Moreover, by performing heterologous competition experiments with biotinylated and native ICPs, it was confirmed that the CryIB receptor is different from the receptor for CryIA(b) and CryIA(c). Retention of activated crystal proteins by the peritrophic membrane was not correlated with toxicity. Furthermore, it was

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demonstrated that CryIA(b), CryIA(c), and CryIB toxins interact in vitro with the epithelial microvilli of Malpighian tubules. In addition, CryIA(c) toxin also adheres to the basement membrane of the midgut epithelium.

Feng, R., J. G. Houseman, A. E. R. Downe and J. T. Arnason (1993). "EFFECTS OF ALPHA-TERTHIENYL ON THE MIDGUT DETOXIFICATION ENZYMES OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS." *Journal of Chemical Ecology* 19(9): 2047-2054.

The biochemical basis for the tolerance of the European corn borer, *Ostrinia nubilalis*, to the phototoxin alpha-terthienyl was investigated by measuring the midgut polysubstrate monooxygenases and glutathione S-transferase activities. alpha-Terthienyl administered in the diet to the corn borers increased the level of cytochrome b5, NADH-cytochrome c reductase, O-demethylase, and glutathione S-transferase activities. The induced detoxification enzyme activities should enable the corn borer to metabolize alpha-terthienyl more efficiently and therefore render the corn borer highly tolerant to alpha-terthienyl.

Hudon, M. and S. Khanizadeh (1993). "MORTALITY OF OVERWINTERING LARVAE OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE), OSTRINIA-NUBILALIS HUBNER, FROM CONVENTIONAL TILLAGE PRACTICES OF MAIZE FIELD DEBRIS." *Journal of Agricultural Entomology* 10(2): 121-124.

Labatte, J. M. and B. Got (1993). "MODELING WITHIN-PLANT DISTRIBUTION OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) LARVAE ON CORN FOR PRETASSELING INFESTATION." *Journal of Economic Entomology* 86(3): 747-760.

To quantify yield losses of corn, *Zea mays* (L.), caused by larvae of the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae), a model describing the within-plant distribution of larvae is proposed and discussed. This paper is restricted to the interorgan and vertical distribution of larvae for pretasseling infestation. Field data collected at Versailles were used to study larval distribution and to estimate and test the model. The model proposed is based on four hypotheses deduced from field data: larval distribution in the tassel is influenced mainly by corn development; distribution in the ear of fourth and fifth instars depends on infestation date; distribution of first instars in the ear is conditional upon ear appearance; and vertical distribution of larvae in vegetative organs depends on corn development. For the 11 infestation conditions, the proposed mathematical model used to quantify the relations between larval distribution and main factors (corn development, infestation conditions) allows the percentages of larvae in ear, tassel, and internodes to be described with a precision of 10-15%.

Lamb, E. M., D. W. Davis and D. A. Andow (1993). "MID-PARENT HETEROSIS AND COMBINING ABILITY OF EUROPEAN CORN-BORER RESISTANCE IN MAIZE." *Euphytica* 72(1-2): 65-72.

Success in breeding maize resistant to the European corn borer has been limited, with the exception of leaf feeding resistance. The inheritance of resistance to leaf, sheath-collar and ear damage in four maize germplasms and their six F-1 crosses was evaluated by diallel analysis. Plants in a completely randomized design were artificially infested at the whorl, anthesis or full silk stage of plant development and were evaluated in the field for insect damage. A damage index based on size, number and location of lesions was calculated for each stage. Stowell's Evergreen (susceptible) had a mean damage index three to six times that of Maiz Amargo (resistant) at the whorl stage and the progeny plants were more resistant than the susceptible parent. Maiz Amargo and its crosses had significantly lower mean indices than Stowell's Evergreen for sheath-collar damage in Year 1 but not Year 2. Zapalote Chico, Maiz Amargo and their cross were significantly less damaged than other genotypes at the full silk stage. Heterosis values indicated an increase in resistance of crosses over the midparent average at all three stages of development. General combining ability (GCA) was highly significant for all types of damage, but specific combining ability was significant only for leaf damage. Based on estimates of GCA, Maiz Amargo was the best source of resistance to leaf and sheath-collar damage and both Zapalote Chico and Maiz Amargo would be good parents for ear damage resistance. Results suggest that resistance at different plant development stages can be combined.

Langenbruch, G. A. and N. Lorenz (1993). "A 10-YEAR STUDY ON THE APPLICABILITY OF PHEROMONE-BAITED TRAPS FOR MONITORING THE EUROPEAN CORN-BORER (OSTRINIA-NUBILALIS HBN) IN THE FEDERAL-REPUBLIC-OF-GERMANY .2. INVESTIGATIONS ON THE APPLICABILITY OF PHEROMONE-BAITED TRAPS FOR CALCULATING THE DATE OF RELEASE OF

TRICHOGRAMMA-WASPS." Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection 100(2): 129-143.

Since 1981, the suitability of pheromone-baited traps for monitoring the European corn borer (Z-strain) has been investigated in South Hesse. The 'Pherocon IC-trap' (Zoecon, USA) with an 'ECBI'-bait as well as the 'Biotrap' (Hoechst AG, FRG) with 20 or 60 μ g of 97 Z- : 3 E-11-tetradecenyl acetate per dispenser proved to be useful in monitoring the beginning of the flight-period and, thus, to appoint the most suitable time for releasing *Trichogramma*-wasps for efficient pest control. A detailed proposal for placing the traps and a preliminary proposal for calculating the date of release are enclosed. Only in few cases, the number of trapped males was correlated with the population density. Even flight peaks of the moth could not be determined with certainty by pheromone traps.

Malvar, R. A., M. E. Cartea, P. Revilla, A. Ordas, A. Alvarez and J. P. Mansilla (1993). "SOURCES OF RESISTANCE TO PINK STEM BORER AND EUROPEAN CORN-BORER IN MAIZE." *Maydica* 38(4): 313-319.

The European corn borer (*Ostrinia nubilalis* Hbn) is an important insect pest of maize (*Zea mays* L.) in Europe. However, the larvae of pink stem borer (*Sesamia nonagrioides* Lef.) produce important damage to the stems, especially in Southern Europe. The first step in an insect-resistance breeding program is to identify sources of resistance. The objective of this work was to study the resistance/tolerance of several populations of maize to attack by corn borers in general, and of *Sesamia nonagrioides* in particular. Twenty landraces of maize were evaluated for two years at two locations under natural infestation. In one location most of the larvae that were found belonged to *Sesamia* while in the other location the larvae of *Ostrinia* were more abundant. Agronomic and resistant traits were analyzed in all trials and the best varieties for resistance, along with new material, were evaluated further under artificial infestation conditions with *Sesamia nonagrioides*. The extraearly and early material suffered less borer damage than the late and midseason material, because the early populations probably escaped the second brood of borers. Moreover, the varieties with small proportion of damaged stems come from the Ebro valley. The germplasm of this area, then, could be a good source of resistance or tolerance to the borers. However, it showed a low yield. The EPS7(S)C2 synthetic also had good resistance under artificial infestations with *Sesamia nonagrioides*. Further, it showed better yield than the landraces because two cycles of S1 recurrent selection for yield have been carried out in this synthetic. Therefore EPS7(S)C2 could be the base material in a breeding program to obtain resistant varieties to the pink stem borer.

Martin, D., F. B. Debuzareingues, P. Barry and S. Derridj (1993). "AN EPIPHYTIC YEAST (*SPOROBOLOMYCES-ROSEUS*) INFLUENCING IN OVIPOSITION PREFERENCE OF THE EUROPEAN CORN-BORER (*OSTRINIA-NUBILALIS*) ON MAIZE." *Acta Oecologica-International Journal of Ecology* 14(4): 563-574.

This study provides one example of the influence of phylloplane microorganisms on insect behaviour. Different densities of an epiphytic yeast (*Sporobolomyces roseus* (Kluyver & van Niel)) reduce the oviposition preference of the European Corn Borer (*Ostrinia nubilalis* (Hbn.)) on maize. On the surface of untreated leaves of plants grown in greenhouse the epiphytic microorganism populations are very low (1 to 10 organisms/cm²). Suspensions of 1×10^4 , 1×10^6 and 1×10^8 yeast cells/ml were sprayed on both sides on these leaves. The treatment yielded in populations of pink yeast of i) less-than-or-equal-to 10, to ii) about 270 and to iii) 20.000 to 80.000 cells/cm² respectively. When the insects were given the choice between plants inoculated with low levels and high levels of epiphytic yeasts, they clearly preferred the plants inoculated with the lowest level, i.e. this effect was concentration dependent. The leaf side preference was also correlated with the concentration of yeast population. Yeast cells and monosaccharides were both localized in great majority in the anticlinal cuticular areas on the junction between the epidermal cells.

Oien, C. T. and D. W. Ragsdale (1993). "SUSCEPTIBILITY OF NONTARGET HOSTS TO *NOSEMA-FURNACALIS* (MICROSPORIDA, NOSEMATIDAE), A POTENTIAL BIOLOGICAL-CONTROL AGENT OF THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (LEPIDOPTERA, PYRALIDAE)." *Biological Control* 3(4): 323-328.

Pavlik, J. (1993). "VARIABILITY IN THE HOST ACCEPTANCE OF EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* HBN (LEP, PYRALIDAE) IN STRAINS OF THE EGG PARASITOID *TRICHOGRAMMA* SPP (HYM, TRICHOGRAMMATIDAE)." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 115(1): 77-84.

The acceptance of the natural host *Ostrinia nubilalis* was compared in *Trichogramma maidis* (5 strains), *T. evanescens* (2 strains), *T. ostrinae* (1 strain) and *T. dendrolimi* (1 strain). Significant interspecific differences were detected in the

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number of parasitized eggs of *O. nubilalis*. The lowest parasitization activity and reduction in the proportion of parasitizing females were recorded in strains of *T. evanescens*. Significant intraspecific differences were also recorded among strains of *T. maidis*. The strains of *T. maidis* from natural host *Mamestra brassicae* did not differ in parasitization from other strains of *T. maidis* from natural host *O. nubilalis*. Great differences were found in the number of progeny per host egg so both at interspecific and intraspecific level. Comparing studied strains no differences were found in sex ratio of female's progeny. The results indicate, that some *Trichogramma* strains did not lose their acceptance of their natural host and successfully develop in this host despite they were reared on factitious host *Ephestia kuehniella* for several years. The implication for evaluation of potential *Trichogramma* strains for inundative control is discussed.

Porter, J. H. (1993). SOME IMPLICATIONS OF CLIMATIC-CHANGE FOR *OSTRINIA-NUBILALIS* IN EUROPE.

Royer, L. and J. N. McNeil (1993). "MALE INVESTMENT IN THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (LEPIDOPTERA, PYRALIDAE) - IMPACT ON FEMALE LONGEVITY AND REPRODUCTIVE-PERFORMANCE." *Functional Ecology* 7(2): 209-215.

1. It is generally assumed that the cost of producing ejaculates is relatively low for males, although the decline observed in spermatophore size with repeated mating in certain lepidopteran species would suggest that this is not always the case. However, despite such observed differences in spermatophores very little research has been done to determine if female reproductive success is affected by the previous mating history of her mate. 2. A study was undertaken, using the European corn borer, *Ostrinia nubilalis*, to determine the extent to which (i) male lifetime reproductive success was related to the number of mates, acquired and the actual number of times that a male mated when provided virgin females daily for a period of 10 days, (ii) spermatophore size changed with successive matings and (iii) previous male mating history affected the longevity and the reproductive performance of singly mated females. 3. Males mated 3.8 +/- 0.5 times, with a refractory period of 1.6 +/- 0.1 days between mating, and their lifetime reproductive output increased directly with the number of mates acquired. 4. The volume of the first spermatophore produced was correlated to male pupal weight. Spermatophore volume decreased exponentially with subsequent matings, although the difference in volume between the first and second spermatophore was affected by the time elapsed between matings. While the decrease in spermatophore size had no effect on female longevity, pre-oviposition or oviposition periods or the daily pattern of egg fertility, there was a linear decline in both lifetime fecundity and fertility of successive mates of a given male. Furthermore, females mating with males that had previously mated at least three times retained a significant portion of their egg complement. 5. These results suggest that the production of sperm, as well as male accessory gland secretions, may limit *O. nubilalis* male reproductive output. These findings are discussed with respect to the potential effect that this may have on mate choice in this species.

Royer, L. and J. N. McNeil (1993). "EFFECT OF RELATIVE-HUMIDITY CONDITIONS ON RESPONSIVENESS OF EUROPEAN CORN-BORER (*OSTRINIA-NUBILALIS*) MALES TO FEMALE SEX-PHEROMONE IN A WIND-TUNNEL." *Journal of Chemical Ecology* 19(1): 61-69.

The responsiveness of 3-day-old European corn borer males to three concentrations of 97:3 Z:E 11-tetradecenyl acetate, the female sex pheromone, was studied over a range of relative humidities (43-100%) in a wind tunnel. The proportion of males taking flight and reaching the source decreased, while the proportion exhibiting in-flight arrestment of upwind progress increased under high humidity conditions at all three concentrations of pheromone tested. The relationships between relative humidity and these behaviors were best described by polynomial equations.

Schon, C. C., M. Lee, A. E. Melchinger, W. D. Guthrie and W. L. Woodman (1993). "MAPPING AND CHARACTERIZATION OF QUANTITATIVE TRAIT LOCI AFFECTING RESISTANCE AGAINST 2ND-GENERATION EUROPEAN CORN-BORER IN MAIZE WITH THE AID OF RFLPS." *Heredity* 70: 648-659.

The European corn borer (*Ostrinia nubilalis* Hubner) is an important pest in the global production of maize (*Zea mays* L.). In this study, we mapped and characterized quantitative trait loci (QTLs) significantly affecting resistance against second-generation European corn borer (2ECB) and plant height with the aid of RFLP markers. A total of 300 F3 lines derived from cross B73 (susceptible) x B52 (resistant) were assayed for their parental F2 genotype at 87 RFLP loci. Field data on plant height and resistance against 2ECB were collected for the 300 F3 lines, the parents and the F2 generation at two sites, Ames and Ankeny, IA, USA. Resistance was assessed by measuring the damage of stalk tissue (tunnel length) caused by severe artificial infestation with 2ECB larvae. Genotypic variances among F3 lines were highly

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significant for tunnel length and plant height, but genotype by location interactions were significantly different from zero only for plant height. Heritabilities were intermediate (0.63) for tunnel length but high (0.87) for plant height. The genotypic correlation between the two traits was 0.29. The method of interval mapping was used for localization of QTLs and estimation of their genetic effects. In the combined analysis across locations, genomic regions significantly affecting resistance against 2ECB were found on chromosome arms 1S, 1L, 2S, 2L, 3L, 7L and 10L. Genomic regions on 1S, 3L and 9L significantly affected plant height. Results were largely consistent across locations. Different types of gene action were found for the putative QTLs for both traits. For tunnel length a total of 38 per cent of the phenotypic variance was explained by simultaneous mapping of the seven putative QTLs. The three putative QTLs for plant height explained 63 per cent of the phenotypic variance. On 3L, evidence was found for an interaction of genes conferring resistance to 2ECB and plant height. Significant genic epistasis was detected for one pair of marker loci.

Shu, S. Q. and R. L. Jones (1993). "EVIDENCE FOR A MULTICOMPONENT SEX-PHEROMONE IN ERIBORUS-TEREBRANS (GRAVENHORST) (HYM, ICHNEUMONIDAE), A LARVAL PARASITOID OF THE EUROPEAN CORN-BORER." *Journal of Chemical Ecology* 19(11): 2563-2576.

Sex Pheromone activity of *Eriborus terebrans* (Gravenhorst) (Hymenoptera: Ichneumonidae) was recovered from acetone rinses of flasks that previously contained females. The acetone flask rinses elicited the following male responses: upwind anemotaxis, casting, hovering, landing, wing-fanning, and mating attempts with other nearby males. Activity of the acetone flask rinse lasted up to four days on a glass substrate. Polar component and nonpolar components were demonstrated in the acetone flask rinse. The polar component elicited male behavioral responses similar to those by the acetone flask rinse, although retention of males at the pheromone source and the period of wing-fanning were of shorter duration. Chromatography data and chemical derivatization indicated that the polar component had the properties of a carboxylic acid with an additional oxygen-containing functional group. The nonpolar component acted as a synergist since it was inactive alone but increased male behavioral responses when added to the polar component. Florisil open column chromatography suggested that the nonpolar component was a hydrocarbon(s).

Sorenson, C. E., G. G. Kennedy, J. W. Vanduyne and J. R. Bradley (1993). "DISTRIBUTION OF 2ND-GENERATION EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS*, EGG MASSES IN FIELD CORN AND RELATIONSHIP TO SUBSEQUENT TUNNELING DAMAGE." *Entomologia Experimentalis Et Applicata* 68(1): 15-23.

The relationship between second generation European corn borer (*Ostrinia nubilalis* Hubner) egg mass numbers and subsequent field corn damage, as measured by stalk cavity numbers, was studied in 79 fields in northeastern North Carolina over three years. A mean of 0.028 egg masses per plant (645 egg masses/23 400 plants) was found over the course of the study. Significant differences in oviposition rate were detected between fields and years. Ca. 85% of egg masses were deposited in a five leaf zone surrounding the primary ear; of these, 89% were found on the lower four leaves in this zone. Egg masses appeared to be distributed randomly within fields but at low rates of incidence, and oviposition was relatively uniform between sampling areas within individual fields. Under moderate to high oviposition pressure (mean number of egg masses per plant over the duration of the oviposition period > ca. 0.02), eggs laid during the early phases of the oviposition period account for more subsequent stalk damage than eggs laid during the later phases of the oviposition period. Variations in second generation egg mass numbers accounted for ca. 70% of variation in stalk cavity numbers.

Udayagiri, S. and R. L. Jones (1993). "VARIATION IN-FLIGHT RESPONSE OF THE SPECIALIST PARASITOID *MACROCENTRUS-GRANDII* GOIDANICH TO ODORS FROM FOOD PLANTS OF ITS EUROPEAN CORN-BORER HOST." *Entomologia Experimentalis Et Applicata* 69(2): 183-193.

The specialist parasitoid *Macrocentrus grandii* Goidanich (Hymenoptera: Braconidae) appears to parasitize its polyphagous host, European corn borer (*Ostrinia nubilalis* (Hubner)) (Lepidoptera: Pyralidae), in only certain habitats. To determine whether it differed in its olfactory response to host-habitat odours, volatiles from four plants were isolated using Tenax. Wind tunnel bioassays of the extracts revealed that, besides corn which was tested in an earlier study, olfactory stimuli for attraction of *M. grandii* females were present in potato and snap bean but not in pepper or soybean. To further characterize the response to pepper and soybean, these extracts were bioassayed in combination with an attractive extract. The results indicated that pepper volatiles evoked a neutral response in *M. grandii* while

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response to soybean volatiles appeared to be neutral or slightly negative. The innate response to soybean volatiles was altered to one of attraction after oviposition experience on soybean. Seven days after oviposition, experienced females continued to respond positively to soybean volatiles. Components of soybean volatiles responsible for the change in flight behaviour resulting from oviposition experience were eluted by nonpolar and slightly polar solvents. These results support the idea that plant odour may be a factor determining the range of plants on which *M. grandii* parasitizes its host. The study indicates the occurrence of associative learning of plant-related volatiles during oviposition in *M. grandii*, and suggests the involvement of diverse plant compounds in the learning process.

Wilson, R. L., L. M. Pollak and K. E. Ziegler (1993). "EVALUATION OF THE UNITED-STATES-NATIONAL-GERMPLASM-SYSTEM POPCORN COLLECTION FOR RESISTANCE TO CORN-EARWORM (LEPIDOPTERA, NOCTUIDAE) AND EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Journal of Economic Entomology* 86(3): 952-956.

The U.S. National Germplasm System's active collection of popcorn, *Zea mays* L., is maintained at the North Central Regional Plant Introduction Station at Ames, IA. From 1983 to 1989 and from 1982 to 1990, 299 accessions of this collection were evaluated for sources of resistance to com earworm, *Helicoverpa zea* (Boddie), and European com borer, *Ostrinia nubilalis* (Hubner), respectively. During 1990, 32 accessions previously rated as resistant to com earworm, and in 1991, 39 accessions previously rated as resistant to leaf feeding by first-generation European com borer were retested for resistance. Corn earworm larval weights, when grown on silks from 21 of the 32 accessions retested for resistance, were not significantly different from the weights of larvae grown on the resistant control but were significantly smaller than larvae grown on the susceptible control. Fourteen of the 39 accessions retested for first-generation feeding resistance to European corn borer retained their resistance. Genetic studies will be necessary to determine if these new sources of resistance are governed by genes different from those in previously identified sources.

Zhang, H. S., Y. Y. Li, Q. R. Liu, H. Wang, W. Kang and A. Int Atom Energy (1993). CROSSING EXPERIMENTS BETWEEN EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (HUBNER), AND ASIAN CORN-BORER, *OSTRINIA-FURNACALIS* (GUENEE), TO EXPLORE THE POSSIBILITY OF HYBRID STERILITY. *Radiation Induced F1 Sterility in Lepidoptera for Area-Wide Control*: 131-133.

Andow, D. A. (1992). "FATE OF EGGS OF 1ST-GENERATION *OSTRINIA-NUBILALIS* (LEPIDOPTERA, PYRALIDAE) IN 3 CONSERVATION TILLAGE SYSTEMS." *Environmental Entomology* 21(2): 388-393.

Percentage hatch, chewing predation, *Chrysopa* sp. predation, other sucking predation, and parasitism by *Trichogramma* sp. of egg masses of first-generation *Ostrinia nubilalis* (Hubner) were estimated in spring chisel plow, ridge tillage, and no-tillage maize, *Zea mays* L., in southeastern Minnesota during 1986 and 1987. Tillage plots were split with and without terbufos application and with and without *Bacillus thuringiensis*-permethrin application in all combinations. Egg masses from laboratory reared *O. nubilalis* were exposed to natural enemies in the field eight times during the oviposition period of first-generation *O. nubilalis*, and population densities of *Coleomegilla maculata* DeGeer were estimated. Parasitism was 0.6% and predation was low during 1986. During 1987, chewing predation was highest in the chisel-plow system and lowest in the no-tillage system; *Chrysopa* sp. predation was lowest in the chisel-plow system and highest in the no-tillage system. *C. maculata* population densities were highest in the chisel-plow system and lowest in the no-tillage system, and chewing predation was positively related to *C. maculata* density. Predation by other unknown chewing predators was also higher in the chisel-plow system and lowest in the no-tillage system. The inverse relation between chewing and *Chrysopa* sp. predation was probably related to species-specific responses to the tillage environments.

Bing, L. A. and L. C. Lewis (1992). "TEMPORAL RELATIONSHIPS BETWEEN ZEA-MAYS, *OSTRINIA-NUBILALIS* (LEP, PYRALIDAE) AND ENDOPHYTIC *BEAUVERIA-BASSIANA*." *Entomophaga* 37(4): 525-536.

The entomopathogenic fungus, *Beauveria bassiana* (Balsamo) Vuillemin, was applied to whorl-stage (V7) corn, *Zea mays* L., by foliar application of a granular formulation of com grits containing conidia or by injection of a conidial suspension. All plants were infested with European com borer larvae, *Ostrinia nubilalis* (Hubner), at the V7 (whorl), V12 (late-whorl), or V17 (pretassel) stage of plant development. Plants infested at whorl and late-whorl stages had significantly more European com borer tunneling than did plants infested at the pretassel stage. The percentage of plants colonized by *B. bassiana* did not differ significantly among the whorl, late-whorl, and pretassel stages. As the

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plants matured, *B. bassiana* was isolated from different plant areas, with the pith more frequently colonized than the leaf collars. Foliar application of *B. bassiana* provided immediate suppression of *O. nubilalis* in those plants infested at whorl stage. The reduced efficacy of *B. bassiana* at the intermediate plant stages relative to efficacy at harvest is discussed.

Buntin, G. D. (1992). "DAMAGE BY THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) TO WINTER-WHEAT." *Journal of Entomological Science* 27(4): 361-365.

The effect of European corn borer, *Ostrinia nubilalis* (Hubner), injury during the spring on yield and yield components of winter wheat, *Triticum aestivum* L. em Thell, was studied. Spike and grain characteristics of infested and uninfested culms were compared in three fields of 'Florida 302' winter wheat in eastern Georgia. Feeding on inner stem tissue by larvae killed the grain spike producing a "white head" symptom in wheat. Most larvae (95.2%) tunneled in the peduncle which caused an average of 3.4% of spikes to be barren. Larval injury did not reduce spike length but did reduce grain weight per spike by 44.6% and grain weight per kernel by 41.9%. Kernel number per spike was reduced by 11.7% mostly because of a 9.9% reduction in kernel number per spikelet. Spikelet number per spike was reduced by 1.8%. Tunnelling by *O. nubilalis* larvae also reduced grain test weight and quality. These results indicated that a culm infestation of 10% or more would be necessary before control measures would be justified in winter wheat.

Coll, M. and D. G. Bottrell (1992). "Mortality of European Corn Borer Larvae by Natural Enemies in Different Corn Microhabitats." *Biological Control* 2(2): 95-103.

Larvae of the European corn borer, *Ostrinia nubilalis* (Hubner), sustained high mortality in field corn, *Zea mays* L., in western Maryland. Mortality was highest in the first two larval stadia but varied greatly among larvae in different corn plant microhabitats. Predation, primarily by the anthocorid, *Orius insidiosus* (Say), was an important larval mortality factor whereas parasitism was minor. Young corn borer larvae in the relatively exposed microhabitats of whorls and leaf axils incurred higher mortality rates (respectively, 80 and 72%) than larvae concealed in ears (53%). Predation and undetermined causes were the key mortality factors of larvae in leaf axils. Predation alone, however, was the important factor affecting mortality in larvae inhabiting corn ears. Predators killed about 33% of second-generation first instar borer larvae in the leaf axils and ears and about 41% of first-generation first instar borer larvae in the whorls. Undetermined (residual) mortality factors (e.g., weather, host plant resistance, pathogens) had more impact on larvae in exposed microhabitats (whorls and leaf axils) than on larvae concealed in ears and stems. *O. insidiosus* appears to be the most important predator of corn borer larvae in western Maryland. The predator's population peaks coincide with corn pollen-shedding and silking. Then, the insect feeds on second-generation borer larvae as well as corn pollen in leaf axils. Successful biological control of corn borer larvae by *O. insidiosus* is therefore linked to both arthropod prey and corn pollen food sources. (c) 1992 Academic Press, Inc.

Derrick, M. E., J. W. Vanduyn, C. E. Sorenson and G. G. Kennedy (1992). "EFFECT OF PHEROMONE TRAP PLACEMENT ON CAPTURE OF MALE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) IN 3 NORTH-CAROLINA CROPS." *Environmental Entomology* 21(2): 240-246.

Modified screen mesh versions of the Hartstack pheromone trap were placed within and adjacent to fields of potato, corn, and cotton to investigate the effect of trap placement on male capture during the first, second, and third flights of *Ostrinia nubilalis* (Hubner). During the first flight in 1988, traps within potato fields captured greater numbers of males than traps outside of the field in the grass border. In 1990, total captures were few and capture rates were equal between locations. Weekly trap captures within the field were significantly correlated with weekly egg mass numbers sampled in the field in 1990. During 1989 and 1990, traps within cornfields at ear level captured greater numbers of second-flight males than traps in the field at canopy height and traps in the field border. Weekly trap captures within the field at ear and canopy level and adjacent to the field were significantly correlated with egg masses. In cotton, traps within the field captured more males than traps outside the field during 1988 and 1989, and captures were equal between locations in 1990. These results confirm that in North Carolina, *O. nubilalis* males seek mates both within and outside of field boundaries and indicate the potential merit of trap placement within the field.

Ellsworth, P. C. and J. R. Bradley (1992). "COMPARATIVE DAMAGE POTENTIAL AND FEEDING DYNAMICS OF THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) AND COTTON BOLLWORM (LEPIDOPTERA, NOCTUIDAE) ON COTTON BOLLS." *Journal of Economic Entomology* 85(2): 402-410.

European corn borer, *Ostrinia nubilalis* (Hubner), larvae are more likely to bore into 7-, 14-, 21-, and 28-d-old cotton bolls, *Gossypium hirsutum* L., when offered a no-choice situation than are cotton bollworm, *Helicoverpa zea* (Boddie) larvae. None of these four boll ages was safe from European corn borer entry for any instar tested. Cotton bollworm larvae were less able to penetrate larger bolls (21 and 28 d old) and did so appreciably only in the fourth and fifth instars. Early instar cotton bollworms did not appreciably penetrate younger bolls (i.e., first instars in 7- and 14-d-old bolls and second instars in 14-d-old bolls). Given adult and larval behaviors, bolls greater-than-or-equal-to 21 d old probably escape cotton bollworm entry; however, European corn borers can enter cotton bolls of any age. The character of the feeding damage is less severe and less cryptic in the cotton bollworm compared with the European corn borer. Bollworm entry holes were larger in surface area, which allowed drying of the wound. European corn borers removed only enough boll wall tissue to gain entry into the carpels and left the wound watery and ideal for growth of boll rot organisms. The relatively few times that the cotton bollworm gained entry into the boll, it entered from the top two-thirds of the boll. However, European corn borers usually entered the boll in the bottom third, often through or from within the axial surface of the calyx. The ramifications of the feeding dynamics of these two species for pest scouting and management are discussed, and a model for predicting the probability that these larvae will enter boll tissue is presented.

Ellsworth, P. C., J. R. Bradley, G. G. Kennedy, R. P. Patterson and R. E. Stinner (1992). "IRRIGATION EFFECTS ON EUROPEAN CORN-BORER - MAIZE WATER RELATIONS." *Entomologia Experimentalis Et Applicata* 64(1): 11-21.

This study examined the impact of irrigation water on certain aspects of an insect-plant relationship in the field including the assessment of plant-mediated water effects on an herbivore's development, survival, and behavior, and plant damage parameters and host tissue water status. Maize (*Zea mays* L.) plants were arranged in a randomized complete block design in the field over two years in North Carolina (NC). Four blocks were subjected to three different irrigation treatments initiated ca. one week before anthesis: optimal, intermediate, deficit water supply. Each plant was infested with one (1986) or two (1987) black head stage, E-race European corn borer [*Ostrinia nubilalis* (Hubn.)] (ECB) egg masses at tasselling. ECB development, tunnelling site, and survival as well as plant tissue water status (tissue % water contents [θ] & leaf water potentials [PSI]) were recorded through July. The irrigation effect on ECB parameters was slight and variable. Internal stalk temperatures of optimal plants were consistently cooler than their deficit counterparts (1 day-degree/day). With degree-days included as an explanatory variable in the analyses, there were no significant irrigation effects on the ECB parameters, except for total proportion of ECB's bored into maize plant parts. More ECB's bored into drier plants than in optimal plants; however, this trend was not significant in 1987. Plant water indices showed that though PSI-responded to irrigation, there were only minor changes in tissue- θ , particularly in view of the larger diurnal tissue changes observed and the relatively high, sustained stalk- θ levels seen over all treatments. Examination of ECB pupal- θ confirmed that dietary water changes were minor or non-limiting to the insects' developmental physiology, because pupal- θ was not sensitive to the irrigation treatments. Though water supply changes have drastic developmental and agronomic consequences for the maize plant, little or no changes were seen in the ECB feeding environment. Furthermore, a plant damage model was developed whereby the total % of ECB's tunnelled into maize was related to the mean larval age. The implications of this model on the understanding of ECB tunnelling behavior, damage potential, and pest management is noted.

Feng, R., J. G. Houseman and A. E. R. Downe (1992). "EFFECT OF INGESTED MERIDIC DIET AND CORN LEAVES ON MIDGUT DETOXIFICATION PROCESSES IN THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS." *Pesticide Biochemistry and Physiology* 42(3): 203-210.

Feng, R., J. G. Houseman, A. E. R. Downe, J. Atkinson and J. T. Arnason (1992). "EFFECTS OF 2,4-DIHYDROXY-7-METHOXY-1,4-BENZOXAZIN-3-ONE (DIMBOA) AND 6-METHOXYBENZOXAZOLINONE (MBOA) ON THE DETOXIFICATION PROCESSES IN THE LARVAL MIDGUT OF THE EUROPEAN CORN-BORER." *Pesticide Biochemistry and Physiology* 44(2): 147-154.

Frenoy, C., C. Durier and N. Hawlitzky (1992). "EFFECT OF KAIROMONES FROM EGG AND FEMALE-ADULT STAGES OF OSTRINIA-NUBILALIS (HUBNER) (LEPIDOPTERA, PYRALIDAE) ON TRICHOGRAMMA-BRASSICAE BEZDENKO (HYMENOPTERA, TRICHOGRAMMATIDAE) FEMALE KINESIS." *Journal of Chemical Ecology* 18(5): 761-773.

Volatile chemicals emanating from the different developmental stages of *Ostrinia nubilalis* Hubner (Lepidoptera, Pyralidae) increase the mobility of *Trichogramma brassicae* Bezdenko (Hymenoptera, Trichogrammatidae) in a linear airflow olfactometer. In this paper, we have demonstrated that airborne chemicals from egg masses and virgin females during calling activity stimulate an intensive search behavior by *Trichogramma* females. On the other hand, emanations from mated females with extruded abdominal tips do not incite the parasitoid's movement. For the moment we cannot elucidate, with these bioassays, the real role of these kairomones as attractants, guides, stimulants, or retainers.

Gelman, D. B., B. S. Thyagaraja, T. J. Kelly, E. P. Masler, R. A. Bell and A. B. Borkovec (1992). "PROTHORACICOTROPIC HORMONE LEVELS IN BRAINS OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS - DIAPAUSE VS THE NONDIAPAUSE STATE." *Journal of Insect Physiology* 38(5): 383-395.

Brains from non-diapause-bound, diapause-bound and diapausing European corn borers contain prothoracicotropic hormone (PTTH) which stimulates the prothoracic glands of both *Lymantria dispar* and *Ostrinia nubilalis* to produce ecdysone and 3-dehydroecdysone in a dose-dependent manner. At a dose of 0.75 brain equivalents, PTTH activity is highest in non-diapause-bound and diapausing prepupae. Levels are approx. 50% as high in younger 5th instars. In diapausing prepupae, PTTH activity again falls to approx. 50% after 5-8 weeks of refrigeration. Prothoracic glands from diapausing *O. nubilalis* prepupae were refractory to stimulation. In vivo experiments indicate that brains from diapausing prepupae have more moult-stimulating activity than those from non-diapause-bound prepupae. However, this may be due to the presence of factors other than PTTH. Based on gel filtration HPLC, the molecular weight range of the small form of *O. nubilalis* PTTH is 1500-3300 Da, somewhat less than the 5000-7000 Da peptide reported for other lepidopterans.

Glover, T. J., P. S. Robbins, C. J. Eckenrode and W. L. Roelofs (1992). "GENETIC-CONTROL OF VOLTINISM CHARACTERISTICS IN EUROPEAN CORN-BORER RACES ASSESSED WITH A MARKER GENE." *Archives of Insect Biochemistry and Physiology* 20(2): 107-117.

The post-diapause development (PDD) time for univoltine European corn borers (ECB) under diapause breaking conditions averages approximately 44 days, whereas the PDD time for bivoltine ECB under the same conditions is approximately 15 days. This difference is the principal component of the life cycle that determines the number of generations possible in a summer. Previous workers have demonstrated some genetic control of differences in voltinism among populations, including apparent control by sex-linked (Z-linked) genes. In the present study allozymes of the enzyme, triose phosphate isomerase (TPI), were used as markers of the Z chromosomes in crosses of a bivoltine colony (Tpi-1) and a univoltine colony (Tpi-2). The F1 resulting from a cross of univoltine females (Z2W) and bivoltine males (Z1Z1) consisted of hemizygous Tpi-1 females (Z1W) with a mean PDD time of 19 days and heterozygous Tpi-1/Tpi-2 males (Z1Z2) with a mean PDD time of 34 days. The F2 progeny consisted of Tpi-1 females (Z1W) (mean PDD time = 15 days), Tpi-2 females (Z2W) (mean PDD time = 40 days), homozygous Tpi-1 males (Z1Z1) (mean PDD time = 16 days), and heterozygous Tpi-1/Tpi-2 males (Z1Z2) (mean PDD time = 25 days). The close correlation of TPI phenotypes and PDD times in these crosses, along with similar results for the maternal and paternal backcrosses of the F1 individuals, indicates that the PDD time is principally controlled by genes on the Z chromosome and that heterozygous males exhibit incomplete or partial dominance of these genes.

Godfrey, L. D., J. M. Norman and T. O. Holtzer (1992). "INTERACTIVE EFFECTS OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) TUNNELING AND DROUGHT STRESS ON FIELD CORN WATER RELATIONS." *Environmental Entomology* 21(5): 1060-1071.

The effects of drought stress and stem tunneling by European corn borer, *Ostrinia nubilalis* (Hubner), on water relations of field corn, *Zea mays* L., were evaluated in 1987 and 1988. Using a pressure chamber, leaf and stem water potentials averaged 3.8 and 3.5 bars, respectively, higher in plants from well-watered soils compared with drought-stressed plants. Larval tunneling had no effect on the leaf or stem water potential. A vacuum infiltration technique was developed to examine the effects of these factors on stem hydraulic conductance and provided hydraulic conductance measurements comparable with that predicted with the Hagen-Poiseuille equation. *O. nubilalis* tunneling reduced the

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internode hydraulic conductance by up to 63.5% compared with undamaged stems, and slight reductions were also seen with conductance through intact stems (internode with attached node). The node appeared to mitigate the effects of tunneling on hydraulic conductance in intact stem sections. Soil moisture status had no effects on hydraulic conductance as measured with the vacuum infiltration technique. *O. nubilalis* tunneling, from a single larva, rendered an average of 36.6% of the medullary xylem vessels nonfunctional and also slightly reduced the functioning of the peripheral xylem vessels. Finally, *O. nubilalis* tunnel dimensions averaged 783.1 mm³ in volume, and 46.7 mm in length, and 9.2% of the stem area was tunneled. Tunnel dimensions were generally similar in stem sections from plants from fully irrigated and drought-stressed soils. Tunnel measurements related to cavity volume and cross-sectional area destroyed were more closely correlated with hydraulic conductance than were tunnel length or shape. The majority of damage to the plants' vascular system, as reflected by hydraulic conductance, stained vessels, and cavity dimensions, occurred during the first 6 d of tunneling.

Houseman, J. G., F. Campos, N. M. R. Thie, B. J. R. Philogene, J. Atkinson, P. Morand and J. T. Arnason (1992). "EFFECT OF THE MAIZE-DERIVED COMPOUNDS DIMBOA AND MBOA ON GROWTH AND DIGESTIVE PROCESSES OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Journal of Economic Entomology* 85(3): 669-674.

The maize derived growth inhibitor, 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA), and one of its degradation products, 6-methoxybenzoxazolin-3-one (MBOA), were assessed for their mode of action on larvae of the European corn borer, *Ostrinia nubilalis* (Hubner). Nutritional indices computed for larvae administered the compounds in their diets showed that DIMBOA reduced the approximate digestibility of food and that MBOA reduced the efficiency of conversion of digested food. The results suggested that DIMBOA acts primarily as a digestive toxin and that the effects of MBOA occurred after digestion. Based on measurements of hydrolysis of artificial protease substrates, inclusion of DIMBOA or MBOA in diet ingested for 48 h or with crude gut homogenates reduced the activity of trypsin. Inclusion of DIMBOA decreased the activity of chymotrypsin on artificial substrates. DIMBOA inhibition of partially purified larval corn borer chymotrypsin was noncompetitive.

Hudon, M., G. Bourgeois, G. Boivin and D. Chez (1992). "YIELD REDUCTIONS IN GRAIN MAIZE ASSOCIATED WITH THE PRESENCE OF EUROPEAN CORN-BORER AND GIBBERELLA STALK ROT IN QUEBEC." *Phytoprotection* 73(3): 101-110.

The impact of European corn borer (*Ostrinia nubilalis*) [Lepidoptera: Pyralidae] infestation and stalk rot infection caused by *Gibberella zeae* on yield of eight grain maize (*Zea mays*) inbreds, two commercial and six experimental hybrids was evaluated from 1975 to 1980. Three criteria were used: leaf feeding, total plant damage at harvest and tunnel length/plant height ratio. For most criteria, the cultivars were significantly different and the artificial European corn borer infestation had an effect almost every year. Although *G. zeae* can have a significant-effect on plant damage at harvest and yield of grain maize, no consistent link was found between stalk rot and European corn borer.

Keil, C. B. and C. Tipping (1992). "STIMULATION OF OVIPOSITION AND HETEROSIS IN INTERSTRAIN CROSSES OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Journal of Entomological Science* 27(3): 239-250.

Hybrid matings of two *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae) colonies (N and O), established in the laboratory a year apart, demonstrated positive heterosis in the F1 generation as indicated by increases in pupal weight (6%), number of egg masses per female (65%) and number of eggs per female (77%) as compared to intra-colony crosses in mass matings. In contrast, pupation date, an indicator of development time, was intermediate in the hybrids relative to the parental colonies. There was also a 37% increase in the numbers of eggs/female and a 45% increase in egg masses/female in the hybrid parental cross. We investigated this stimulation of oviposition in single female, reciprocal crosses. Oviposition stimulation was directional with the cross of N colony males x O colony females exhibiting significantly higher numbers of total eggs/female and egg masses/female on a daily basis. Colony O females in this cross laid more large egg masses than females in other crosses. Data from individual female crosses demonstrated that egg production in hybrid mass mating experiments was consistent with random mating of males and females from both colonies.

Klun, J. A., M. Schwarz and E. C. Uebel (1992). "BIOLOGICAL-ACTIVITY AND INVIVO DEGRADATION OF TRITIATED FEMALE SEX PHERMONE IN THE MALE EUROPEAN CORN-BORER." *Journal of Chemical Ecology* 18(3): 283-298.

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Isomers of [11,12-H-3(2)]-11-tetradecenyl acetate (57 Ci/mM) were synthesized. Behavioral assay of the two compounds using Z- and E-type European corn borer (ECB) males showed that introduction of tritons into the double bond of the pheromone caused a significant isotope effect in the E-type ECB but not in the Z-type ECB. Measurements of tritium associated with the male antennae after a 3-min exposure showed that radioactivity equivalent to 10(-17) mol pheromone was adsorbed onto male antennae. Time-course in vivo metabolic studies with picogram amounts of compound applied topically to antennae of E- and Z-type males and Z-type females showed that they metabolized pheromone similarly but females degraded pheromone more slowly than males. Pheromone was hydrolyzed, and the only other major radiolabeled metabolite observed by combined high-pressure liquid chromatography-radiodetection was tritiated water. Capillary gas chromatography and radiomonitoring permitted detection of a trace amount of 11-tetradecenoic acid, which indicated alcohol oxidase activity is associated with the antennae. Evidence shows that clearing of pheromone from the ECB male antennae involves hydrolysis and oxidation of the alcohol to fatty acid, which in turn is degraded, probably via beta-oxidation, to carbon dioxide and water.

Labatte, J. M., B. Got, M. Chartier and F. Ruget (1992). "VALIDATION OF THE EUROPEAN CORN-BORER DAMAGE MODEL ON MAIZE USING X-RAYS." *Annals of Applied Biology* 121(3): 483-491.

In order to explain and predict yield losses caused by European corn borer larvae, *Ostrinia nubilalis* Hbn. (Lepidoptera: Pyralidae), a mechanistic model was proposed to describe cavity appearance, their lengthwise extension, and their within-plant distribution. It integrates main dynamical processes of larvae: mortality, development and within-plant distribution. After its estimation and test under field conditions in 1988 and 1989, its validation, based upon X-ray photographs, is presented. This method allows cavity appearance and lengthwise extension to be followed without damaging the plants. This study confirms the relevance of the damage model and the rate of cavity lengthwise extension estimated with it.

Landis, D. A. and M. J. Haas (1992). "INFLUENCE OF LANDSCAPE STRUCTURE ON ABUNDANCE AND WITHIN-FIELD DISTRIBUTION OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) LARVAL PARASITOIDS IN MICHIGAN." *Environmental Entomology* 21(2): 409-416.

Studies were conducted at eight locations in Ingham County, Michigan, during 1989-1990 to determine the within-field distribution of European corn borer, *Ostrinia nubilalis* (Hubner), larval parasitism. *O. nubilalis* larval sampling was conducted at multiple locations on three transects across large 1st-yr corn fields during the F1 and F2 generations. Plants were destructively sampled to determine *O. nubilalis* abundance and larvae were returned to the lab to determine parasitism. *Eriborus terebrans* (Gravenhorst) (Hymenoptera: Ichneumonidae) was the dominant parasitoid of *O. nubilalis* in the sampled fields, accounting for 92.5% of the F1 and 99.2% of the F2 parasitism during 1989; and for 92.2% of the F1 and 99.1% of the F2 during 1990. Average parasitism by *E. terebrans* (n = 4 fields) was 4.9 and 18.7% of F1, 10.2 and 9.1% of F2 larvae during 1989 and 1990 respectively. The maximum *E. terebrans* parasitism observed (37.4%) of the *O. nubilalis* larvae in one field (F1, 1990), is the highest level reported for this species in the Midwest. Parasitism by *E. terebrans* during the F1 generation was greater along field margins than in field interiors in most fields during both years. During 1990, *O. nubilalis* larvae near wooded edges had significantly higher *E. terebrans* parasitism than those near nonwooded edges or field interiors. In the F2 generation, parasitism did not vary significantly from field margins to field interiors in either year. There was no consistent relationship between *O. nubilalis* larval density per infested plant and *E. terebrans* parasitism. These data suggest that local landscape structure, including proximity of particular noncrop habitats, plays an important role in the effectiveness of this natural enemy.

Langenbruch, G. A. and N. Lorenz (1992). "A 10-YEAR STUDY ON THE APPLICABILITY OF PHEROMONE-BAITED TRAPS FOR MONITORING THE EUROPEAN CORN-BORER (*OSTRINIA-NUBILALIS* HBN) IN THE FEDERAL-REPUBLIC-OF-GERMANY. 1. DISTRIBUTION OF PHEROMONE STRAINS AND TESTING OF DIFFERENT TRAP TYPES, BAITS AND TRAP SITES." *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection* 99(1): 80-92.

Since 1981, the suitability of pheromone-baited traps for monitoring the European corn borer has been investigated in several regions of the Federal Republic of Germany (mainly in South Hesse, Rheinland-Pfalz, Baden-Wurtemberg and Bavaria). In all regions with remarkable corn borer damage, the Z-strain of the moth was of superior importance as compared to the E-strain and associated hybrids. At least in South Hesse, the 'Pherocon 1C-trap' (Zoecon, USA) with an ECB-I bait as well as the 'Biotrap' (Hoechst AG, FRG) with 20- μ -g or 60- μ -g of 97 Z-: 3 E-11-tetradecenyl acetate per

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dispenser proved to be useful. For reduction of catches of non-target insects in 'Biotrap' traps, a green or black painting of the white-coloured trap is recommended.

Losey, J. E., P. Z. Song, D. M. Schmidt, D. D. Calvin and D. J. Liewehr (1992). "LARVAL PARASITOIDS COLLECTED FROM OVERWINTERING EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) IN PENNSYLVANIA." *Journal of the Kansas Entomological Society* 65(1): 87-90.

Three imported parasitoids emerged from larvae of the European corn borer, *Ostrinia nubilalis* (Hubner), from overwintering sites in corn in Pennsylvania in 1990. *Macrocentrus grandii* was the principal parasitoid, emerging from 17.4% of the overwintering larvae collected. The other specimens, *Lydella thompsoni* and *Eriborus terebrans*, were recovered from less than three percent of the overwintering larvae. The entomopathogenic fungus, *Beauveria bassiana* appeared in 8.8% of the larvae. In total 34% of the larvae produced an identifiable parasitoid or pathogen, and another 10.2% were killed by unknown causes.

Ma, R. L. Z., P. D. Swedenborg and R. L. Jones (1992). "HOST-SEEKING BEHAVIOR OF ERIBORUS-TEREBRANS (HYMENOPTERA, ICHNEUMONIDAE) TOWARD THE EUROPEAN CORN-BORER AND THE ROLE OF CHEMICAL STIMULI." *Annals of the Entomological Society of America* 85(1): 72-79.

Newly designed T trap and wind tunnel bioassays demonstrated that attraction of female *Eriborus terebrans* (Gravenhorst) to larvae of the European corn borer, *Ostrinia nubilalis* (Hubner), was elicited by odors of host plant complex (HPC), frass, corn plants, host larvae, feces, and oral secretion. Female experience had a fundamental influence on behavior, and green and yellow colors were attractive to females in the wind tunnel. Antennation, intensive examination, and probing-oviposition behavior of the parasitoid were readily stimulated in contact bioassays by HPC, host larva silk, frass, oral secretion, and cuticle. Serine and certain other amino acids elicited intensive examination and occasional probing. Volatile and contact chemicals mediating behavior were extractable with hexane, acetone, chloroform, and methanol. The role of vision and the possibility of multiple chemical cues involved in both long- and close-range host-seeking behaviors are discussed.

Marionpoll, F. C., D. Guillaumin and C. Masson (1992). "SEXUAL DIMORPHISM OF TARSAL RECEPTORS AND SENSORY EQUIPMENT OF THE OVIPOSITOR IN THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS*." *Cell and Tissue Research* 267(3): 507-518.

Sensilla on legs and ovipositor of the moth *Ostrinia nubilalis* were investigated by light and scanning electron microscopy. The ovipositor is composed of two papillae densely packed with medium length mechanoreceptor sensilla (MRb: 80-160- μ -m, n = 420-460). Long mechanoreceptor sensilla (MRa: 250-300- μ -m, n = 20-24) and contact chemoreceptors (CRa: 30-40- μ -m, n = 20-28) are evenly distributed at the periphery of these papillae. Legs support contact chemoreceptors (CRa), scattered among the scales. The pretarsus structure of each leg includes a single contact chemoreceptor (125- μ -m) inserted dorsally. The fifth tarsomere bears a ventral area without scales on which contact chemoreceptors are disposed in two parallel rows (CRb: 40-60- μ -m). A sexual dimorphism was found in the number and density of these sensilla (females: mean = 5.3, SD = 1.0; males: mean = 3.3, SD = 0.7), and in the size of the sensory field. The possible involvement of these sensory structures in oviposition site selection is discussed.

Ohnesorge, B. (1992). "INVESTIGATIONS ON THE POPULATION-DYNAMICS OF THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* HBN (LEP, PYRALIDAE) IN BADEN-WURTTENBERG .3. THE FLUCTUATIONS." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 113(4): 321-329.

The population density of *Ostrinia nubilalis* (ECB) was recorded during 1976-1990 in a semiquantitative way from 18-40 margins of maize fields in an area south from Stuttgart, called the "Filder Plain". Until the begin of the investigations, maize had not experienced severe borer damage in this area, but from 1978 onward ECB increased in numbers and damaged from 1983 to 1987 in parts of the area numerous maize fields. Thereafter, a decline started. The population dynamics of ECB followed a typical cyclic pattern. Meteorological data from a nearby station suggest a modificatory influence of spring and summer temperatures on the fluctuations, but this influence is not strong enough to interfere essentially with the general trend. The possible driving forces of the cycles are discussed but remain unknown. The fluctuation curves in the different subareas parallel each other to a fairly large extent but progress on completely different levels: In subareas in which a high proportion of maize was grown for grain production and harvested late in

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the season, ECB density was about 10fold of the density in those subareas in which almost all maize was harvested early and used for cattle fodder or ensilage. Time of harvest, therefore, seems to be an essential factor in determining the level of ECB attack. The data indicate that a proportion of 20 % grain maize or CCM in an area might be sufficient to keep up a fairly dense ECB population. It is concluded that the increase of ECB density during the first part of the investigation period has been caused by some changes in maize production and use.

Pavuk, D. M. and B. R. Stinner (1992). "Influence of Weed Communities in Corn Plantings on Parasitism of *Ostrinia nubilalis* (Lepidoptera: Pyralidae) by *Eriborus terebrans* (Hymenoptera: Ichneumonidae)." *Biological Control* 2(4): 312-316.

Parasitism of second generation European corn borer, *Ostrinia nubilalis* (Hubner), larvae by parasitoids was examined in corn (*Zea mays*) plantings having different weed communities. Treatments were corn without weeds, corn principally with broadleaf weeds, corn principally with grassy weeds, and corn with a mixture of broadleaves and grasses. *O. nubilalis* larvae were collected and maintained on artificial diet under constant environmental conditions in the laboratory to determine levels of parasitization. The ichneumonid, *Eriborus terebrans* (Gravenhorst), was the only parasitoid species reared, with the exception of a single tachinid, tentatively identified as *Lydella thompsoni*. Neither broadleaf nor grassy weeds had significant influences on parasitization of larvae during the study. Parasitism was positively correlated with host density (number of larvae per plant) in the corn-broadleaf weed community in 1988. Parasitism was greater in all treatments in 1989 than in 1988, ranging from 2.1 to 5.6% in 1988 and from 20.0 to 29.1% in 1989. The results were inconclusive as to whether weeds within corn plantings augment parasitism of *O. nubilalis* larvae by *E. terebrans* or by other parasitoids. (c) 1992 Academic Press, Inc.

Prokrym, D. R., D. A. Andow, J. A. Ciborowski and D. D. Sreenivasam (1992). "SUPPRESSION OF *OSTRINIA-NUBILALIS* BY *TRICHOGRAMMA-NUBILALE* IN SWEET CORN." *Entomologia Experimentalis Et Applicata* 64(1): 73-85.

We conducted inundative release experiments with *Trichogramma nubilale* (Hymenoptera: Trichogrammatidae) to suppress *Ostrinia nubilalis* (Lepidoptera:Pyralidae) in sweet corn (*Zea mays*): two experiment during *O. nubilalis* first generation and three experiments during second generation. Five measurements of ear and stalk damage were used to assess *O. nubilalis* control in treated and untreated plots within each experimental field. In one experiment during second generation, natural *O. nubilalis* populations were sufficiently high to demonstrate that the parasitoids (three releases totaling 4.4 million parasitoids per ha) parasitized an estimated 57.4% of the placed *O. nubilalis* egg masses and reduced the mean number of *O. nubilalis* larvae per ear by 97.4%, the number of tunnels per stalk by 92.9%, and the number of larvae per stalk by 94.3% in the release plot. Ear damage in this experiment was suppressed to meet acceptable standards for use in cut-corn commercial processing. Larval mortality was apparently density independent, which implies that density-dependent larval loss would not compensate for egg parasitism by *T. nubilale*.

Renou, M., P. Nagnan, A. Berthier and C. Durier (1992). "IDENTIFICATION OF COMPOUNDS FROM THE EGGS OF *OSTRINIA-NUBILALIS* AND *MAMESTRA-BRASSICAE* HAVING KAIROMONE ACTIVITY ON *TRICHOGRAMMA-BRASSICAE*." *Entomologia Experimentalis Et Applicata* 63(3): 291-303.

In the presence of an extract of *Ostrinia nubilalis* or *Mamestra brassicae* eggs, female *Trichogramma brassicae* exhibited increased rates of upwind locomotion in the tubes of a linear olfactometer. GC and GC-MS analyses of *O. nubilalis* and *M. brassicae* egg extracts revealed the presence of fatty acids, their ethyl esters, and various hydrocarbons. Exposing the wasps to a mixture of the five main saturated hydrocarbons (heneicosane, tricosane, pentacosane, heptacosane and nonacosane) increased the upwind progression in the olfactometer. Single hydrocarbons elicited reduced or no activity. Ethyl palmitate and palmitic acid were also effective in increasing upwind locomotion. Z11- 14:Ac, the main component of the female sex pheromone of *O. nubilalis* was inactive, regardless of its concentration. It is concluded that various compounds present on the surface of the *O. nubilalis* egg masses may play a role in the orientation of *T. brassicae* to its host.

Royer, L. and J. N. McNeil (1992). "EVIDENCE OF A MALE SEX-PHEROMONE IN THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (HUBNER) (LEPIDOPTERA, PYRALIDAE)." *Canadian Entomologist* 124(1): 113-116.

European corn borer males have hair pencils located ventrally on the 8th sternite and these are extruded when a male approaches a calling female. The fact that (i) antennectomized females mated significantly less than both intact controls and individuals subjected to other forms of surgery, and (ii) males with hair pencils removed had a significantly lower

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mating success than control males, suggests that a male pheromone is involved in the mating system of the European corn borer.

Sajap, A. S. and L. C. Lewis (1992). "CHRONOLOGY OF INFECTION OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) WITH THE MICROSPORIIDIUM NOSEMA-PYRAUSTA - EFFECT ON DEVELOPMENT AND VERTICAL TRANSMISSION." *Environmental Entomology* 21(1): 178-182.

Nosema pyrausta (Paillot) detrimentally affected the development of its host, *Ostrinia nubilalis* (Hubner). Larvae exposed to the microsporidium during the first two stadia formed abnormal pupae or emerged as abnormal adults. Infections of later instars reduced average longevity of resultant adult females by at least 2 d and fecundity by at least 50%. Eggs from infected adults were contaminated with the microsporidium. The prevalence of transovarial-transovum infections, determined by the presence of spores in eggs or in emerging larvae, varied with the spore concentrations to which the parent females were exposed and with the time (within the oviposition period) that the eggs were laid. Per os infection of *O. nubilalis* larvae with *N. pyrausta* is important in maintaining this microsporidium in a population of *O. nubilalis* as well as reducing the vitality of the population.

Sorenson, C. E., G. G. Kennedy, W. Vanduyne, J. R. Bradley and J. F. Walgenbach (1992). "GEOGRAPHICAL VARIATION IN PHEROMONE RESPONSE OF THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS*, IN NORTH-CAROLINA." *Entomologia Experimentalis Et Applicata* 64(2): 177-185.

The response of male European corn borer, *Ostrinia nubilalis* (Hubner) to synthetic pheromone lures containing various isomeric blends of the sex pheromone 11-tetradecenyl acetate was measured in 13 counties in North Carolina. The blends consisted of either 3% Z ('E strain'), 97 % Z ('Z strain'), or 35% Z ('hybrid') 11-tetradecenyl acetate. Response to E strain lures predominated in those counties located in the Coastal Plain (east) of the state, while response to the Z strain pheromone was dominant in the west. A zone of overlap of these broad strain distributions appears to occur in the eastern Piedmont. Within this zone there was substantial response to both E and Z blends. The proportion of these responses changed considerably between generations within years as well as between years. Significantly higher capture rates in hybrid baited traps in parts of the overlap zone may be indicative of increased rates of hybridization between the E and Z strains.

Stewart, J. G. (1992). "THE EUROPEAN CORN-BORER, *OSTRINIA-NUBILALIS* (LEPIDOPTERA, PYRALIDAE) - A POTENTIAL PEST OF POTATOES GROWN ON PRINCE-EDWARD-ISLAND." *Phytoprotection* 73(1): 25-29.

The effects of the European corn borer, *Ostrinia nubilalis* [Lepidoptera: Pyralidae], on yield of 'Russet Burbank' potatoes (*Solanum tuberosum*) was investigated at two sites in Prince Edward Island in 1989 and 1990. At Summerside, the mean number of larvae per stalk did not exceed 0.19 in either year, and no significant differences in yield were found between untreated plots (check) and plots protected with *Bacillus thuringiensis* var. *kurstaki* (B.t.k.). At Tryon in 1989, a seasonal average of 1.16 larvae per stalk reduced total and marketable yields by 7.5% and 8.8%, respectively, compared to plots protected with B.t.k. A similar but not statistically significant trend was observed in 1990 at this site. The higher degree of damage by the European corn borer to potatoes grown on P.E.I., relative to crops grown in more southerly locations, may be due to the longer interval of attack. On P.E.I., the action threshold for the European corn borer on potatoes appears to be between 0.11 and 0.30 egg masses per stalk.

Udayagiri, S. and R. L. Jones (1992). "FLIGHT BEHAVIOR OF *MACROCENTRUS-GRANDII* GOIDANICH (HYMENOPTERA, BRACONIDAE), A SPECIALIST PARASITOID OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) - FACTORS INFLUENCING RESPONSE TO CORN VOLATILES." *Environmental Entomology* 21(6): 1448-1456.

Flight behavior of the specialist parasitoid *Macrocentrus grandii* Goidanich to olfactory stimuli from corn, the principal food plant of its host, European corn borer, *Ostrinia nubilalis* (Hubner), was studied in a wind tunnel. Extracts of corn volatiles, isolated using Tenax, elicited flight initiation, upwind anemotaxis, casting, landing, and ovipositor unsheathing behaviors in *M. grandii*. Flight responses were dependent on certain plant- and parasitoid-related factors. Leaf and husk volatiles were attractive, while kernel, silk, and tassel volatiles were not. Similar responses were exhibited to volatile extracts from leaves of plants at 2-leaf, 12-leaf, and tassel stages of development and to those of field- and sweet-corn cultivars. Flight response to isolated corn volatiles was gender and age specific. Males and newly emerged females were not attracted. After 4 d, flight response in females increased with age. Attraction was also enhanced after females were

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provided the opportunity to oviposit in corn-fed European corn borers possibly through the process of associative learning. The results of this study suggest that corn volatiles have potential for use for increasing parasitism of European corn borer by *M. grandii*. However, certain plant- and parasitoid-related factors that influence flight behavior of *M. grandii* need to be considered while developing the technique for application in the field.

Udayagiri, S. and R. L. Jones (1992). "ROLE OF PLANT ODOR IN PARASITISM OF EUROPEAN CORN-BORER BY BRACONID SPECIALIST PARASITOID MACROCENTRUS-GRANDII GOIDANICH - ISOLATION AND CHARACTERIZATION OF PLANT SYNONOMES ELICITING PARASITOID FLIGHT RESPONSE." *Journal of Chemical Ecology* 18(10): 1841-1855.

In an earlier study we documented attraction of the specialist parasitoid *Macrocentrus grandii* Goidanich to odors of corn, potato, and snap bean. In the present study the chemical bases of the parasitoid's attraction to these food plants of its European corn borer host were compared. Volatile compounds from corn leaves were isolated using Tenax and identified by capillary gas chromatographic-mass spectrometry. Twenty-one compounds including aldehydes, ketones, alcohols, esters, and sesquiterpenes were present in corn. These were separated into fractions by column chromatography on Florisil. Wind-tunnel bioassays of the fractions indicated that *M. grandii* was attracted to fractions containing nonpolar and slightly polar compounds including sesquiterpenes, aldehydes, a ketone, and esters. More polar compounds in corn, like alcohols, were not attractive. Attraction to potato odor was based on the presence of the same classes of compounds that were attractive in corn, but more polar compounds were involved in attraction to snap bean odor. This study indicated that only some compounds in each of the three odor complexes tested were attractive. It also documented that different compounds were involved in attraction of *M. grandii* to different plant odors.

Weissling, T. J., F. B. Peairs and S. D. Pilcher (1992). "COMPARISON OF CHEMIGATED AND AERIALY-APPLIED CHLORPYRIFOS AND FENVALERATE FOR CONTROL OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) LARVAE." *Journal of Economic Entomology* 85(2): 539-543.

Aerial and overhead center-pivot irrigation system (chemigated) applications of chlorpyrifos 4 emulsifiable concentrate (EC) and fenvalerate 2.4EC significantly reduced numbers of first- and second-generation European corn borer, *Ostrinia nubilalis* Hubner, larvae in field corn, *Zea mays* L. The number of first-generation *O. nubilalis* larvae, pupae, or cavities per plant in plots chemigated with chlorpyrifos in 1984 was significantly less than in plots where chlorpyrifos was applied aerially. A similar trend was observed for fenvalerate in 1985. No significant differences among application methods were observed for second-generation *O. nubilalis* treatments. Chlorpyrifos and fenvalerate were effective *O. nubilalis* control agents but efficacy differences between these two insecticides were variable. Corn yields did not vary significantly among application methods.

Andow, D. A. and D. R. Prokrym (1991). "RELEASE DENSITY, EFFICIENCY AND DISAPPEARANCE OF TRICHOGRAMMA-NUBILALE FOR CONTROL OF EUROPEAN CORN-BORER." *Entomophaga* 36(1): 105-113.

We evaluated how many *Trichogramma nubilale* should be released at a single location to control *Ostrinia nubilalis* in sweet corn. Six 8.6 x 16 m plots received 18.4 to 2 090 females *T. nubilale*/SAI when plants were in the mid to late whorl stage, where SAI, surface area index, is the plant surface area/m². To evaluate the potential control by our releases, we exposed laboratory-reared *O. nubilalis* egg masses to the released parasitoids at 4 times after the release. When an egg mass was parasitized by *T. nubilale*, 75.7 % of the eggs in the egg mass were parasitized. We developed an equation to estimate the percent of egg masses that a single female was expected to parasitize in a day (efficiency of parasitism) and female disappearance (death and dispersal) rates, if both were constant during our experiment. The exponential disappearance rate was - 0.52 +/- 0.03 day⁻¹, which implied that 40 % of the remaining females disappeared per day. The efficiency of parasitism was 0.050 % parasitism/female/SAI/day, which implied that at least 351,000 females/ha would be needed to achieve 90 % parasitism. Clearly, for *T. nubilale* to be a successful biological control agent, efficiency of parasitism must be increased and disappearance rates must be reduced.

Barry, D. and L. L. Darrah (1991). "EFFECT OF RESEARCH ON COMMERCIAL HYBRID MAIZE RESISTANCE TO EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Journal of Economic Entomology* 84(3): 1053-1059.

Economic loss caused by the European corn borer, *Ostrinia nubilalis* (Hubner), amounts to millions of dollars per year. Maize breeding programs funded from public and private sources have developed and released germplasm with resistance to European corn borer whorl leaf feeding and, to a lesser extent, sheath and sheath collar feeding during

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flowering. A 4-yr study of 100 hybrids each year was undertaken to evaluate levels of resistance to European corn borer available to the farmer in commercial hybrids. About 90% of the maize hybrids evaluated have some resistance to whorl leaf feeding and about 75% have some resistance to sheath and sheath collar feeding. In approximately two-thirds of the hybrids evaluated in Missouri, the resistance levels could be further enhanced and susceptible hybrids improved with the introduction of additional genes for resistance.

Barry, D. and M. Mendscoble (1991). "ORIENTATION OF THE EUROPEAN CORN-BORER WITHIN THE MAIZE PLANT." *Journal of the Kansas Entomological Society* 64(2): 179-184.

Maize (*Zea mays* L.) plants were artificially infested during 1987 and 1988 during anthesis with second-generation European corn borer (ECB), *Ostrinia nubilalis* [Hubner] larvae at three locations on the plant to determine the effect of larval placement on borer orientation within the plant. Infestation site had a minimal effect on borer orientation in the plant. Survival of borers was influenced by plant susceptibility and environment (season), and the number of surviving borers per plant affected orientation. The orientation response of ECB in susceptible and resistant plants differed. In resistant plants in 1987, the number of insects surviving was considerably less than in the susceptible plants, and significantly more ECB larvae and larval activity were found around the ear zone. No significant difference in borers and activity were noted either above or below the ear zone. The susceptible hybrid in 1987 had the orientation of borers skewed towards the lower areas of the plant. Less than 10% of the borers were found above the ear zone. During 1988, which had a hot, dry growing season, the population of ECB was reduced to such a low level that ECB effects on the resistant hybrid were not noticeable. The results of our study indicate that it is not necessary to dissect the upper portion of the maize plant to obtain an estimate of ECB population for pest management surveys and host plant resistance studies. Except when evaluating very susceptible cultivars, adequate estimates of the ECB population can probably be obtained by dissecting from one internode above the primary ear attachment point to one internode below the lowest ear attachment point.

Bing, L. A. and L. C. Lewis (1991). "SUPPRESSION OF OSTRINIA-NUBILALIS (HUBNER) (LEPIDOPTERA, PYRALIDAE) BY ENDOPHYTIC BEAUVERIA-BASSIANA (BALSAMO) VUILLEMIN." *Environmental Entomology* 20(4): 1207-1211.

The ubiquitous entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin was applied to whorl-stage corn plants, *Zea mays* L., by foliar application of a granular formulation of conidia and by injection of a conidial suspension. Plants were analyzed at harvest for presence of *B. bassiana* and for the amount of tunneling by laboratory-reared European corn borer larvae, *Ostrinia nubilalis* (Hubner). In 1989, 98.3% of the foliarly treated plants, 95.0% of the injected plants, and 33.3% of the nontreated plants were colonized by *B. bassiana* at harvest. In 1988, there were no significant differences between treatment effects on *O. nubilalis* tunneling in plants. In 1989, when environmental conditions were more conducive to fungal growth, tunneling was significantly greater in the control plants, followed by the injected and foliarly treated plants. When applied to foliage, *B. bassiana* provided the greatest amount of *O. nubilalis* suppression. The entomopathogenic fungus colonized the corn plant at whorl stage, moved within the plant, and persisted to provide season-long suppression of *O. nubilalis*.

Borek, V. and B. Kalinova (1991). EFFECTS OF AGE, PHOTOPERIODIC REGIME AND PRESENCE OF HOST PLANT ON PHEROMONE PRODUCTION IN OSTRINIA-NUBILALIS.

Calvin, D. D., R. A. Higgins, M. C. Knapp, F. L. Poston, S. M. Welch, W. B. Showers, J. F. Witkowski, C. E. Mason, H. C. Chiang and A. J. Keaster (1991). "SIMILARITIES IN DEVELOPMENTAL RATES OF GEOGRAPHICALLY SEPARATE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) POPULATIONS." *Environmental Entomology* 20(2): 441-449.

Developmental velocities of European corn borer, *Ostrinia nubilalis* (Hubner), colonies collected at four geographically separate locations (Delaware, Iowa, Missouri, and North Dakota) were compared. Each colony was reared under five or six constant temperature regimes. Mean developmental times and standard deviations about the means were determined. Developmental velocities were used to formulate both linear and sigmoid developmental velocity equations. Because the sigmoid and linear functions exhibited similar fits to the data, the latter were used in a European corn borer phenology model that predicts the period of second generation oviposition. The resulting predicted oviposition periods are reported for model runs using developmental velocity equations generated for the four colonies. The resulting predictions suggest that developmental rates are similar among the four geographically

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separate European corn borer populations. For European corn borers reared at 32-degrees-C, however, developmental times and developmental threshold temperatures during the period of larval eclosion to adult emergence appeared different among the colonies.

Coll, M. and D. G. Bottrell (1991). "MICROHABITAT AND RESOURCE SELECTION OF THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) AND ITS NATURAL ENEMIES IN MARYLAND FIELD CORN." *Environmental Entomology* 20(2): 526-533.

In western Maryland, the European corn borer, *Ostrinia nubilalis* (Hubner), exhibited three flight periods (from late May to mid-September 1986-1988) but completed only two generations in corn. Oviposition by corn borer moths increased when the tassels emerged and shed pollen. Peak density of the predators *Orius insidiosus* (Say) and *Coleomegilla maculata* (DeGeer) coincided with peak density of the borer's second-generation eggs and neonates. Second-generation egg masses and second and older instars were randomly distributed between plants in the field where first instars were aggregated. Corn borer females of the second flight period deposited most eggs (82%) on the ventral surfaces of leaves in the middle sections of plants near silking ears (76.7%). The emerging neonates initially dispersed randomly on the leaves. However, 30 min after emergence, most neonates cued on leaf axils, which served as the most common microhabitat for young larvae. Larval microhabitat differed substantially between the nonoverwintering and overwintering forms and between early and late instars of the nonoverwintering form. Leaf axils were the preferred microhabitat of young larvae, but preference shifted to stalks and ears as larvae matured. Overwintering larvae inhabited almost only stalks. Similarly, *O. insidiosus* adults and nymphs changed their within-plant distribution throughout the season. These changes in the distribution of borer larvae and their predators are discussed in relation to prey and pollen availability in different corn plant microhabitats.

Derrick, M. E. and W. B. Showers (1991). "COMPARISON OF AN ADULT AND LARVAL CONTROL STRATEGY FOR THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) IN SEED CORN." *Journal of the Kansas Entomological Society* 64(2): 185-192.

Efficacy of adult-directed insecticide applications were compared with standard larval control treatments in an effort to reduce second generation larval infestations of the European corn borer, *Ostrinia nubilalis* (Hubner) in seed corn. The treatments included methomyl applied to grassy adult aggregation areas, or "action sites," for adult suppression, fenvalerate applied to the field for larval control, a combination of methomyl applied to the action site with fenvalerate applied to the field, and an untreated check. Two applications were made in and around fields of hybrid seed production during the second flight (mid-July to late-August) in Iowa. The male, or tasselled inbred, sustained higher levels of larval infestation, resulting in a greater response to treatment. Larval tunnelling damage and infestation level were reduced with applications of fenvalerate to the field. Although applications of methomyl resulted in fewer adults in the grass following action site treatment, the subsequent effect on infestation and damage was not significant. Adult sampling data during high population levels in 1986 documented a temporary reduction of adults in the action site after treatment, suggesting a lack of residual activity by methomyl. Blacklight trap data indicated that the timing of initial insecticide applications in the action site corresponded with a majority of newly mated and actively ovipositing females and second applications targeted ovipositing and post-oviposition females.

Frenoy, C., J. P. Farine, N. Hawlitzky and C. Durier (1991). "ROLE OF KAIROMONES IN THE RELATIONS BETWEEN OSTRINIA-NUBILALIS HUBNER (LEP, PYRALIDAE) AND TRICHOGRAMMA-BRASSICAE BEZDENKO (HYM, TRICHOGRAMMATIDAE)." *Redia: Giornale Di Zoologia*, Vol Lxxiv, N 3, Terza Serie, Appendice: 143-151.

Frolov, A. N. (1991). "ANALYSIS OF THE TROPHIC RELATIONS OF EUROPEAN CORN-BORER AND BRUSHLEG STEM BORER (LEPIDOPTERA, PYRAUSTIDAE) ON A CORN FIELD, OVERGROWN WITH MUGWORT." *Soviet Journal of Ecology* 22(3): 186-191.

A study was conducted on the larval distribution of European corn borer *Ostrinia nubilalis* (Hbn.) and brushleg borer *O. scapularis* (Wik.) on corn and mugwort in Charkassy Region. In the area of direct contact between host plants, at the edges of a corn field, overgrown with mugwort, our studies recorded an average 11.9% brushleg borer larvae on corn, and 8.1% corn borer larvae on mugwort over a four-year period. Outside these areas corn borer larvae were encountered exclusively on corn, and brushleg borer on mugwort. It transpires that feeding by brushleg borer larvae on corn at the field edge is not connected with the effects of hybridization with its close relative, the European corn borer,

but may serve as a model of the prevailing conditions, when the corn borer initially altered its food preference to cereal crops.

Gelman, D. B., A. B. Demilo, B. S. Thyagaraja, T. J. Kelly, E. P. Masler, R. A. Bell and A. B. Borkovec (1991). "3-OXOECDYSTEROID 3-BETA-REDUCTASE IN VARIOUS ORGANS OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS (HUBNER)." *Archives of Insect Biochemistry and Physiology* 17(2-3): 93-106.

Extracts of brains, subesophageal ganglia, Malpighian tubules, mandibular glands, proctodaea, salivary glands, testes, and fat body from mature fifth-stage European corn borer larvae contain a 3-oxoecdysteroid 3-beta-reductase that converts 3-dehydroecdysone to an RIA-detectable ecdysteroid that has the same retention time (on HPLC and TLC) as ecdysone. Enzyme activity is destroyed by boiling, exposure to organic solvents, and treatment with trypsin. The reductase has a molecular weight in the range of 24-37 kD and is dependent upon the presence of NADPH for activity. Under the conditions utilized here, subesophageal ganglia, proctodaea, and brain extracts exhibited the highest specific activity; mandibular glands, testes, salivary glands, and Malpighian tubules had moderate specific activity; and fat body had the least. Based on total organ activity, however, fat body and salivary glands had the greatest activity; testes, Malpighian tubules, mandibular glands, and proctodaeum had moderate activity; and brain and subesophageal ganglion had the least.

Glover, T. J., M. G. Campbell, C. E. Linn and W. L. Roelofs (1991). "UNIQUE SEX-CHROMOSOME MEDIATED BEHAVIORAL-RESPONSE SPECIFICITY OF HYBRID MALE EUROPEAN CORN-BORER MOTHS." *Experientia* 47(9): 980-984.

Unlike the narrow response windows exhibited by the parent races, hybrid male European corn borers resulting from crosses of the E and Z races respond to a wide range of sex pheromone blends. The F1 response profile consists of some individuals that respond to both the Z pheromone and the 65:35 E/Z blend produced by F1 females. Some F1 males fail to respond to any blend and some do not respond as broadly as others. The hybrid male populations, however, are not tuned optimally to the pheromone blend produced by F1 females and there is no coupling of F1 blend production and response.

Glover, T. J., J. J. Knodel, P. S. Robbins, C. J. Eckenrode and W. L. Roelofs (1991). "GENE FLOW AMONG 3 RACES OF EUROPEAN CORN BORERS (LEPIDOPTERA, PYRALIDAE) IN NEW-YORK-STATE." *Environmental Entomology* 20(5): 1356-1362.

In New York state, there are three races of European corn borer moths, which are characterized principally by differences in voltinism and the sex pheromone communication system. One race is bivoltine, with females producing and males responding to a 99:1 E/Z isomeric ratio of DELTA-11-14:OAc's as the sex pheromone. Two races, one univoltine and one bivoltine, produce and respond to a 3:97 E/Z blend of DELTA-11-14:OAc's. The races are referred to as BE, UZ, and BZ to denote these differences. Analyses by gas chromatography of field-collected females indicate that there is significant hybridization between the Z and E races when in sympatry, with hybrid females producing a 68:32 ratio of E/Z11-14:OAc. Gene flow among the races was investigated using differences in triose phosphate isomerase (TPI) allozyme frequencies of moths from sites sampled across the state. The fixed nature of the Tpi-1 allele in the BE race and increases in the Tpi-1 allele frequencies in UZ populations in sympatry with the BE race support the hypothesis that gene flow following hybridization is unidirectional from BE populations into the Z populations. In addition, the TPI genotypes of the 10 hybrid females analyzed were consistent with hybridization occurring by E males mating with Z females.

Godfrey, L. D., K. E. Godfrey, T. E. Hunt and S. M. Spomer (1991). "NATURAL ENEMIES OF EUROPEAN CORN-BORER OSTRINIA-NUBILALIS (HUBNER) (LEPIDOPTERA, PYRALIDAE) LARVAE IN IRRIGATED AND DROUGHT-STRESSED CORN." *Journal of the Kansas Entomological Society* 64(3): 279-286.

Insect parasitoids and arthropod predators of European corn borer larvae were surveyed in corn grown on an irrigation gradient in Lincoln County, Nebraska in 1987 and 1989. *Eriborus terebrans* Gravenhorst (Hymenoptera: Ichneumonidae) was recovered in both years of the survey and was found parasitizing 2.04% in 1987 and 2.9% in 1989 of the European corn borer larvae recovered. In 1989, *Lixophaga* sp. (Diptera: Tachinidae) was found parasitizing 1.1% of the European corn borer larvae recovered. Recoveries of both species of parasitoids represent new county records, and this is the first report of *Lixophaga* sp. parasitizing European corn borer larvae in Nebraska. No clear trend of the effects of host plant water stress on European corn borer larval parasitism was observed. The arthropod predator complex was comprised

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mainly of anthocorids, spiders, and coccinellids. The drought-stressed corn showed a trend towards larger densities of arthropod predators than the fully-irrigated corn.

Godfrey, L. D. and T. O. Holtzer (1991). "INFLUENCE OF TEMPERATURE AND HUMIDITY ON EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) EGG HATCHABILITY." *Environmental Entomology* 20(1): 8-14.

European corn borer, *Ostrinia nubilalis* (Hubner), egg hatch was studied under several temperature and humidity regimes. Percentage of hatch was severely decreased, regardless of the humidity, at 36 and 39-degrees-C. Hatch ranged from 74.0 to 0.5% at vapor pressure deficits of 7.5-32.5 mb over the temperature range of 24-33-degrees-C in 3-degrees-C increments. European corn borer egg hatch was affected similarly, from oviposition to larval eclosion, by a 12-h stress period of 14.5, 17.5, and 20.5 mb (at 30-degrees-C). Two separate aspects of the egg chorion or two processes in egg hatch are hypothesized to be disrupted by the stressful conditions as evidenced by three plateaus in percentage of eggs hatching as the length of exposure to stress increased. Percentage of hatch remained relatively stable at about 68% with exposure to 33.9-mb stress for less-than-or-equal-to 24 h. As the length of stress increased to 36-60 h, the percentage was about 22%. The percentage of hatch fell to only 2.7% at 72 and 84 h of consecutive exposure. Finally, the effect of environmental conditions on egg hatch was additive whether the eggs experienced constant stress or experienced periods of stress alternated with periods of moderate conditions. Results of this study suggest that environmental stresses (i.e., "stress units") may accumulate and affect survival of European corn borer eggs in a manner analogous to temperature units and insect development.

Godfrey, L. D., T. O. Holtzer and J. M. Norman (1991). "EFFECTS OF EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) TUNNELING AND DROUGHT STRESS ON FIELD CORN GAS-EXCHANGE PARAMETERS." *Journal of Economic Entomology* 84(4): 1370-1380.

The influence of European corn borer, *Ostrinia nubilalis* (Hubner), larval tunneling on corn (*Zea mays* L.) gas exchange parameters was examined in a 2-yr field study. Manual larval infestations were established in corn (two planting dates per year) grown on a soil moisture gradient. Larval tunneling significantly reduced the corn photosynthetic rate compared with uninfested plants by 11.4 and 22.1% in 1987 for 3 and 5 larvae per plant infestations, respectively, whereas the 1 larva per plant infestation significantly increased the photosynthetic rate. In 1988, when the drought stress was not as severe as in 1987, only the high infestation rate affected the photosynthetic rate (an 11.7% reduction). Other consequences of larval tunneling were reduced stomatal conductance (up to 28.1%), decreased intercellular CO₂ concentration, and increased leaf temperature (up to 1.8-degrees-C). The interactions with soil moisture level were not significant. In all four planting dates, once the larval tunneling ceased, i.e., pupation occurred, the effect on photosynthetic rate waned, even though the vascular obstruction (tunnel) was still present. The plants appeared to have some mechanism to compensate for the injury. These results suggest that European corn borer tunneling directly affected plant physiology, possibly through disturbing the source-sink relationship (upper photosynthesizing leaves-developing ear). Compared with adequately watered soils, water deficit conditions resulted in reduced photosynthetic rates, stomatal conductances, and intercellular CO₂ concentrations (1988 only), and in increased leaf temperatures; however, the effects were not transient as were the effects from the larval tunneling.

Godfrey, L. D., T. O. Holtzer, S. M. Spomer and J. M. Norman (1991). "EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) TUNNELING AND DROUGHT STRESS - EFFECTS ON CORN YIELD." *Journal of Economic Entomology* 84(6): 1850-1860.

The effect of simultaneous stresses from European corn borer, *Ostrinia nubilalis* (Hubner), tunneling and drought stress on corn, *Zea mays* L., yield was evaluated in a 2-yr field study. Physiological yield losses (i.e., potential yield that was not produced) and potential harvest yield losses (i.e., yield loss from stalk breakage) were both evaluated. European corn borer larvae were manually infested in the plants at corn pollen shed. Physiological yield losses up to 59.1% occurred in plants grown with slight irrigation (5% of full irrigation amount) compared with fully irrigated plants. An infestation of five larvae per plant (corresponding to 3.25 cavities per plant) reduced the corn yield across the irrigation gradient by an average of 18.8 and 13.3% in 1987 and 1988, respectively, compared with undamaged plants. Under conditions of severe drought stress, the percentage yield loss per larva generally increased as the soil moisture level decreased. In 1987, plants grown in soils near the field capacity moisture level suffered a 3.1% loss per larva, compared with a 7.1% loss in plants grown in dry soils (slightly over the permanent wilting point). Yield losses from larval tunneling were primarily caused by a reduction in kernel size rather than a reduction in kernels per ear. Drought stress frequently

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reduced both kernels per ear and kernel density. In addition, European corn borer tunneling resulted in a 9.3% yield loss from unharvestable ears.

Got, B., G. F. Lacan, N. Smits and E. Stephan (1991). "VALIDATION OF A MODEL FOR EUROPEAN CORN-BORER DEVELOPMENT IN FRANCE." *Agronomie* 11(1): 45-57.

The validation of a temperature-dependent model for European Corn Borer development on 3 different corn varieties (LG11, DEA and ISORA), at 4 sites in France: Avignon, Bordeaux, Colmar and Versailles, and with 2 infestation times for each site and variety, is presented. The model consist of 2 parts: a degree-day model and 4 normal distributions (fig 1). It has been estimated and tested at Versailles (table II). The validations show that the mean differences between predicted and observed data are systematically less than a week under the different experimental conditions (tables III and IV, figs 3a, 3b, 4 and 5). The model is then an appropriate representation of development for agronomical purposes (prediction of losses, pest control). Possible improvements of the model are discussed: using a non linear model between growth rate and temperature and taking into account the temperature under vegetation seem to be the most realistic ways to improve the model, considering the knowledge of European corn borer biology.

Gray, M. E., D. D. Walgenbach, A. Carrick, N. N. Troxclair and G. L. Hein (1991). "EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE) MOTH CAPTURES IN AERIAL WATER PAN TRAPS INFLUENCED BY REPLACEMENT OF PHEROMONE AT DIFFERENT INTERVALS." *Journal of Economic Entomology* 84(4): 1196-1202.

Aerial water pan pheromone traps were used to monitor flights of the European corn borer, *Ostrinia nubilalis* (Hubner), in two locations in South Dakota during 1987 and at three sites in Illinois in 1988. Our objective was to evaluate the effect of different pheromone septa replacement intervals on European corn borer moth captures in aerial water pan pheromone traps. At each location, four treatments were arranged in a randomized complete-block design. The treatments consisted of differing the length of time pheromone septa were allowed to remain in the water pan traps and were as follows: (1) septa replaced weekly, (2) septa replaced biweekly (once every 2 wk), (3) septa replaced every 3 wk or monthly, and (4) traps used without septa. Results indicate that even when pheromone septa are changed very infrequently (3 wk to monthly), distinct flights of male European corn borer moths can be detected. Moth captures were generally greater in water pan traps in which septa were changed weekly; however, in many instances, no significant differences in trap catches occurred among the three pheromone replacement treatments. When European corn borer populations are very low, the length of time between pheromone septa replacement may not significantly affect the capture of male moths. Replacement of pheromone septa on a biweekly basis should work satisfactorily for a large-scale monitoring program where expense is a concern.

Gruborljajic, G., W. Block, V. Palanacki and S. Glumac (1991). "COLD HARDINESS PARAMETERS OF OVERWINTERING DIAPAUSE LARVAE OF OSTRINIA-NUBILALIS IN VOJVODINA, YUGOSLAVIA." *Cryo-Letters* 12(3): 177-182.

Overwintering diapause larvae of the European corn borer *Ostrinia nubilalis* (Hubn.) are able to survive freezing of their extracellular body fluids, and hence may be termed freeze tolerant. However, their whole body supercooling points, measured monthly from November to March during the 1988-89 winter, varied between -20.5 and -25.0-degrees-C. Glycerol, at maximum concentration of 1.53 +/- 0.13 M in January, was the only polyhydric alcohol present in significant amounts overwinter. Changes in osmolality of larval haemolymph tracked variations in glycerol concentration. Trehalose levels increased throughout winter reaching a maximum (35.0 +/- 2.6 mM) in March. The deep supercooling capacity of an otherwise freeze tolerant insect may be related to its diapause state, but it is also further evidence of the existence of a continuum between freeze tolerance and intolerance in cold hardy species.

Hassan, S. A. and M. F. Guo (1991). "SELECTION OF EFFECTIVE STRAINS OF EGG PARASITES OF THE GENUS TRICHOGRAMMA (HYM, TRICHOGRAMMATIDAE) TO CONTROL THE EUROPEAN CORN-BORER OSTRINIA-NUBILALIS HB (LEP, PYRALIDAE)." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 111(4): 335-341.

Trichogramma strains were compared for their suitability to control the European corn borer *Ostrinia nubilalis* Hb. The host preference was tested in laboratory experiments by offering single parasite females the choice between eggs of the target pest and eggs of the replacement mass rearing host Angoumois grain moth *Sitotroga cerealella*. Only the following three strains, from a total of 20 tested, showed preference to and/or satisfactorily parasitized the corn borer eggs, in order of effectiveness: *Trichogramma ostriniae* from China P.R. (strain 62), *Trichogramma evanescens* from

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Moldavia, USSR (strain 10) and *T. evanescens* from Germany F.R. (strain 105). The number of parasite eggs laid in the corn borer and that laid in the *Sitotroga* eggs were 17.6 and 5.83 for strain 62; 9.1 and 12.73 for strain 10; and 3.73 and 16.1 for strain 105. The remaining 17 strains almost completely ignored the *Ostrinia* eggs and only parasitized the grain moth eggs. The searching capacity of *T. ostriniae* and *T. evanescens* was compared by conducting parasite release experiments on corn plants in cages. No significant differences between the two species were found. The results of these experiments confirmed that the choice of the two species *T. ostriniae* and *T. evanescens* (Moldavia), that are presently being used in practice to control the corn borers in Asia and Europe is justified. The simple laboratory method to test the host preference used in these experiments was found to be suitable for the selection of effective species of the genus *Trichogramma* for biological control.

Hudon, M. and M. S. Chiang (1991). "EVALUATION OF RESISTANCE OF MAIZE GERMPLASM TO THE UNIVOLTINE EUROPEAN CORN-BORER *OSTRINIA-NUBILALIS* (HUBNER) AND RELATIONSHIP WITH MAIZE MATURITY IN QUEBEC." *Maydica* 36(1): 69-74.

From 1976 to 1988, 63 grain maize inbred lines and selections derived from synthetic and open-pollinated varieties were rated for their resistance to leaf feeding (antibiosis) and their tolerance to plant damage (stalk breakage) at harvest by the univoltine European corn borer, *Ostrinia nubilalis* (Hubner). They were also evaluated for their maturity in Quebec. A number of lines were resistant to leaf feeding but had severe plant damage resulting from stalk breakage at harvest, and vice versa. Some lines were considered resistant in their country of origin but showed intermediate resistance and/or some susceptibility in Quebec. The yield and borer attack of 119 inbreds or breeding lines of the International Working Group on *Ostrinia* (IWGO) trials are herewith reported.

Hudon, M., R. E. Pitblado, R. I. Hamilton, G. Bourgeois, S. Kuzir and R. Girgis (1991). "RESPONSE OF MAIZE INBRED LINES TO 2 EUROPEAN CORN-BORER (*OSTRINIA-NUBILALIS*) STRAINS IN CANADA." *Phytoprotection* 72(2): 69-76.

In 1986 and 1987, six maize inbred lines (CM47, A619, F2, CM107, CM7, and A654) were evaluated at four locations across Ontario and Quebec for their resistance to artificially infested univoltine and 1st generation bivoltine strains of the European corn borer, *Ostrinia nubilalis*. Three criteria were used: leaf feeding, total plant damage at harvest and length of tunnels/plant height ratio. Substantial interactions in borer damage measurements were observed between locations and years, but inbred reaction was relatively consistent. For all criteria, the univoltine strain often caused significantly more damage than the bivoltine borer. In general, A619 had the greatest resistance-tolerance with good standability until harvest. Wherever possible, evaluation of genetic resistance in maize germplasm should be conducted using the univoltine borer strain.

Jarvis, J. L., W. A. Russell, J. E. Campbell and W. D. Guthrie (1991). "LEVEL OF RESISTANCE IN MAIZE TO PREVENT OR REDUCE YIELD LOSSES BY 2ND-GENERATION EUROPEAN CORN BORERS." *Maydica* 36(3): 267-273.

A 2 year study was conducted to determine the effect of infestation by 2nd-generation European corn borer (ECB), *Ostrinia nubilalis* (Hubner), on 12 maize hybrids and two synthetic cultivars that vary in resistance or susceptibility to the ECB. Total yield, harvestable yield, and kernel weights were all reduced by ECB infestation but the amount of reduction was dependent upon the hybrid or cultivar. ECB resistant hybrids had the least amount of yield loss. Some hybrids had antibiosis type of resistance whereas others had tolerance (a small amount of loss per unit of damage). Antibiosis resistance and tolerance did not always occur in the same hybrids and seem to be unrelated characteristics.

Kaster, L. V., M. A. Carson, M. E. Meehan and R. Sisco (1991). "RAPID METHOD OF EVALUATING MAIZE FOR SHEATH-COLLAR FEEDING RESISTANCE TO THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Journal of Economic Entomology* 84(1): 324-327.

An internal visual rating method of evaluating *Zea mays* L. for sheath-collar feeding resistance to *Ostrinia nubilalis* (Hubner) is presented. The method involves determining the number of stalk subsections containing larval tunneling almost-equal-to 60 d after artificial infestation of plants. The subsections examined range from four nodes above the ear node to four nodes below the ear node. Comparisons were made between internal visual ratings and two previously described methods: centimeters of larval tunneling within the stalk and sheath-collar damage ratings. Correlations between the various methods showed that the internal visual rating can be used to evaluate maize genotypes for resistance. Also, the internal visual rating is almost-equal-to 40% faster than determining centimeters of tunneling.

Klun, J. A., M. Schwarz and E. C. Uebel (1991). "EUROPEAN CORN-BORER - PHEROMONAL CATABOLISM AND BEHAVIORAL-RESPONSE TO SEX-PHEROMONE." *Journal of Chemical Ecology* 17(2): 317-334.

When physiologically excessive amounts of the female sex pheromone of the European corn borer (ECB) or esters analogous to the pheromone were applied to the antennae of males, their behavioral responsiveness to pheromone in a flight tunnel was significantly impaired for 2 hr. Concurrent quantitative analyses of heptane extracts of the male antennae by gas-liquid chromatography showed that the compounds applied to antennae were hydrolyzed and, at 2 and 4 hr posttreatment, little or none of the compound applied or hydrolysis product was detectable in the antennal extracts. After 4 hr of *in vivo* incubation, male responsiveness to pheromone was restored among moths treated with the analogs but not among moths treated with pheromone. Esterase activity on the antennae was moderately inhibited *in vivo* by a pheromone analog that is a so-called transition-state esterase inhibitor, 1,1,1-trifluoro-14-heptadecen-2-one. However, the analog did not inhibit male behavior when it was coevaporated with pheromone in a flight-tunnel assay. Therefore, in the presence of pheromone, the analog did not compete well for esterase or the pheromone receptor. Treating the antennae of intact males with tetrahydrofuran obliterated sex pheromone response capability in males, but the treatment did not significantly attenuate esterase and other catabolic activity of the antennae. Indications are that degradation of esters on the ECB antennae involves substrate-nonspecific esterase activity and other metabolic processes that in turn remove hydrolysis products from the antennae. Maintenance of a male's ability to respond to pheromone is linked to these processes.

Labatte, J. M. (1991). "MODEL FOR THE WITHIN-PLANT VERTICAL-DISTRIBUTION OF EUROPEAN CORN-BORER (LEP PYRALIDAE) LARVAE." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 111(2): 120-136.

The European Corn Borer (ECB) is a major pest of corn in many countries. Yield losses due to ECB depend on the stalk tunneling data, the number and location of cavities on the corn. To describe the location of cavities due to ECB, a model of larval distribution within the plant is proposed here and tested on field data collected at INRA-Versailles, France. Comparison of changes in larval distribution on the plant for different infestation dates suggested that the stage of corn growth is the main factor to be taken into account. Statistical tests did not reveal any effect of instar nor of infestation date or rate. For a given infestation, the larval distribution changed also significantly with corn growth. The proposed model consists of two parts. We first showed that, for a given observation, Weibull density describes correctly larval vertical distribution on the different internodes of the plant with only two parameters. Then we represent the course of these parameters with corn growth by regression curves on degree days (base 6-degrees-C). For the seven climatic sequences recorded, this simple model is an appropriate representation of the larval vertical distribution and movement within the plant.

Labatte, J. M. and B. Got (1991). "MODELING DAMAGE ON MAIZE BY THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS." *Annals of Applied Biology* 119(3): 401-413.

The European Corn Borer (ECB), *Ostrinia nubilalis* Hbn. (Lepidoptera: Pyralidae), is a major pest of maize in many countries. Yield losses caused by larvae of this insect depend mainly on the extent of cavity damage, the timing of tunnelling, and their within-plant distribution. To describe these factors, a mechanistic model of cavity appearance is proposed here. It takes into account the main biological processes which determine damage. These are the development, mortality and within-plant distribution of the ECB larvae. The model has been estimated and tested on field data collected at INRA-Versailles in France. Model fittings showed that (i) creation and lengthwise extension rates of cavities per larva depend on location and instar of the larvae, and that (ii) only instars 4 and 5 make cavities. This model described, with a high precision level, the appearance and lengthwise extension of cavities over time and their within-plant distribution for two maize varieties, several infestation dates and levels, and various climatic sequences.

Lewis, L. C. and L. A. Bing (1991). "BACILLUS-THURINGIENSIS BERLINER AND BEAUVERIA-BASSIANA (BALSAMO) VUILLIMEN FOR EUROPEAN CORN-BORER CONTROL - PROGRAM FOR IMMEDIATE AND SEASON-LONG SUPPRESSION." *Canadian Entomologist* 123(2): 387-393.

Combinations of *Bacillus thuringiensis* Berliner subspecies *kurstaki* and *Beauveria bassiana* (Balsamo) Vuillimen formulated on granules were applied separately and in combination to field corn to suppress larval populations of the European corn borer, *Ostrinia nubilalis* (Hubner). Research was conducted in 2 separate years. Laboratory-reared *O. nubilalis* eggs or larvae were placed on the plant during either the whorl stage (V6) or the pollen-shedding stage (R1)

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to simulate first- and second-generation *O. nubilalis* oviposition periods, respectively. Efficacy was determined by measuring the length of European corn borer tunnels in the corn stalk at harvest time. In the 1st year, first generation, and second generation (of 2nd year) *B. thuringiensis* and *B. bassiana* alone and in combination caused significant reductions in tunneling compared with that in the check populations. There were no significant differences in tunneling between any treatments in the second-generation study of year 1. *Bacillus thuringiensis* and *B. bassiana* were independent of each other in their suppression of insects. Tunneling by the naturally occurring second-generation larvae (year 2) was recorded to determine if *B. thuringiensis* and *B. bassiana* applied in the V6 stage persisted in the plant. Pith samples were excised from nodal plates 7-10 of the corn stalk to determine the incidence of *B. bassiana*. There was a significant correlation ($r = -0.376$) (P less-than-or-equal-to 0.05) between the occurrence of *B. bassiana* in the corn plant and tunneling by second-generation larvae. These data indicate that *B. bassiana* placed in the whorl of the corn plant may provide season-long suppression of *O. nubilalis*.

Mason, C. E., R. L. Jones and M. M. Thompson (1991). "REARING LYDELLA-THOMPSONI (DIPTERA, TACHINIDAE), A PARASITE OF THE EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Annals of the Entomological Society of America* 84(2): 179-181.

The exotic parasite *Lydella thompsoni* (Herting) was reintroduced and successfully established as a natural enemy of *Ostrinia nubilalis* (Hubner) in Delaware in the late 1970s after it disappeared from North America in the early 1960s. It has since spread from Delaware into adjacent states, and new interest has been generated in rearing this parasite for possible release in other geographic locations and for research. A laboratory rearing technique is described using European corn borer larvae as hosts in corn stalks. Critical aspects of rearing include temperatures for maintaining caged adults, production of fresh frass as a source of protein and as a stimulant for larviposition, and the provision of a strong light source to facilitate larviposition and mating behavior. Time of development from larviposition to adult emergence was 16.7 d at 25-degrees-C.

Onstad, D. W., J. P. Siegel and J. V. Maddox (1991). "DISTRIBUTION OF PARASITISM BY MACROCENTRUS-GRANDII (HYMENOPTERA, BRACONIDAE) IN MAIZE INFESTED BY OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE)." *Environmental Entomology* 20(1): 156-159.

Macrocentrus grandii Goidanich is a braconid parasitoid of the European corn borer, *Ostrinia nubilalis* (Hubner). Over a 3-yr period, we collected corn borer larvae from maize fields in Illinois to determine how host density and other factors influence the distribution of parasitism. The proportion of parasitized larvae was not density dependent at the single-stalk and field scales. Parasitism was always higher in the first generation of the bivoltine population. Proportion of parasitized larvae was correlated with the proportion of stalks that had at least one parasitized larva and with the frequency of infested stalks. These correlations indicated that searching and oviposition by the female parasitoid may be random among maize stalks. The apparent inefficiency of this parasitoid is discussed.

Pavuk, D. M. and B. R. Stinner (1991). "NEW LEPIDOPTERA PARASITOID ASSOCIATIONS IN WEEDY CORN PLANTINGS - A POTENTIAL ALTERNATE HOST FOR OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE) PARASITOID." *Great Lakes Entomologist* 24(4): 219-223.

Larvae of the common sooty wing, *Pholisora catullus*, and pupae of the yellow-collared scape moth, *Ciseps fulvicollis*, were collected in corn plantings containing different manipulated, indigenous weed communities to determine if these Lepidoptera had parasitoid species in common with the European corn borer, *Ostrinia nubilalis*. *Pholisora catullus* larvae were collected from lambsquarter, *Chenopodium album*, and redroot pigweed, *Amaranthus retroflexus*, whereas pupae of *C. fulvicollis* were obtained from corn. Four parasitoid species were reared from *P. catullus*: *Cotesia pholisorae*, *Oncophanes americanus* (Hymenoptera: Braconidae), *Gambrus ultimus*, and *Sinophorus albipalpus* (Hymenoptera: Ichneumonidae). Of these, *O. americanus* and *S. albipalpus* represent new host records. *Gambrus ultimus*, however, was probably parasitizing a primary parasitoid of *P. catullus*. *Itopectis conquisitor* and *Vulgichneumon brevicinctor* (Hymenoptera: Ichneumonidae) were reared from *C. fulvicollis*; *V. brevicinctor* had not previously been associated with this host. Both species reared from *C. fulvicollis* and *Gambrus ultimus* have been reported from *O. nubilalis*.

Pavuk, D. M. and B. R. Stinner (1991). "INFLUENCE OF WEEDS IN CORN PLANTINGS ON POPULATION-DENSITIES OF AND DAMAGE BY 2ND-GENERATION OSTRINIA-NUBILALIS (HUBNER) (LEPIDOPTERA, PYRALIDAE) LARVAE." *Environmental Entomology* 20(1): 276-281.

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In a 2-yr study, population densities of and damage by second-generation European corn borer, *Ostrinia nubilalis* (Hubner), larvae were compared among corn plantings containing or lacking different weed communities. Treatments were corn without weeds, corn principally with broadleaves, corn principally with grasses, and corn with a mixture of broadleaves and grasses. In both years, larval density (number of larvae per corn plant) and damage (number of tunnels per corn plant) were significantly lower in treatments with broadleaves than in treatments without broadleaves. Larval density was significantly lower in treatments with grasses than in treatments without grasses in 1989. The broadleaf x grass interaction was significant for larval density in 1989, and significant for damage in both years. Although natural enemies of *O. nubilalis* may be more abundant and effective in weedy corn, the presence of weeds, particularly grasses, attracts adult moths to cornfields, which may result in larger infestations of corn and greater damage. In addition, weeds may harbor other pests of corn and compete with corn for nutrients and water, leading to reduced yields.

Prokrym, D. R. and D. A. Andow (1991). FIELD-EVALUATION OF TRICHOGRAMMA-NUBILALE AGAINST OSTRINIA-NUBILALIS IN SWEET CORN.

Reid, C. D. (1991). "ABILITY OF ORIUS-INSIDIOSUS (HEMIPTERA, ANTHOCORIDAE) TO SEARCH FOR, FIND, AND ATTACK EUROPEAN CORN-BORER AND CORN-EARWORM EGGS ON CORN." *Journal of Economic Entomology* 84(1): 83-86.

The ability of *Orius insidiosus* (Say) to search for, find, and destroy eggs of European corn borer, *Ostrinia nubilalis* (Hubner), and corn earworm, *Helicoverpa zea* (Boddie), was investigated in the field. Mobility of *O. insidiosus* on individual corn plants, attack rates on corn borer and corn earworm eggs, and searching capacity on corn plants were studied. Egg position on the corn plant and predator density affected egg mortality. Mortality rates rose with increased predator numbers. *O. insidiosus* searched in the corn silks first, followed by searching on the corn leaves but not in the tassel.

Reid, L. M., J. T. Arnason, C. Nozzolillo and R. I. Hamilton (1991). "LABORATORY AND FIELD-RESISTANCE TO THE EUROPEAN CORN-BORER IN MAIZE GERMPLASM." *Crop Science* 31(6): 1496-1502.

There is a continuing need to screen maize (*Zea mays* L.) germplasm for sources of resistance to the European corn borer, *Ostrinia nubilalis* (Hubner). This study was conducted to determine the resistance characteristics to a univoltine strain of the European corn borer of six groups of maize germplasm and to examine the relationship among resistance characteristics. The groups of germplasm consisted of (i) a latitudinal series of inbred lines; (ii) a set of the indigenous landraces of Mexico; (iii) two Argentine landraces; (iv) three Canadian synthetic populations; (v) three International Maize and Wheat Improvement Center (CIMMYT) maize pools; and (vi) two inbred lines used as controls. In addition, a multiple borer resistance population was studied. All germplasm was evaluated for seedling DIMBOA [2,4-dihydroxy-7-methoxy-(2H)-1,4-benzoxazin-3(4H)-one] content, susceptibility to leaf-feeding (both laboratory and field) and to stalk tunneling by the European corn borer, susceptibility to *Gibberella zeae* (Schwein.) Petch (stalk rot) and *Ustilago zeae* (Beckm.) Unger (corn smut), and their ability to mature in the climatic conditions prevailing at Ottawa, ON. The inbred lines were characterized by high resistance to leaf feeding, but susceptibility to stalk tunneling, whereas the indigenous Mexican landraces were susceptible to leaf feeding. Many significant correlations were found among the various parameters, including validation of the relation of seedling DIMBOA levels and laboratory leaf-feeding tests with the field resistance to European corn borer. This study confirms the importance of examining broad groups of germplasm when searching for sources of resistance to the European corn borer.

Royer, L. and J. N. McNeil (1991). "CHANGES IN CALLING BEHAVIOR AND MATING SUCCESS IN THE EUROPEAN CORN-BORER (*OSTRINIA-NUBILALIS*), CAUSED BY RELATIVE-HUMIDITY." *Entomologia Experimentalis Et Applicata* 61(2): 131-138.

We examined the calling behaviour of *O. nubilalis* virgin females, held at three different constant conditions of relative humidity from the time of emergence through their sixth night of calling, as well as the incidence of mating over time at low or high relative humidity conditions. The mean age at which females initiated calling in their life was independent of relative humidity conditions, although more variable at low humidity. On successive nights of calling, fewer virgin European corn borer females called under low compared with high humidity conditions, and those that did began later in scotophase, had fewer calling bouts, and spent less time calling. These changes in the female prereproductive behaviour were reflected on the incidence of mating which, in the first two days following emergence,

was significantly less at low than at high humidity conditions. The ecological significance of these results is discussed in relation with the susceptibility of *O. nubilalis* to desiccation.

Solter, L. F., J. V. Maddox and D. W. Onstad (1991). "TRANSMISSION OF NOSEMA-PYRAUSTA IN ADULT EUROPEAN CORN BORERS." *Journal of Invertebrate Pathology* 57(2): 220-226.

Thiery, D. and J. L. Lequere (1991). A POSSIBLE OVIPOSITION DETERRING PHEROMONE IN THE EUROPEAN CORN-BORER.

Wilson, R. L., B. R. Wiseman and G. L. Reed (1991). "EVALUATION OF ELDRIDGE, J. C. POPCORN COLLECTION FOR RESISTANCE TO CORN-EARWORM, FALL ARMYWORM (LEPIDOPTERA, NOCTUIDAE), AND EUROPEAN CORN-BORER (LEPIDOPTERA, PYRALIDAE)." *Journal of Economic Entomology* 84(2): 693-698.

Discovery that popcorn (*Zea mays* L.) PI 340856 was resistant to corn earworm (*Heliothis zea* (Boddie)) led us to evaluate 34 additional lines developed by J. C. Eldredge for resistance to corn earworm, European corn borer (*Ostrinia nubilalis* (Hubner)), and fall armyworm (*Spodoptera frugiperda* J. E. Smith). The 35 lines were evaluated for corn earworm resistance in the field with artificial infestation at Ames, Iowa, and Tifton, Ga., and with natural infestation at Hermiston, Oreg. None of the lines was better than the resistant check, 'Zapalote Chico' (PI 217413), at any of the three locations. Several lines had significantly better damage ratings than the susceptible checks. A bioassay of these materials for corn earworm resistance was run in the laboratory at Ames and Tifton by adding dried maize silks to laboratory diets and monitoring insect growth and development. Six lines were evaluated as resistant at both locations. In the field at Ames, two of these six lines were rated resistant to European corn borer. Fall armyworm field resistance ratings at Tifton indicated that one line was resistant after 7 d, but it was intermediate after 14 d. The J. C. Eldredge collection of popcorns provides sources of antibiosis to corn earworm and European corn borer and is available for use by plant breeders. Corn earworm resistance may be enhanced by breeding for husk protection, which may provide an environment that will capitalize on the antibiotic factors found in the maize silks.

Andow, D. A. (1990). "CHARACTERIZATION OF PREDATION ON EGG MASSES OF OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE)." *Annals of the Entomological Society of America* 83(3): 482-486.

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Cagan, L. and M. Grecnik (1990). "NOXIOUSNESS OF THE EUROPEAN CORN-BORER (OSTRINIA-NUBILALIS HBN) ON GRAIN MAIZE." *Rostlinna Vyroba* 36(2): 203-212.

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Gadenne, C., L. Varjas and B. Mauchamp (1990). "EFFECTS OF THE NONSTEROIDAL ECDYSONE MIMIC, RH-5849, ON DIAPAUSE AND NONDIAPAUSE LARVAE OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS HBN." *Journal of Insect Physiology* 36(8): 555-559.

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Glover, T., M. Campbell, P. Robbins and W. Roelofs (1990). "SEX-LINKED CONTROL OF SEX-PHEROMONE BEHAVIORAL-RESPONSES IN EUROPEAN CORN-BORER MOTHS (OSTRINIA-NUBILALIS) CONFIRMED WITH TPI MARKER GENE." *Archives of Insect Biochemistry and Physiology* 15(2): 67-77.

Grenier, S., P. Anglade, B. Naibo, P. F. Galichet and N. Hawlitzky (1990). "SURVEY ON DISTRIBUTION OF TACHINARIA (DIPTERA, TACHINIDAE), PARASITOIDS OF CORN MOTHS OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE) IN FRANCE (1985-1987)." *Entomophaga* 35(3): 485-492.

Grenier, S. and G. Plantevin (1990). "DEVELOPMENT MODIFICATIONS OF THE PARASITOID PSEUDOPERICHAETA-NIGROLINEATA (DIPT, TACHINIDAE) BY FENOXYCARB, AN INSECT GROWTH-REGULATOR, APPLIED ONTO ITS HOST OSTRINIA-NUBILALIS (LEP, PYRALIDAE)." *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 110(5): 462-470.

The action of the fenoxycarb (an IGR JH mimetic) on the development of the tachinid parasitoid *P. nigrolineata* was tested by application onto its host *O. nubilalis* (by dipping larvae into acetone solution at 0 to 5 $\mu\text{g}/\mu\text{l}$). The duration of the larval development of the parasitoid (from host 4/5 ecdysis to pupariation) increased with the fenoxycarb concentrations from 11 days for control to 19 for 5 μg . the duration of the puparial stage was only slightly affected. Fenoxycarb treatment induced a high mortality of parasitoid instars II and III: 37% with 5 μg vs. 0 with control. The yield in flies was reduced from 49% for controls to 31% for 5 μg . the larval growth was strongly delayed by the IGR: about 50% of "treated" parasitoids were still in instar, I, 6 d after 4/5 host ecdysis vs. 5% in controls. Fenoxycarb "treated" larvae stopped their growth especially in instar II, at a weight near 1 mg, such that 50% were still in this state 22 d after 4/5 ecdysis while 92% of control larvae had become pupariae. Contrary to some questionable results previously reported on the benign action of fenoxycarb on different beneficial insects, this IGR appeared harmful for the tachinid larvae tested. This JH mimetic, broadly used especially on orchard pests should be more carefully sprayed with consideration for natural enemies.

Keil, C. B., C. E. Mason and W. B. Showers (1990). "APYRENE SPERMATOGENESIS IN OSTRINIA-NUBILALIS (HUBNER) - OBLIGATE AND FACULTATIVE DIAPAUSING STRAINS." *Journal of Heredity* 81(1): 72-74.

Kelker, D. H., D. A. Lee and J. R. Spence (1990). "USE OF STANDARD TEMPERATURE THRESHOLDS AND PHENOLOGICAL PREDICTION FOR THE EUROPEAN CORN-BORER (OSTRINIA NUBILALIS HUBNER) IN ALBERTA." *Canadian Entomologist* 122(11-12): 1247-1258.

A degree-day model was developed for Alberta populations of *Ostrinia nubilalis* Hubner. Starting with overwintered fifth-instar larvae, the model calculates the temporal distribution of first- and second-instar larvae which are the stages most vulnerable to chemical suppression. Predictions from three alternative models were compared against field data from southern Alberta. Use of a standard 10-degrees-C growth threshold to calculate physiological time scales allowed predictions as accurate as those obtained using either a pooled threshold (11.4-degrees-C) calculated specifically from Alberta populations, or a model using two thresholds (12.3-degrees-C for fifth-instar larvae to adult and 10.2-degrees-C for eggs to second-instar larvae) that incorporated significant differences in growth characteristics observed among life stages. We conclude that standard thresholds are sufficient for degree-day models for northern populations of *O. nubilalis*. The standard model ($t_0 = 10\text{-degrees-C}$) predicts that moth emergence will peak at ca. 145 degree-days after median pupation, and that numbers of eggs, and first- and second-instar larvae should peak at 200, 310, and 450 degree-days, respectively. Model predictions can be used to time sampling effort in support of management decisions.

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Larocque, A. M. and J. G. Houseman (1990). "EFFECT OF INGESTED SOYBEAN, OVOMUCOID AND CORN PROTEASE INHIBITORS ON DIGESTIVE PROCESSES OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE)." *Journal of Insect Physiology* 36(9): 691-697.

Lupoli, R., F. Marionpoll, M. H. Phamdelegue and C. Masson (1990). "INFLUENCE OF MAIZE LEAF VOLATILES ON THE OVIPOSITION PREFERENCES OF OSTRINIA-NUBILALIS (LEPIDOPTERA, PYRALIDAE)." *Comptes Rendus De L Academie Des Sciences Serie Iii-Sciences De La Vie-Life Sciences* 311(6): 225-230.

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Palaniswamy, P., B. Galka and B. Timlick (1990). "PHENOLOGY AND INFESTATION LEVEL OF THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS (HUBNER) (LEPIDOPTERA, PYRALIDAE), IN SOUTHERN MANITOBA." *Canadian Entomologist* 122(11-12): 1211-1220.

Studies were conducted from 1985 to 1988 in commercial corn fields distributed throughout the main corn growing areas of Manitoba to determine the distribution, phenology, and the level of infestation of the European corn borer, *Ostrinia nubilalis* (Hubner). Pheromone and blacklight traps were used to monitor the flight activity of European corn borer throughout the flight period. The level of European corn borer infestation was determined by sampling for egg masses, hatched egg masses, plants with egg masses, plants with shot holes, larvae, and stalk breakage. Results indicated that the European corn borer infestation occurred throughout the corn growing areas of Manitoba and that the population has declined from 1985 through 1988. Significant positive correlations existed among the number of egg masses, plants with egg masses, plants with shot holes, larvae per plant, and plants with broken stalks. Peak capture of moths in pheromone traps occurred well after peak oviposition, and 10-14 days after the peak blacklight trap capture. Blacklight trap catch, but not the pheromone trap catch, was positively correlated with egg mass density. Both blacklight and pheromone traps were equally efficient in determining the onset and the duration of European corn borer flight, although for initiating surveys of egg masses and shot hole damage, pheromone traps are recommended. In Manitoba, corn growers apply pesticides well before the recommended damage threshold is reached.

Peypelut, L., P. Beydon and L. Lavenseau (1990). "20-HYDROXYECDYSONE TRIGGERS THE RESUMPTION OF IMAGINAL WING DISK DEVELOPMENT AFTER DIAPAUSE IN THE EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS." *Archives of Insect Biochemistry and Physiology* 15(1): 1-19.

Reid, L., J. T. Arnason, C. Nozzolillo and R. Hamilton (1990). "RESISTANCE OF MAIZE GERM PLASM TO EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS, AS RELATED TO GEOGRAPHICAL ORIGIN." *Canadian Journal of Botany-Revue Canadienne De Botanique* 68(2): 311-316.

Reid, L. M., J. T. Arnason, C. Nozzolillo, B. R. Baum and R. Hamilton (1990). "TAXONOMY OF MEXICAN LANDRACES OF MAIZE, ZEA-MAYS, BASED ON THEIR RESISTANCE TO EUROPEAN CORN-BORER, OSTRINIA-NUBILALIS." *Euphytica* 46(2): 119-131.

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Sreng, L., R. Moreau and A. Girardie (1990). "LOCUST NEUROPEPTIDES STIMULATING SEX-PHEROMONE PRODUCTION IN FEMALE EUROPEAN CORN-BORER MOTH, OSTRINIA-NUBILALIS." *Journal of Insect Physiology* 36(10): 719-726.

Valterova, I., T. S. Bolgar, B. Kalinova, B. G. Kovalev and J. Vrkoc (1990). "HOST PLANT-COMPONENTS FROM MAIZE TASSEL AND ELECTROANTENNOGRAMME RESPONSES OF OSTRINIA-NUBILALIS TO THE IDENTIFIED COMPOUNDS AND THEIR ANALOGS." *Acta Entomologica Bohemoslovaca* 87(6): 435-444.

An extract of maize tassel was analyzed by gas chromatography-mass spectrometry. Twenty four substances were identified and the majority tested for olfactory activity on antennae of unmated males and females of the European

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corn borer moth, (ECB), *Ostrinia nubilalis*. Electroantennogrammes (EAG) were recorded in response to a series of aliphatic alcohols, aldehydes, ketones, and phenylacetaldehyde and its analogues. Greatest EAG response was elicited by phenylacetaldehyde and phenylethanol. Alcohols and aldehydes related to the "general green leaf volatile complex" were active for both sexes. It was found that the olfactory system of both males and females can perceive host plant odour, but differences in their sensitivity to some compounds tested were observed.

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