CLD DES JARDINS-DE-NAPIERVILLE
Pôle d'excellence en lutte intégrée

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Veille d'informations sur la mouche du chou *(Delia radicum)*

Ce document présente une liste d'articles et de rapports de recherches réalisés au Québec ou en dehors du Québec. Dernière mise à jour : 16 janvier 2017.

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Articles parus en 2016

Bili, M., Cortesero, A. M., Mougel, C., Gauthier, J. P., Ermel, G., Simon, J. C., ... & Poinsot, D. (2016). Bacterial Community Diversity Harboured by Interacting Species. PloS one, 11(6), e0155392.

> All animals are infected by microbial partners that can be passengers or residents and influence many biological traits of their hosts. Even if important factors that structure the composition and abundance of microbial communities within and among host individuals have been recently described, such as diet, developmental stage or phylogeny, few studies have conducted cross-taxonomic comparisons, especially on host species related by trophic relationships. Here, we describe and compare the microbial communities associated with the cabbage root fly Delia radicum and its three major parasitoids: the two staphylinid beetles Aleochara bilineata and A. bipustulata and the hymenopteran parasitoid Trybliographa rapae. For each species, two populations from Western France were sampled and microbial communities were described through culture independent methods (454 pyrosequencing). Each sample harbored at least 59 to 261 different bacterial phylotypes but was strongly dominated by one or two. Microbial communities differed markedly in terms of composition and abundance, being mainly influenced by phylogenetic proximity but also geography to a minor extent. Surprisingly, despite their strong trophic interaction, parasitoids shared a very low proportion of microbial partners with their insect host. Three vertically transmitted symbionts from the genus Wolbachia, Rickettsia, and Spiroplasma were found in this study. Among them, Wolbachia and Spiroplasma were found in both the cabbage fly and at least one of its parasitoids, which could result from horizontal transfers through trophic interactions. Phylogenetic analysis showed that this hypothesis may explain some but not all cases. More work is needed to understand the dynamics of symbiotic associations within trophic network and the effect of these bacterial communities on the fitness of their hosts.

Bili, M., Cortesero, A. M., Outreman, Y., & Poinsot, D. (2016). Host specialisation and competition asymmetry in coleopteran parasitoids. Oecologia, 1-8.

When specialists and generalists compete for a limited resource, specialists are more constrained because they are less likely to find an alternative resource. In parasitoids with overlapping host ranges, asymmetric competition should therefore exist where specialists are more likely to win the host in a contest. Competition between parasitoids has been studied mostly in hymenopterans. In hymenopteran parasitoid wasps, females must reach the host to lay their eggs and can thus strongly influence the outcome of competition between future offspring by killing eggs or larvae of competitors. We studied competition between the free-ranging larvae of two sympatric coleopteran parasitoid rove beetles (one specialist, Aleochara bilineata and a generalist, Aleochara bipustulata) with overlapping host ranges competing in agricultural fields for pupae of the cabbage root fly. In these species, females lay their eggs in the soil, then first instars find the host where they will develop as solitary parasitoids and deal with potential competitors. Because adult longevity and fecundity favour the generalist, we postulated that first instars of the specialist would be superior larval competitors. Accordingly, we studied the outcome of encounters between first instars of the two species provided with a single host. Irrespective of its release prior to or simultaneously with its generalist competitor, the larva of the specialist most often won. Moreover, specialist larvae still won half of the encounters when generalist larvae were given a 24-h advantage. This might explain the coexistence of the two species in the field.

Cao, M. (2016). Limitations of RNA interference as a potential technique for crop protection against insect pests (Doctoral dissertation, Durham University).

The RNAi response suppresses gene expression at the post-transcriptional level and the potential of this technique to give control of insect pests in crops has been recognised for a decade. This project focuses on a comparison of RNAi responses in insects of different orders by injecting and feeding dsRNA directed against thread (APIN) and V-Type-ATPase E homologues in the target species. The results showed systemic RNAi responses, and mortality, occurred in larvae of the Tribolium castaneum (T. castaneum), Coleopteran, but not a Hemipteran, the Acyrthosiphon pisum (A. pisum), where comparatively low levels of gene down-regulation were only achieved by injection of dsRNA. DsRNA injection produced both a lethal phenotype and gene down- regulation in larvae of the dipteran species Musca domestica (M. domestica), and Delia radicum (D. radicum), although the effects were found to be stage dependent. Rapid dsRNA degradation in the extracellular environment could lead to a limitation of RNAi reponses. In vitro experiments show that dsRNA was degraded rapidly by A. pisum haemolymph and gut extracts, and less rapidly by D. radicum larval extracts. However, T. castaneum larval extracts differ in both the amount and qualitative nature of their RNase activity; dsRNA was degraded at a slow rate, predominantly by exonuclease activity rather than endonuclease activity. A strategy using recombinant proteins was used to address limitations of RNAi effects after feeding dsRNA in insects. A recombinant protein containing an RNA binding domain (RBD) was selected to conjugate dsRNA forming a protein-RNA complex. The complexed protein enhanced the stability of dsRNA and protected it from degradation from insect extracts. A fusion protein containing snowdrop lectin (GNA) linked to RBD was also developed to produce a "systemic" RNAi effect, by transporting the protein-RNA complex to the insect haemolymph using the lectin as a "carrier".

Eigenbrode, S. D., Birch, A. N. E., Lindzey, S., Meadow, R., & Snyder, W. E. (2016). REVIEW: A mechanistic framework to improve understanding and applications of push-pull systems in pest management. Journal of Applied Ecology, 53(1), 202-212.

To locate and evaluate host patches before oviposition, parasitoids of herbivorous insects utilize plant volatiles and host-derived cues, but also evaluate predator-derived infochemicals to reduce predation risks. When foraging in host habitats infested with entomopathogenic fungi that can infect both a parasitoid and its host, parasitoids may reduce the risk of intraguild predation (IGP) by avoiding such patches. In this study, we examined whether the presence of the entomopathogenic fungi Metarhizium brunneum and Beauveria bassiana in soil habitats of a root herbivore, Delia radicum, affects the behavior of Trybliographa rapae, a parasitoid of D. radicum. Olfactometer bioassays revealed that

T. rapae avoided fungal infested host habitats and that this was dependent on fungal species and density. In particular, the parasitoid avoided habitats with high densities of the more virulent fungus, M. brunneum. In addition, host density was found to be important for the attraction of T. rapae. Volatiles collected from host habitats revealed different compound profiles depending on fungal presence and density, which could explain the behavior of T. rapae. We conclude that T. rapae females may use volatile compounds to locate high densities of prey, but also compounds related to fungal presence to reduce the risk of IGP towards themselves and their offspring.

Guerra, P. C., Keil, C. B., Stevenson, P. C., Mina, D., Samaniego, S., Peralta, E., ... & Chancellor, T. C. (2016). Larval performance and adult attraction of Delia platura (Diptera: Anthomyiidae) in a native and an introduced crop. Journal of Economic Entomology, tow237.

Delia platura Meigen is an important pest in crops around the world. Its host range includes almost 50 species, and it can develop in soil organic matter. In Ecuador, D. platura is a serious problem for the crop, Lupinus mutabilis Sweet (Chocho), and it also attacks broccoli (Brassica oleracea L.). After broccoli is harvested, crop residue is mixed with soil or collected and stored close to Chocho fields. The objectives of this study were to determine the adaptive responses of larvae reared on different hosts and whether D. platura females are preferentially attracted to germinating L. mutabilis seeds or broccoli residue. Accordingly, larval performance and attraction of female D. platura reared on broccoli residue and L. mutabilis seeds were evaluated. The number of larvae, pupae, and adults were higher when reared on broccoli. Conversely, pupal weight was higher and time from larva to pupa, pupa to adult, and total life cycle were longer in flies reared on L. mutabilis. Although D. platura developed more quickly on broccoli, L. mutabilis was also a good host since pupae were heavier compared with flies reared on broccoli. Delia platura females reared on broccoli preferred broccoli residue to L. mutabilis in an olfactometer. Volatiles from broccoli residue in soil may attract D. platura females and stimulate oviposition on L. mutabilis seeds. Environmentally benign production of L. mutabilis crops with minimal insecticide applications may require the elimination of fresh broccoli residue as fertilizer in soils where L. mutabilis is cultivated.

Hassan, K. (2016). Effect of different herbivore induction in plants of different developmental stages, and consequences for flower-associated organisms.

Joseph, S. V. (2016). Insecticides effective against cabbage maggot. Crops and Soils, 49(2), 45-46.

Cabbage maggot is a serious insect pest of brassica crops such as broccoli and cauliflower in the Central Coast of California. The efficacy of 29 insecticides was determined against cabbage maggot through a laboratory bioassay by exposing field-collected maggots to insecticide-treated soil immediately after application.

Joseph, S. V. (2016). Timing of Insecticide Application for Cabbage Maggot 1 Control in Seeded Turnip on the Central Coast of California. Southwestern Entomologist, 41(3), 625-632.

Because infestation by cabbage maggot, Delia radicum (L.), does not peak immediately after planting seeds, experiments in 2014 and 2015 determined the effect of timing insecticide application for control on direct-seeded turnip, Brassica rapa var. rapa (L.). Treatments were one chlorpyrifos application either at planting or 2 weeks after planting. Twenty turnip roots were sampled three times starting 2 weeks after the second application. Roots were evaluated for the number of roots infested with cabbage maggots and severity of damage on a scale of 0 = no injury, through 9 = no root hairs or >90% root destroyed. In both years, incidence of cabbage maggot was significantly less in turnip roots treated with insecticide 2 weeks after planting than at planting. Implications of these results for management of cabbage maggot on the Central Coast of California are discussed.

Lamy, F. C., Poinsot, D., Cortesero, A. M., & Dugravot, S. (2016). Artificially applied plant volatile organic compounds modify the behavior of a pest with no adverse effect on its natural enemies in the field. Journal of Pest Science, 1-11.

The use of volatile organic compounds (VOCs) derived from plants to manipulate insect pest behavior can be applied in an integrated pest management strategy (IPM) using a combination of attractive and repulsive stimuli. The "push–pull" strategy was developed on this idea in order to disturb and modify the distribution and abundance of pests to protect crops and reduce the use of agrochemicals. This field experiment investigates, in a "push–pull" context using broccoli as a target crop and Chinese cabbage as a pull component, the stimulo-deterrent effect of five synthetic VOCs (dimethyl disulfide, linalool, geraniol, eucalyptol and citronellol) on the oviposition of the cabbage root fly Delia radicum. With the exception of linalool, all compounds tested had a significant effect in the field and eucalyptol showed the most promising results, reducing oviposition on broccoli by 45 %. Moreover, eucalyptol was the only VOC able to reduce the final infestation of D. radicum, i.e., the number of pupae. The other VOCs reduced oviposition by 20–30 %. No adverse effect of the treatments was found on major parasitoids (Trybliographa rapae and Aleochara bipustulata) and potential predators of D. radicum. This study highlights the potential of VOCs as deterrent stimuli against agricultural pests in the field.

Savage, J., Fortier, A. M., Fournier, F., & Bellavance, V. (2016). Identification of Delia pest species (Diptera: Anthomyiidae) in cultivated crucifers and other vegetable crops in Canada. Canadian Journal of Arthropod Identification, (29), 1-40.

A number of root maggot fly species from the large genus Delia Robineau-Desvoidy (Diptera: Anthomyiidae) are important pests of cultivated crucifers and many other field and vegetable crops. The present work provides identification keys in English and French to the adults, third instar larvae, puparia, and eggs of all pests of cultivated crucifers and other vegetable crops in Canada, namely Delia antiqua (Meigen), D. floralis (Fallén), D. florilega (Zetterstedt), D. planipalpis (Stein), D. platura (Meigen) and D. radicum (Linnaeus). DNA barcodes are provided for all species except D. planipalpis and new data on larval host associations in southern Québec are presented.

Shuhang, W., Voorrips, R. E., Steenhuis-Broers, G., Vosman, B., & Loon, J. J. Antibiosis resistance against larval cabbage root fly, Delia radicum, in wild Brassica-species. Euphytica, 1-17.

Cabbage root flies (Delia radicum) are a major threat to cabbage production in Western Europe and North America. Host plant resistance is the most promising option in controlling cabbage root fly damage. In a no-choice field test, we evaluated 94 accessions belonging to 16 Brassica-species for antibiosis resistance against the larvae. Thirteen accessions were selected as putatively resistant, which were subsequently re-tested in the greenhouse. The proportion of eclosed flies was introduced as the main parameter to assess antibiosis in the greenhouse, together with other insect and plant parameters. High levels of antibiosis resistance were identified in B. fruticulosa PI663081 and B. spinescens BRA2994, with significantly lower proportions of eclosed flies (1 % of the number of eggs used for infestation) compared to other accessions. Both species are difficult to cross with B. oleracea. Plants with a high level of antibiosis and medium to high tolerance were found in several accessions of other Brassica species (B. villosa BRA2922, B. montana BRA2950, B. hilarionis HRIGU12483, B. macrocarpa BRA2944) which are more amenable for crossing with B. oleracea. Selection of the most resistant plants belonging to these accessions may yield promising candidates for breeding cabbages resistant to Delia radicum.

van Geem, M., Gols, R., Raaijmakers, C. E., & Harvey, J. A. (2016). Effects of population-related variation in plant primary and secondary metabolites on aboveground and belowground multitrophic interactions. Chemoecology, 26(6), 219-233.

Insects feeding on aboveground and belowground tissues can influence each other through their shared plant and this is often mediated by changes in plant chemistry. We examined the effects of belowground root fly (Delia radicum) herbivory on the performance of an aboveground herbivore (Plutella xylostella) and its endoparasitoid wasp (Cotesia

vestalis). Insects were reared on three populations of wild cabbage (Brassica oleracea) plants, exhibiting qualitative and quantitative differences in root and shoot defense chemistry, that had or had not been exposed to root herbivory. In addition, we measured primary (amino acids and sugars) and secondary [glucosinolate (GS)] chemistry in plants exposed to the various plant population-treatment combinations to determine to what extent plant chemistry could explain variation in insect performance variables using multivariate statistics. In general, insect performance was more strongly affected by plant population than by herbivory in the opposite compartment, suggesting that population-related differences in plant quality are larger than those induced by herbivory. Sugar profiles were similar in the three populations and concentrations only changed in damaged tissues. In addition to population-related differences, amino acid concentrations primarily changed locally in response to herbivory. Whether GS concentrations changed in response to herbivory (indole GS) or whether there were only population-related differences (aliphatic GS) depended on GS class. Poor correlations between performance and chemical attributes made biological interpretation of these results difficult. Moreover, trade-offs between life history traits suggest that factors other than food nutritional quality contribute to the expression of life history traits.

van Herk, W. G., Vernon, R. S., Waterer, D. R., Tolman, J. H., Lafontaine, P. J., & Prasad, R. P. (2016). Field Evaluation of Insecticides for Control of Cabbage Maggot (Diptera: Anthomyiidae) in Rutabaga in Canada. Journal of Economic Entomology, tow238.

At the time of this research, there were only two insecticides registered for control of cabbage maggot, Delia radicum L., in rutabaga in Canada, one of which (diazinon) will be deregistered by 2017, and resistance having been reported in some areas for the other (chlorpyrifos). To screen for chemistries to replace these organophosphates, and obtain efficacy data comparable between key vegetable brassica production areas in Canada, four small plot field studies were conducted concurrently in British Columbia, Saskatchewan, Ontario, and Quebec in 2009. These studies followed standardized protocols for seeding, application of insecticide drenches, sampling and damage assessment, and generally tested the same products. Of the insecticides evaluated, none provided maggot control comparable with the industry standard, chlorpyrifos. However, cyantraniliprole (Cyazypyr 200SC; registered in 2015 as Verimark) applied at 3 g AI (15.0 ml product)/100 m row of seeded rutabagas consistently provided the next highest reduction in % culls, suggesting the efficacy of this chemical may be improved if used at higher rates. The results of these studies are discussed in the context of current literature on D. radicum management in rutabaga. Future management strategies are also discussed, including a transplant plug treatment approach for increasing the dosage per plant and efficacy of chemistries such as Cyazypyr 200SC in the field.

Vukasinovic, D. (2016). Climate Change Effects Overwintering of Insects.

Climate change is modifying winter conditions rapidly and predicting species' reactions to global warming has been the "the holy grail" of climate sciences, especially for managed systems, like agro-ecosystems. Intuitively, increased winter temperatures should release insects from coldinduced mortality, but warmer winters can lead to fitness costs via increased metabolic rate and a drain on energy reserves.The overall objective of this thesis was to investigate differences in species responses in mild(+5°C) and cold (−5°C) winters. This was done by assessing organismal physiology, overwintering fitness and post-winter performance in two species: 1) a natural enemy Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae), the Harlequin Ladybird, overwintering as an adult and 2) the agricultural pest Delia radicum (L.) (Diptera: Anthomyiidae), the cabbage root fly, overwintering as pupae.Physiological traits measured during winter were as follows: Standard Metabolic Rate (SMR), Q10, energy reserves: dry mass, lipids, glycogen and proteins. The overwintering fitness: longevity, mortality and body mass (loss) were assessed.Post-winter fitness was tested, in H. axyridis: the status of survivors, feeding capacity, mating and the length of the pre-oviposition period. Post winter fitness in D. radicum: the time of emergence of flies.Energy metabolismSMR was higher in mild compared to cold winters (H. axyridis) especially at the end of wintertreatment (in both H. axyridis and D. radicum), indicating earlier

termination of diapause. Ingeneral, SMR increased with time and temperature measured in respiration chambers, indicatingloss of endogenous control of metabolism.In cold winter H. axyridis relied on dry mass depletion and lipid catabolism for energy and in mild winters they lost water, probably due to higher respiration evidenced at the end of winter. Glycogen was equally catabolized by H. axyridis in both winter conditions, again supporting a lack of endogenous control of metabolism to specific winter conditions. Winter and post-winter fitnessMild winters increased mortality of H. axyridis for two subsequent years, compared to cold winters. Conversely, D. radicum had increased mortality during cold winters. The mortality risk factor in H. axyridis seemed to depend on high SMR and concurrent water depletion, in short the failure to adapt to the mild winters. H. axyridis males suffered increased mortality with decreasing body mass.Post-winter performance of H. axyridis was positively affected by mild winter conditions such that higher feeding capacity and shorter pre-oviposition period was recorded, but may be affected negatively by cold winters, which caused chill injury related mortality (recorded after winter) and could affect post-winter reproduction. In the case of D. radicum, mild winter caused earlier emergence of flies.Overall, this study showed that mild winters increased mortality of H. axyridis, but earlier onset of population growth may compensate for this, and in D. radicum mild winters decreased mortality and induced earli er emergence of flies. Thus, for some species, like H. axyridis, mild winters may not benefit nor conclusively stress the species, but for others like D. radicum, mild winters may benefit the population and be of concern to farmers.Agricultural insect fauna is a prime example of a rapid, contemporary evolution, optimal formeasuring species response under constant selection pressure, including organismal physiology.Thus, the methodological approach applied in this study, could prove a valuable tool for improving predictability of field population dynamics during climate change.

Welte, C. U., de Graaf, R. M., van den Bosch, T. J., Op den Camp, H. J., van Dam, N. M., & Jetten, M. S. (2016). Plasmids from the gut microbiome of cabbage root fly larvae encode SaxA that catalyses the conversion of the plant toxin 2-phenylethyl isothiocyanate. Environmental microbiology, 18(5), 1379-1390.

Cabbage root fly larvae (Delia radicum) cause severe crop losses (≥ 50%) of rapeseed/ canola and cabbages used in the food and biofuel industries. These losses occur despite the fact that cabbages produce insecticidal toxins such as isothiocyanates. Here we describe the cabbage root fly larval gut microbiome as a source of isothiocyanate degrading enzymes. We sequenced the microbial gut community of the larvae and analysed phylogenetic markers and functional genes. We combined this with the isolation of several microbial strains representing the phylogenetic distribution of the metagenome. Eleven of those isolates were highly resistant towards 2-phenylethyl isothiocyanate, a subset also metabolized 2-phenylethyl isothiocyanate. Several plasmids appeared to be shared between those isolates that metabolized the toxin. One of the plasmids harboured a saxA gene that upon transformation gave resistance and enabled the degradation of 2-phenylethyl isothiocyanate in Escherichia coli. Taken together, the results showed that the cabbage root fly larval gut microbiome is capable of isothiocyanate degradation, a characteristic that has not been observed before, and may help us understand and design new pest control strategies.

Articles parus en 2015

Bourhis, Y., Poggi, S., Mammeri, Y., Cortesero, A. M., Le Ralec, A., & Parisey, N. (2015). Perception-based foraging for competing resources: Assessing pest population dynamics at the landscape scale from heterogeneous resource distribution. Ecological Modelling, 312, 211-221.

Resource distribution, through its effects on individual foraging and survival, drives population dynamics across the landscape. In an agricultural context, resource distribution is therefore a key information in assessing whether or not a pest population may invade and persist in a given environment. Addressing this issue by means of numerical

exploration requires a population model with a sound dependence on the landscape. In this paper, we demonstrate that this dependence is effectively secured by a multi-scale description of the population. We derived a reaction–diffusion population model accounting for two individual-scale processes determining resource utilisation: (1) resource perception as a determinant of mobility and (2) energy supply management as a determinant of survival. In this model, the distribution of two competing resources (feeding and laying sites) affects the spatial population dynamics of a dipteran pest through a heterogeneous dispersion of the individuals and a metabolic currency. We conducted a global sensitivity analysis to evaluate the impact of both individual-scale processes on the population dynamics. This exploration demonstrated the biological relevance of the model according to field observations and theoretical expectations. Our key finding is that resource perception and energy supply management appear as significant as the demographic component regarding the resulting dynamics of the pest. Building on its acute multi-scale landscape dependence, this model may be particularly useful for investigating the putative relationships between agricultural landscape features and pest outbreaks.

Cotes, B., L.-M. Rannback, M. Bjorkman, H. R. Norli, N. V. Meyling, B. Ramert and P. Anderson (2015). "Habitat selection of a parasitoid mediated by volatiles informing on host and intraguild predator densities." Oecologia 179(1): 151-162.

To locate and evaluate host patches before oviposition, parasitoids of herbivorous insects utilize plant volatiles and host-derived cues, but also evaluate predator-derived infochemicals to reduce predation risks. When foraging in host habitats infested with entomopathogenic fungi that can infect both a parasitoid and its host, parasitoids may reduce the risk of intraguild predation (IGP) by avoiding such patches. In this study, we examined whether the presence of the entomopathogenic fungi Metarhizium brunneum and Beauveria bassiana in soil habitats of a root herbivore, Delia radicum, affects the behavior of Trybliographa rapae, a parasitoid of D. radicum. Olfactometer bioassays revealed that T. rapae avoided fungal infested host habitats and that this was dependent on fungal species and density. In particular, the parasitoid avoided habitats with high densities of the more virulent fungus, M. brunneum. In addition, host density was found to be important for the attraction of T. rapae. Volatiles collected from host habitats revealed different compound profiles depending on fungal presence and density, which could explain the behavior of T. rapae. We conclude that T. rapae females may use volatile compounds to locate high densities of prey, but also compounds related to fungal presence to reduce the risk of IGP towards themselves and their offspring.

Danner, H., P. Brown, E. A. Cator, F. J. M. Harren, N. M. van Dam and S. M. Cristescu (2015). "Aboveground and Belowground Herbivores Synergistically Induce Volatile Organic Sulfur Compound Emissions from Shoots but Not from Roots." Journal of Chemical Ecology 41(7): 631-640.

Studies on aboveground (AG) plant organs have shown that volatile organic compound (VOC) emissions differ between simultaneous attack by herbivores and single herbivore attack. There is growing evidence that interactive effects of simultaneous herbivory also occur across the root-shoot interface. In our study, Brassica rapa roots were infested with root fly larvae (Delia radicum) and the shoots infested with Pieris brassicae, either singly or simultaneously, to study these root-shoot interactions. As an analytical platform, we used Proton Transfer Reaction Mass Spectrometry (PTR-MS) to investigate VOCs over a 3 day time period. Our set-up allowed us to monitor root and shoot emissions concurrently on the same plant. Focus was placed on the sulfur-containing compounds; methanethiol, dimethylsulfide (DMS), and dimethyldisulfide (DMDS), because these compounds previously have been shown to be biologically active in the interactions of Brassica plants, herbivores, parasitoids, and predators, yet have received relatively little attention. The shoots of plants simultaneously infested with AG and below-ground (BG) herbivores emitted higher levels of sulfur-containing compounds than plants with a single herbivore species present. In contrast, the emission of sulfur VOCs from the plant roots increased as a consequence of root herbivory, independent of the presence of an AG herbivore. The onset of root emissions was more rapid after damage than the onset of shoot emissions. The shoots of double infested plants also emitted higher levels of methanol. Thus, interactive effects of root and shoot herbivores exhibit more strongly in the VOC emissions from the shoots than from the roots, implying the involvement of specific signaling interactions.

Deasy, W. P. (2015). Novel approaches for the management of cabbage root fly.

Delia radicum L. (Diptera: Anthomyiidae), the cabbage root fly, is a specialist root-feeding insect pest of Brassica crops. The impending withdrawal of chlorpyrifos, one of the main pesticides used against D. radicum, opens new

opportunities to research alternative pest management strategies. Manipulating host plant location cues to influence D. radicum adult and larval behaviour, along with induced plant defence responses, offer potential integrative crop protection solutions (Chapter 1). This thesis aimed to identify the semiochemistry underpinning D. radicum larval host plant location, and to investigate whether plant defence induction treatments (methyl jasmonate [MeJA], D-Fructose) and a herbivore induced volatile (dimethyl disulfide [DMDS]) affect D. radicum larval performance and adult oviposition preference. In choice-test bioassays, larvae were inconsistent in their responses to root exudates collected from Brassica host plants (Chapter 2). A combined bioassay and EthoVision® video-tracking approach was developed to record and analyse larval movements in response to volatiles emitted from host and non-host plant roots (Chapter 3). Larvae were significantly attracted to host plant root volatiles. Olfactory stimuli from roots of the non-host plant onion (Allium cepa L. 'Ailsa Craig'), which share overlapping, yet distinctive volatile profiles to that of Brassica plants, also elicited positive taxis. By analysing the volatile metabolome of broccoli (B. oleracea L. convar. botrytis L. Alef. var. cymosa Duchesne 'Parthenon') and onion roots using solid phase micro extraction-gas chromatography-mass spectrometry (SPME-GCMS), a suite of candidate volatile orientation cues were identified. A SPME-based method was developed to non-invasively collect root volatiles in situ from glasshouse- and field-grown broccoli plants pre- and post-D. radicum infestation (Chapters 4, 5 and 6). GC-MS analyses revealed that sulfur compounds, showing characteristic temporal emission patterns, were the principal volatiles released by roots in response to damage. This new method, which has potential for wide application in chemical ecology research, allows the study of volatiles in the soil in situ that are critical for interactions between trophic levels. In EthoVision® bioassays, a major volatile constituent of broccoli roots, DMDS, was attractive to larvae, but toxic at the highest dose tested (Chapter 3). Glasshouse and on-farm experiments using broccoli were conducted to evaluate the efficacy of MeJA, D-Fructose and DMDS against D. radicum compared to commercially available crop protection products (chlorpyrifos [Dursban® WG], spinosad [Tracer®], Steinernema feltiae Filipjev [Nematoda: Steinernematidae] [Entonem] and garlic granules [ECOguard®]). MeJA and garlic reduced larval performance under glasshouse conditions whereas D-Fructose and DMDS did not at the concentrations tested (Chapter 7). In field studies, MeJA combined with reduced rate chlorpyrifos, spinosad, and S. feltiae all showed partial efficacy for controlling D. radicum larvae. Inherent field site, weather and D. radicum population density variability highlighted that glasshouse results cannot always be reproduced in more complex field environments (Chapter 8). Further research is needed into formulation, mode of application and timing to improve efficacy of promising treatments that may help in future integrated pest management (IPM) for this key pest in the absence of existing pesticides.

Guo, Q., Y.-J. Hao, Y. Li, Y.-J. Zhang, S. Ren, F.-L. Si and B. Chen (2015). "Gene cloning, characterization and expression and enzymatic activities related to trehalose metabolism during diapause of the onion maggot Delia antiqua (Diptera: Anthomyiidae)." Gene 565(1): 106-115.

Trehalose represents the main hemolymph sugar in many insects, and it functions in energy metabolism and protection in extreme environmental conditions. To gain an insight into trehalose functions in Delia antiqua diapausing pupae, genes encoding trehalose-6-phosphate synthase (TPS), trehalose-6-phosphatase (TPP) and trehalase (TRE) were identified and characterized. Analysis of the deduced amino acid sequences indicated that these genes were highly similar to each homolog from Diptera insects. Gene expressions and their enzyme activities were also investigated. The differential expressions of TPS and TPP shared very similar trends for summer and winter diapausing pupae. Their enzyme activities were consistent with the gene expressions. Trehalose concentrations in summer- and winter-diapausing pupae were lower at the initial phase (4.37-5.09 mu g/mg) but increased gradually and peaked in the maintenance phase (10.59-14.36 mu g/mg); the concentrations then declined in the quiescence phase. We speculated that a higher trehalose content during the maintenance stage may contribute to protein and/or biological membrane stabilization in winter or to desiccation resistance in the summertime. Diapause termination requires a decrease in the trehalose concentration to promote pupal-adult development. The glucose content also varied during the diapausing processes. Our results provide an overview of the differential expression levels of trehalose metabolic enzymes, confirming the important roles of trehalose in diapausing pupae of the onion maggot. Further work remains to explore its actual functions. (C) 2015 Elsevier B.V. All rights reserved.

Hommes, M., Birch, N., Cortesero, A. M., Deasy, W., Faloya, V., Herbst, M., ... & Vlaswinkel, M. (2015). Field vegetables-IPM solutions ready to use in practise. Ipm Innovation in Europe.

https://www.ior.poznan.pl/plik,2058,hommes-martin-pdf.pdf

Joseph, S. V., Hoebeke, E. R., & McHugh, J. V. (2015). Rove Beetles of the Genus Aleochara Gravenhorst (Coleoptera: Staphylinidae) Parasitizing the Cabbage Maggot, Delia radicum (L.)(Diptera: Anthomyiidae), in the Northern Central Coast of California. Proceedings of the Entomological Society of Washington, 117(4), 525-528.

Joseph, S. V. and J. Zarate (2015). "Comparing efficacy of insecticides against cabbage maggot (Diptera: Anthomyiidae) in the laboratory." Crop Protection 77: 148-156.

The efficacy of 29 insecticides was determined against cabbage maggot, Delia radicum (L.) through a laboratory bioassay by exposing field collected D. radicurn maggots to insecticide-treated soil immediately after application. In an assay, 10 D. radicum maggots were exposed to insecticide treated soil and then efficacy of insecticides was determined using three parameters: (1) proportion of maggots on the soil surface after 24 h, (2) proportion of change in weight of turnip bait, and (3) dead maggots after 72 h. Efficacy index (scale of 0-100) was developed based on the three parameters. Efficacy index of 11 insecticides was >= 70 against D. radicum and they were zeta-cypermethrin, tolfenpyrad, fenpropathrin, clothianidin, bifenthrin, lambda-cyhalothrin, chlorpyrifos, ethoprop, thiamethoxam + lambda-cyhalothrin, pyrethrins, and oxamyl in the order of highest to lowest efficacy. There was a significant positive correlation (R-2 > 0.5) among the three parameters. Furthermore, persistence of efficacy was examined on eight insecticides, where D. radicum maggots were exposed to field aged (1, 3, 7, 14, and 30 d) insecticide treated soil. Percentages of D. radicum maggots dead and on the soil surface were significantly greater when field aged soil was treated with bifenthrin, tolfenpyrad and clothianidin than other insecticides for most of the field age interval treatments. Efficacy of clothianidin did not change through field age interval treatments. The implications of these results on D. radicum management in the central coast of California are discussed. Published by Elsevier Ltd.

Kergunteuil, A., A. M. Cortesero, V. Chaminade, S. Dourlot, C. Paty, A. Le Ralec and S. Dugravot (2015). "Field and laboratory selection of brassicaceous plants that differentially affect infestation levels by Delia radicum." Journal of Applied Entomology 139(7): 487-495.

Several plant traits control plant-insect interactions and shape host range of herbivorous insects according to their degree of dietary specialization. Understanding how plant species diversity influences herbivore infestations is of interest for the development of alternative crop protection strategies. In a pest management context, an appropriate selection of plants can modify pest distribution at the field scale. To develop a push-pull' strategy against the cabbage root fly, Delia radicum, we conducted a field study to both determine which plants exhibit contrasted pest infestation levels and to evaluate their influence on egg predation activity. Our field experiment reveals that infestation levels of brassicaceous plants by the cabbage root fly in the field can vary considerably according to plant genotype and species, while the number of predated eggs is only slightly affected by plant species. Olfactometry studies carried out under laboratory conditions revealed that plants harbouring the highest number of eggs in the field were also highly attractive, suggesting that olfactory stimuli are responsible, at least partially, for the differential infestation levels observed in the field. In a push-pull' context, this study demonstrates that different brassicaceous plants could be used to redistribute cabbage root flies in broccoli crops without compromising herbivore control by natural enemies. In addition, the importance of plant volatiles for infestation levels suggests a potential for developing a semiochemically assisted push-pull' system in which trap plants would be enhanced by synthetic release of attractive compounds.

Kergunteuil, A., S. Dugravot, H. Danner, N. M. van Dam and A. M. Cortesero (2015). "Characterizing Volatiles and Attractiveness of Five Brassicaceous Plants with Potential for a 'Push-Pull' Strategy Toward the Cabbage Root Fly, Delia radicum." Journal of Chemical Ecology 41(4): 330-339.

Volatile Organic Compounds (VOCs) released by plants are involved in various orientation processes of herbivorous insects and consequently play a crucial role in their reproductive success. In the context of developing new strategies for crop protection, several studies have previously demonstrated the possibility to limit insect density on crops using either host or non-host plants that release attractive or repellent VOCs, respectively. The cabbage root fly, Delia radicum, is an important pest of brassicaceous crops for which control methods have to be implemented. Several studies have shown that plant odors influence cabbage root fly behavior, but only few VOCs have been identified so far. The present study aimed at selecting both plants and olfactory stimuli that could be used in the development of a "push-pull" strategy against the cabbage root fly. Olfactometer results revealed that plants belonging to the same

family, even to the same species, may exhibit different levels of attractiveness toward D. radicum. Plants that were found attractive in behavioral observations were characterized by high release rates of distinct terpenes, such as linalool, beta-caryophyllene, humulene, and alpha-farnesene. This study represents a first step to identify both attractive plants of agronomic interest, and additional volatiles that could be used in the context of trap crops to protect broccoli fields against the cabbage root fly.

Lascaux, E., Gerard, S., & Dutertre, R. (2015). Results of 4 years of studies with biocontrol solution in the management of Delia sp. flies in horticulture. In 5th Conférence Internationale sur les Méthodes Alternatives de Protection des Plantes, 11-13 mars, 2015, Nouceau Siècle, Lille, France (pp. 499-509). Association Française de Protection des Plantes (AFPP).

This article tends to be an assessment of 4 years of experimentation in horticulture, to find strategies of management of the pest Delia sp. flies: seed corn maggot Delia platura, cabbage maggot Delia radicum, onion maggot Delia antiqua. Since 2011, the study of a new soil predatory mite Macrocheles robustulus which consume eggs and new larva stages of Delia sp. flies, has promoted an experimental program concerning this pest management. Therefore on a base of 18 trials, this beneficial has been tested alone or in association in different strategies of protection in radish, turnips and onions. If strategies lead to promising results in crops under tunnels, there are more difficult to set up and evaluate in open field. These trials have allowed to enhance the interest of mulch as physical barrier for pest and favorable soil cover to maintain the mites.

McLellan, C. R., Worton, B. J., Deasy, W., & Birch, A. N. E. (2015). Modelling larval movement data from individual bioassays. Biometrical Journal, 57(3), 485-501.

We consider modelling the movements of larvae using individual bioassays in which data are collected at a high-frequency rate of five observations per second. The aim is to characterize the behaviour of the larvae when exposed to attractant and repellent compounds. Mixtures of diffusion processes, as well as Hidden Markov models, are proposed as models of larval movement. These models account for directed and localized movements, and successfully distinguish between the behaviour of larvae exposed to attractant and repellent compounds. A simulation study illustrates the advantage of using a Hidden Markov model rather than a simpler mixture model. Practical aspects of model estimation and inference are considered on extensive data collected in a study of novel approaches for the management of cabbage root fly.

Muška, F., Kazda, J., & Cerkal, R. (2015). Cabbage maggot (Delia radicum) as a potential rapeseed (Brassica napus L.) pest in the Czech Republic. Can we make use of the German experience?. Nachrichtenblatt des Deutschen Pflanzenschutzdienstes, 60(11), 252.

Cabbage maggot (Delia radicum) belongs to one of the most significant pests of Brassicaceae vegetables (especially cauliflower) in the Czech Republic. Nowadays, it is also presented as a potentially major pest of rapeseed (Brassica napus L.). This work provides a historical overview of the cabbage maggot's occurrences on Brassicaceae vegetables in the Czech Republic territory up to the year 2005. In addition, it offers a prognosis of this pest's prospective spread. Based on the German experience, it can be assumed that the high concentration of rapeseed will cause a considerable spread of the cabbage maggot, and consequently, it will lead to an increase in the economic injury. Therefore, Czech growers are faced with another serious problem – there are no pesticides registered for the rapeseed usage to protect rapeseed plants against the cabbage maggot. However, the possibility of using rapeseed-registered pesticides against this crop's other pests is one of the solutions at hand. Moreover, other countries' observations may be successfully employed in an effort to solve this problem. In these countries, the damage caused by the cabbage maggot has been reduced by modification of the growing technology.

Myrand, V., J. P. Buffet and C. Guertin (2015). "Susceptibility of Cabbage Maggot Larvae (Diptera: Anthomyiidae) to Hypocreales Entomopathogenic Fungi." Journal of Economic Entomology 108(1): 34-44.

The pathogenicity of six Metarhizium spp., four Beauveria bassiana (Balsamo) Vuillemin, and four Tolypocladium cylindrosporum Gams (Ascomycota: Hypocreales) fungal pathogens exposed to third-instar Delia radicum L. was evaluated in laboratory bioassays. The presence of intra- and intergeneric variations concerning the pathogenicity of the isolates was investigated. Results show that all Metarhizium spp. and T. cylindrosporum isolates caused a noteworthy mortality to the third instar and consequently reduced adult eclosion. The well-known standard, F52 strain

(identified as Metarhizium brunneum), resulted in up to 79% reduction in D. radicum eclosion. The other Metarhizium isolates including UAMH 9197 (Metarhizium anisopliae) and UAMH 2801 (M. brunneum), as well as T. cylindrosporum DAOM 167325 and DAOM 183952, produced a mean eclosion reduction of >50%. While the pathogenicity of Metarhizium spp. and T. cylindrosporum is similar, the B. bassiana isolates are undoubtedly less pathogenic. Based on the results obtained with the selected isolates, no intrageneric differences relative to the pathogenicity of the isolates appeared to be present. Globally, this study deepened the knowledge about D. radicum susceptibility toward Hypocreales entomopathogenic fungi, chiefly T. cylindrosporum. The implications of this study regarding the development of a biological control agent are discussed.

Nilsson, U., Rännbäck, L. M., Anderson, P., Björkman, M., Futter, M., & Rämert, B. (2015). Effects of conservation strip and crop type on natural enemies of Delia radicum. Journal of Applied Entomology.

This 3-year field study investigated the combined effect of floral resources and perennial shelter habitats (i.e. conservation strips), and crop rotation in supporting natural enemies of the cabbages root fly, Delia radicum. Habitat manipulation with conservation strips increased the overall catches of hymenopteran parasitoids. However, conservation strips did not increase parasitism by either of the two dominant parasitoid species, Trybliographa rapae and Aleochara bipustulata, in any study year. In fact, higher parasitism was found in control plots in the second year. This could be explained by parasitoid mobility and higher patch detectability, as more plants in the control plots were infested with D. radicum larvae. Conservation strips did not result in increased predation of D. radicum eggs. However, the activity densities of two Bembidion species were correlated with egg predation. The species assemblage distribution of epigeal predators was best explained by seasonal period, followed by year and, to a low extent, crop type, while treatment with conservation strips had no effect. However, during the egg laying peak of D. radicum, a higher number of A. bipustulata, an important larval predator was observed in conservation strips during one study year. In conclusion, positive effects of conservation strips were demonstrated for abundance of some natural enemies of D. radicum, but a consistent increase in performance could not be adequately demonstrated due to experimental set-up, the short timescale and the complex landscape in which our study site was located.

Oduor, A. M., Stift, M., & Van Kleunen, M. (2015). The Interaction between Root Herbivory and Competitive Ability of Native and Invasive-Range Populations of Brassica nigra. PloS one, 10(10), e0141857.

The evolution of increased competitive ability (EICA) hypothesis predicts that escape from intense herbivore damage may enable invasive plants to evolve higher competitive ability in the invasive range. Below-ground root herbivory can have a strong impact on plant performance, and invasive plants often compete with multiple species simultaneously, but experimental approaches in which EICA predictions are tested with root herbivores and in a community setting are rare. Here, we used Brassica nigra plants from eight invasive- and seven native-range populations to test whether the invasive-range plants have evolved increased competitive ability when competing with Achillea millefolium and with a community (both with and without A. millefolium). Further, we tested whether competitive interactions depend on root herbivory on B. nigra by the specialist Delia radicum. Without the community, competition with A. millefolium reduced biomass of invasive- but not of native-range B. nigra. With the community, invasive-range B. nigra suffered less than native-range B. nigra. Although the overall effect of root herbivory was not significant, it reduced the negative effect of the presence of the community. The community produced significantly less biomass when competing with B. nigra, irrespective of the range of origin, and independent of the presence of A. millefolium. Taken together, these results offer no clear support for the EICA hypothesis. While native-range B. nigra plants appear to be better in dealing with a single competitor, the invasive-range plants appear to be better in dealing with a more realistic multi-species community. Possibly, this ability of tolerating multiple competitors simultaneously has contributed to the invasion success of B. nigra in North America.

Rännbäck, L. M. (2015). Biological control strategies against the cabbage root fly Delia radicum (Vol. 2015, No. 53).

Contemporary intensified agroecosystems are contributing to a reduction in natural enemy (NE) populations. In conservation biological control (CBC), NEs are favoured by providing supporting resources. CBC could be complemented with inoculation biological control (IBC) to enhance the effect of NEs. However, increased NE species richness may result in positive (e.g. niche complementarity [NC]) or negative (e.g. intraguild predation [IGP]) effects on pest suppression through species interactions. The research reported in this thesis investigated the potential of

combining CBC with IBC as a strategy for cabbage root fly, Delia radicum, control. A three-year field experiment explored the combined effect of floral resources and perennial shelter habitats (i.e., conservation strips [CS]) on NEs of D. radicum. CS increased the abundance of hymenopteran parasitoids, but did not increase parasitism by either of the two dominant parasitoid species, Trybliographa rapae and Aleochara bipustulata. The entomopathogenic fungi Metarhizium brunneum and Beauveria bassiana were found to be pathogenic to both D. radicum and T. rapae, thus representing an IGP risk to T. rapae. However, the parasitoid laid more eggs in healthy than in M. brunneum infected D. radicum larvae in choice assays. Host plant habitats harbouring high densities of M. brunneum were avoided when given a choice, but host density was more important for attraction than fungal presence, indicating a trade-off between IGP risk and reproductive success. Despite the IGP risk, field cage studies showed that combining T. rapae and M. brunneum, at both low and high fungal densities, reduced D. radicum population levels more than when either NE acted alone. Selective ovipositioning in healthy larvae presumably led to this resource partitioning and resulting NC. However, fungal presence, particularly at high density, reduced the number of emerged F1 T. rapae. Consequently, combining CBC of T. rapae with IBC using a relatively low density of M. brunneum is recommended to ensure stable, long-term D. radicum control.

Rannback, L.-M., B. Cotes, P. Anderson, B. Ramert and N. V. Meyling (2015). "Mortality risk from entomopathogenic fungi affects oviposition behavior in the parasitoid wasp Trybliographa rapae." Journal of Invertebrate Pathology 124: 78-86.

Biological control of pests in agroecosystems could be enhanced by combining multiple natural enemies. However, this approach might also compromise the control efficacy through intraguild predation (IGP) among the natural enemies. Parasitoids may be able to avoid the risk of unidirectional IGP posed by entomopathogenic fungi through selective oviposition behavior during host foraging. Trybliographa rapae is a larval parasitoid of the cabbage root fly, Delia radicum. Here we evaluated the susceptibility of D. radicum and T. rapae to two species of generalist entomopathogenic fungi, Metarhizium brunneum isolate KVL 04-57 and Beauveria bassiana isolate KVL 03-90. Furthermore, T. rapae oviposition behavior was assessed in the presence of these entomopathogenic fungi either as infected hosts or as infective propagules in the environment. Both fungi were pathogenic to D. radicum larvae and T. rapae adults, but with variable virulence. When host patches were inoculated with M. brunneum conidia in a no-choice situation, more eggs were laid by T. rapae in hosts of those patches compared to control and B. bassiana treated patches. Females that later succumbed to mycosis from either fungus laid significantly more eggs than non-mycosed females, indicating that resources were allocated to increased oviposition due to perceived decreased life expectancy. When presented with a choice between healthy and fungal infected hosts, T. rapae females laid more eggs in healthy larvae than in M. brunneum infected larvae. This was less pronounced for B. bassiana. Based on our results we propose that T. rapae can perceive and react towards IGP risk posed by M. brunneum but not B. bassiana to the foraging female herself and her offspring. Thus, M. brunneum has the potential to be used for biological control against D. radicum with a limited risk to T. rapae populations. (C) 2014 The Authors. Published by Elsevier Inc.

Razinger, J., M. Lutz, H. J. Schroers, G. Urke and J. Grunder (2015). "Evaluation of insect associated and plant growth promoting fungi in the control of cabbage root flies (vol 107, pg 1348, 2014)." Journal of Economic Entomology 108(2): 377-377.

Samudrala, D., P. A. Brown, J. Mandon, S. M. Cristescu and F. J. M. Harren (2015). "Optimization and sensitive detection of sulfur compounds emitted from plants using proton transfer reaction mass spectrometry." International Journal of Mass Spectrometry 386: 6-14.

Proton transfer reaction mass spectrometry (PTR-MS) is employed as a highly sensitive detection method for trace gas analysis of sulfur compounds. The effects of drift tube humidity and the reduced electric field (E/N value) were evaluated to measure traces of methanethiol, dimethyl sulfide (DMS) and dimethyl disulfide (DMDS) under optimal conditions. The three sulfur compounds showed a maximum intensity of the product ion signal at a low fraction of the protonated water clusters as compared to the total reagent ion signal. For methanethiol, DMS and DMDS the highest intensity was observed when the percentage branching ratio of H3O+center dot H2O with total reagent ion signal was 3%, 5% and 3%, respectively. The methanethiol signal dropped sharply with an increase in H3O+center dot H2O while DMS and DMDS showed a less strong dependence. This could be explained by their difference in proton affinity as compared to that of the water cluster (methanethiol 773 kJ mol(-1), DMS 830 kJ mol(-1), DMDS 815 kJ mol(-1), H2O center dot H2O >800 kJ mol(-1)). Taking into account the mean kinetic energy in the drift tube (19 kJ mol(-1)), the

direct proton transfer reaction between DMS or DMDS and H3O+center dot H2O is possible, in contrast to methanethiol. The PTR-MS was used to monitor trace gas emissions of methanethiol, DMS and DMDS emitted from Brassica rapa plants in real time. The concentrations of these sulfur compound emissions are in the part per billion range (ppbv) and optimization of the instrument for these compounds helps to measure the low concentrations emitted from control and infested plants. The plant roots were infested with Delia radicum larvae and all three sulfur compounds showed an immediate rise in the ion signal intensity after infestation, indicating that the plants were reacting after the roots were damaged by the insects. The sulfur compound emissions lasted for 30 h. (C) 2015 Elsevier B.V. All rights reserved.

Scheufele, S. B., McKeag, L., Campbell-Nelson, K., & Hazzard, R. (2015). Efficacy of Thiamethoxam Seed Treatments to Control Cabbage Root Maggot in Broccoli, 2014. Arthropod Management Tests, 40(1), E43.

Because the feeding by cabbage root maggot (CRM) larvae causes stunting and collapse of cultivated brassicas, stands of spring transplants may be reduced and damage to root crops may occur in the spring and fall. Seed treatments offer a simpler way for growers to apply insecticides compared to soil drenches which require much time and water to apply. We evaluated efficacy of different formulations and rates of thiamethoxam seed treatments compared to imidacloprid applied as a soil drench banded over the row post-transplant.

Scheufele, S. B., McKeag, L., Campbell-Nelson, K., & Hazzard, R. (2015). Insecticides for Control of Cabbage Root Maggot in Spring Cabbage, 2014. Arthropod Management Tests, 40(1), E44.

Because the feeding by cabbage root maggot (CRM) larvae causes stunting and collapse of cultivated brassicas, stands of spring transplants may be reduced and damage to root crops may occur in the spring and fall. Anthranilic diamide and spinosyn insecticides were evaluated relative to the industry standard, chlorpyrifos, a chlorinated organophosphate for which resistance is known to have developed in some populations.

Ugrinović, K., Škof, M., & Mechora, Š. (2015). Response of some brassica pests to broccoli transplants enriched with selenate [Conference poster]. Zbornik predavanj in referatov 12. Slovenskega posvetovanja o varstvu rastlin z mednarodno udeležbo, 3.-4. marec 2015, Ptuj, Slovenija, 328-333.

In vegetable brassicas production the main problems in pest management in our ecological conditions are caused by insects. Due to reduced assortment of plant protection products alternative strategies of plant protection are needed. Earlier studies, performed on selenium (Se) accumulating plants, have shown that Se accumulated in plant tissue can act as defence against pests. The trials presented in this paper aimed to check the response of two major brassica pests, i.e. cabbage root fly (Delia radicum) and cabbage flea beetles (Phylotretta spp.), on broccoli plants treated with Se in the form of sodium selenate. Preliminary pot trial was conducted under the controlled conditions in experimental glasshouse. The broccoli transplants were supplemented with 0, 25, 37.5 or 50 µg Se to the growing substrate. Afterwards the transplants were transplanted to bigger pots and the larvae of D. radicum were added. Two weeks later the control plants were the shortest and had the least number of leaves, while the plants treated with 37.5 µg Se were the highest. One month after the Se treatment when the experiment was terminated, the plants treated with 37.5 µg Se were still the highest and had the least damaged roots. For other parameters (number of leaves, plant weight and the number of larvae) also recorded at the end of trial, the differences between the treatments were not significant. Under the field conditions only transplants treated with 25 µg Se and control transplants without Se treatment were compared. Females of cabbage root fly laid more eggs to transplants treated with Se than to control plants. Despite that, the number of pupae recovered at harvest was significantly less for Se treated plants than for untreated control. Young broccoli plants treated with Se also attracted more flea beetles which caused more damage on Se treated than on control plants.

Van Geem, M., J. A. Harvey, A. M. Cortesero, C. E. Raaijmakers and R. Gols (2015). "Interactions Between a Belowground Herbivore and Primary and Secondary Root Metabolites in Wild Cabbage." Journal of Chemical Ecology 41(8): 696-707.

Plants are attacked by both above- and belowground herbivores. Toxic secondary compounds are part of the chemical defense arsenal of plants against a range of antagonists, and are subject to genetic variation. Plants also produce primary metabolites (amino acids, nutrients, sugars) that function as essential compounds for growth and survival. Wild cabbage populations growing on the Dorset coast of the UK exhibit genetically different chemical defense profiles,

even though they are located within a few kilometers of each other. As in other Brassicaceae, the defensive chemicals in wild cabbages constitute, among others, secondary metabolites called glucosinolates. Here, we used five Dorset populations of wild cabbage to study the effect of belowground herbivory by the cabbage root fly on primary and secondary chemistry, and whether differences in chemistry affected the performance of the belowground herbivore. There were significant differences in total root concentrations and chemical profiles of glucosinolates, amino acids, and sugars among the five wild cabbage populations. Glucosinolate concentrations not only differed among the populations, but also were affected by root fly herbivory. Amino acid and sugar concentrations also differed among the populations, but were not affected by root fly herbivory. Overall, population-related differences in plant chemistry were more pronounced for the glucosinolates than for amino acids and sugars. The performance of the root herbivore did not differ among the populations tested. Survival of the root fly was low (< 40 %), suggesting that other belowground factors may override potential differences in effects related to primary and secondary chemistry.

Wrzodak, R., Woszczyk, K., Lewandowski, A., & Rybczyński, D. (2015). Determining the optimal timing of insecticide applications for control of cabbage root fly (Delia radicum L.) based on monitoringUstalenie optymalnego terminu wykonania zabiegu zwalczania śmietki kapuścianej (Delia radicum L.) na podstawie monitoringu. Progress in Plant Protection, 55(3), 369-374.

The research to determine the optimal terms of treatments against cabbage root fly (Delia radicum L.) on early and late cultivars of white cabbage was conducted in the 2012–2013, in Research Institute of Horticulture in Skierniewice and on the farm of agricultural college in Powiercie. The efficacy of treatments applied at different times: 2, 5 and 7 days after exceeding the threshold of harmfulness were compared in the field experiments. The treatment performed five days after exceeding the threshold of harmfulness provided the best result. The developed method will be the basis of integrated brassica crop protection against cabbage root fly.

Wilson, R. G., S. B. Orloff and A. G. Taylor (2015). "Evaluation of insecticides and application methods to protect onions from onion maggot, Delia antiqua, and seedcorn maggot, Delia platura, damage." Crop Protection 67: 102-108.

Onion maggot, Delia antiqua (Meigen), and seedcorn maggot, Delia platura (Meigen), are important pests of spring-sown onions, Allium cepa L Larvae of both species feed on developing epicotyls and roots of young onion plants often resulting in seedling mortality. Cultural controls used in combination with the insecticide chlorpyrifos are currently the standard practice for maggot control in the western USA. However, cultural controls are only partially effective and reliance on chlorpyrifos has several potential problems including future availability and development of resistance. Insecticides including clothianidin, imidacloprid, spinosad, and thiamethoxam were evaluated in California, USA in 2011-2013 to identify efficacious alternatives to chlorpyrifos. Some insecticides were applied in multiple ways including seed treatment, in-furrow application at planting, and rototiller incorporation prior to planting. Onion plant population, vigor, and yield were measured to assess insecticide efficacy. Maggots reduced onion plant populations by more than 65% of the seeding rate in the untreated controls. Seed treatments with spinosad or clothianidin imidacloprid were the best alternative to chlorpyrifos for minimizing onion mortality from maggot feeding. Onions treated with both seed treatments had similar or higher plant populations and bulb yields compared to chlorpyrifos. The efficacy of spinosad was greatly improved when applied as a seed treatment compared to an in-furrow application at planting or when incorporated into the soil with a rototiller prior to planting. Spinosad seed treatment increased onion plant populations by 256%, 76%, and 853% compared to untreated controls in 2011, 2012, and 2013, respectively. Conversely, in-furrow and rototill-incorporated applications of spinosad were similar to the untreated control in terms of onion plant population and yield. Seed treatments with newer chemistries could provide an efficacious alternative to chlorpyrifos for protecting onions from maggot damage in western onion production systems. Published by Elsevier Ltd.

Zhang, N.-X., G. Yu, T.-J. Li, Q.-Y. He, Y. Zhou, F.-L. Si, S. Ren and B. Chen (2015). "The Complete Mitochondrial Genome of Delia antiqua and Its Implications in Dipteran Phylogenetics." Plos One 10(10): e0139736-e0139736.

Delia antiqua is a major underground agricultural pest widely distributed in Asia, Europe and North America. In this study, we sequenced and annotated the complete mitochondrial genome of this species, which is the first report of complete mitochondrial genome in the family Anthomyiidae. This genome is a double-stranded circular molecule with a length of 16,141 bp and an A+T content of 78.5%. It contains 37 genes (13 protein-coding genes, 22 tRNAs and 2 rRNAs) and a non-coding A+T rich region or control region. The mitochondrial genome of Delia antiqua presents a clear bias in nucleotide composition with a positive AT-skew and a negative GC-skew. All of the 13 protein-coding

genes use ATN as an initiation codon except for the COI gene that starts with ATCA. Most protein-coding genes have complete termination codons but COII and ND5 that have the incomplete termination codon T. This bias is reflected in both codon usage and amino acid composition. The protein-coding genes in the D. antiqua mitochondrial genome prefer to use the codon UUA (Leu). All of the tRNAs have the typical clover-leaf structure, except for tRNASer(AGN) that does not contain the dihydrouridine (DHU) arm like in many other insects. There are 7 mismatches with U-U in the tRNAs. The location and structure of the two rRNAs are conservative and stable when compared with other insects. The control region between 12S rRNA and tRNAIle has the highest A+T content of 93.7% in the D. antiqua mitochondrial genome. The control region includes three kinds of special regions, two highly conserved poly-T stretches, a (TA)n stretch and several G(A)nT structures considered important elements related to replication and transcription. The nucleotide sequences of 13 protein-coding genes are used to construct the phylogenetics of 26 representative Dipteran species. Both maximum likelihood and Bayesian inference analyses suggest a closer relationship of D. antiqua in Anthomyiidae with Calliphoridae, Calliphoridae is a paraphyly, and both Oestroidea and Muscoidea are polyphyletic.

Articles parus en 2014

Beck, B., P. Spanoghe, M. Moens, E. Brusselman, F. Temmerman, S. Pollet and D. Nuyttens (2014). "Improving the biocontrol potential of Steinernema feltiae against Delia radicum through dosage, application technique and timing." Pest Management Science 70(5): 841-851.

BACKGROUND The potential of the entomopathogenic nematode (EPN) Steinernema feltiae Filipjev as a biocontrol agent against the cabbage maggot Delia radicum (L.), was assessed in three field tests, focusing on EPN dosage, application technique and timing. RESULTS Spraying cabbage plant trays with different doses of infective juveniles (IJs) (50 000, 100 000 and 200 000 per plant) generated a similar reduction of plant mortality. Spraying plant trays with 200 000 IJs of Steinernema feltiae per plant temporarily reduced the number of maggots around the plants' roots, while neither spraying a lower dose (50 000 IJs/plant) nor soil drenching with 200 000 or 50 000 IJs/plant) reduced maggot numbers. When applied as a plant tray spray, IJs of S. feltiae took 1-2 weeks to spread through the soil surrounding the roots. The pathogenicity of the EPNs, as evaluated by a Galleria mellonella bait test, was highest (up to 100% mortality) until up to five weeks after application, and declined to control levels after 4-7 weeks. Follow-up drench applications with EPNs, applied one and/or two weeks after the first EPN application, did not influence control of Delia radicum. CONCLUSION Plant tray spraying provides better placement of Steinernema feltiae than soil drench treatments for control of Delia radicum. Plant mortality was not dose-dependent in the presented trials, unlike the reduction of maggot numbers. Further research into timing and application technique of follow-up treatments with S. feltiae is required to increase efficacy to commercial standards. (c) 2013 Society of Chemical Industry

Lepage, M. P., G. Boivin, J. Brodeur and G. Bourgeois (2014). "Oviposition Pattern of Early and Late-Emerging Genotypes of Delia radicum (Diptera: Anthomyiidae) at Different Temperatures." Environmental Entomology 43(1): 178-186.

The cabbage maggot, Delia radicum L., has a bimodal pattern of emergence caused by the presence in populations of early and late-emerging genotypes that differ in their pupal development time. These genotypes could also express different egg-laying strategies. To examine oviposition patterns between genotypes and, particularly, their response to temperature, the egg-laying activity of females and egg mortality from each genotype were evaluated at temperatures from 12 to 30 degrees C. Several criteria were used to describe the oviposition pattern: longevity of females, preoviposition period, lifetime fecundity, number of oviposition bouts, duration and number of eggs for each oviposition bout, duration of an oviposition cycle, and time interval between oviposition bouts. All criteria were similar between genotypes, except the preoviposition period and time interval between oviposition bouts. The preoviposition period was 1-4 d longer for the early emerging genotype than for the late-emerging genotype at temperatures <25 degrees C, but similar at temperatures >= 25 degrees C. The time interval between oviposition bouts of early emerging genotype was a few hours longer than for the late-emerging genotype at all temperatures. All oviposition pattern criteria responded to temperature, except the duration of oviposition bouts (approximate to 6.5 d) and egg mortality (approximate to 11%). The duration of a bout could be a compromise between oogenesis duration and the risks

associated with egg deposition. According to these results, early and late-emerging genotypes express similar egg-laying strategies for all temperatures tested.

Razinger, J., M. Lutz, H.-J. Schroers, M. Palmisano, C. Wohler, G. Urek and J. Grunder (2014). "Direct plantlet inoculation with soil or insect-associated fungi may control cabbage root fly maggots." Journal of Invertebrate Pathology 120: 59-66.

A potential Delia radicum biological control strategy involving cauliflower plantlet inoculation with various fungi was investigated in a series of laboratory and glasshouse experiments. In addition to entomopathogenic fungi, fungi with a high rhizosphere competence and fungi with the ability to survive as saprotrophs in soil were tested. The following fungal species were evaluated in the experiments: Trichoderma atroviride, T. koningiopsis, T. gamsii, Beauveria bassiana, Metharhizium anisopliae, M. brunneum and Clonostachys solani. A commercial carbosulfan-based insecticide was used as a positive control. Additionally, two commercial products, one based on B. bassiana (Naturalis) and one on Bacillus thuringiensis (Delfin) were used as reference biocontrol agents. The aims were (i) to assess the pathogenicity of the selected fungal isolates to Delia radicum, (ii) to evaluate the fungal isolates' rhizosphere competence, with the emphasis on the persistence of the original inoculum on the growing roots, (iii) to assess possible endophytic plant tissue colonization, and (iv) to evaluate potential plant growth stimulating effects of the added inoculi. Significant pathogenicity of tested fungi against Delia radicum was confirmed in in vitro and glasshouse experiments. All tested fungi persisted on cauliflower rhizoplane. More importantly, the added fungi were found on thoroughly washed roots outside the original point of inoculation. This provided us with evidence that our tested fungi could be transferred via or grow with the elongating roots. In addition to colonizing the rhizoplane, some fungi were found inside the plant root or stem tissue, thus exhibiting endophytic characteristics. The importance of fungal ecology as a criterion in appropriate biological control agent selection is discussed. (C) 2014 Elsevier Inc. All rights reserved.

Razinger, J., M. Lutz, H.-J. Schroers, G. Urek and J. Grunder (2014). "Evaluation of Insect Associated and Plant Growth Promoting Fungi in the Control of Cabbage Root Flies." Journal of Economic Entomology 107(4): 1348-1354.

Delia radicum L. or cabbage maggot is an important pest for Brassicaceous crops. There are currently no registered chemical control agents for its control in Slovenia. Fungal control agents for cabbage maggot were therefore sought among nine rhizosphere-compatible and plant growth-promoting, soil-adapted, and entomopathogenic species to cabbage maggots and were assayed in in vitro and soil laboratory bioassays. In the in vitro tests, the conidial suspensions were applied directly to cabbage maggot eggs. The soil tests mimicked pathways of natural exposure of various insect life stages to the fungal strains. Conidial concentrations used in soil tests were comparable to economic rates for in-furrow application. The following fungi were tested: Trichoderma atroviride P. Karst. (2 isolates), Trichoderma koningiopsis Samuels, C. Suarez & H. C. Evans (1), Trichoderma gamsii Samuels & Druzhin. (3), Beauveria brongniartii (Saccardo) Petch (1), Beauveria bassiana (Balsamo-Crivelli) Vuillemin (2), Metarhizium robertsii J. F. Bisch., Rehner & Humber (1), Metarhizium anisopliae (Metschn.) Sorokin (4), Purpureocillium lilacinum (Thom) Luangsa-ard, Houbraken, Hywel-Jones& Samson (2), and Clonostachys solani f. nigrovirens (J. F. H. Beyma) Schroers (2). Abbott's corrected mortality in the in vitro tests ranged from 0.0 +/- 18.9 to 47.6 +/- 9.0% and in the soil test from 2.4 +/- 13.0 to 68.2 +/- 21.5%. Seven isolates (B. bassiana [isolate 1174], C. solani [1828], M. anisopliae [1154 and 1868], T. atroviride [1872], T. koningiopsis [1874], and T. gamsii [1876]) caused significant cabbage maggot mortality in either in vitro or soil tests. The importance of fungal ecology as a criterion during the screening of potential biological control agents is discussed.

Articles parus avant 2014

Agostini, C., R. G. Albaladejo, A. Aparicio, W. Arthofer, P. Berrebi, P. T. Boag, I. Carbone, G. C. Conroy, A. M. Cortesero, E. C. Goncalves, D. Costa, A. Couto, M. De Girolamo, H. Du, S. J. Fu, T. Garrido-Garduno, L. Gettova, A. Gilles, I. G. Hamoy, C. M. Herrera, C. Heussler, E. Isidro, C. Josso, P. Krapf, R. W. Lamont, A. Le Ralec, S. Lopes, C. Luis, H. Luo, F. Maheo, I. A. M. Marino, L. Mieuzet, B. W. Murray, S. M. Ogbourne, A. Pallavicini, C. Parejo-Farnes, T. Patarnello, C. Paty, C. Pereira, C. Pinho, P. Pinto, D. Poinsot, A. Powell, A. I. Putman, A. Santoro, S. Santos, B. C. Schlick-Steiner, C. Scott, M. S. Barbosa, A. Simkova, J. C. Simon, A.

Sole-Cava, F. M. Steiner, Z. X. Sun, V. Torboli, L. P. Tredway, P. J. V. de Groot, A. Vasconcellos, E. Vazquez-Dominguez, D. Q. Wang, Y. X. Wang, Q. W. Wei, L. Zane, S. H. Zhang and C. Mol Ecology Resources Primer Dev (2013). "Permanent Genetic Resources added to Molecular Ecology Resources Database 1 April 2013-31 May 2013." Molecular Ecology Resources 13(5): 966-968.

This article documents the addition of 234 microsatellite marker loci to the Molecular Ecology Resources Database. Loci were developed for the following species: Acipenser sinensis, Aleochara bilineata, Aleochara bipustulata, Barbus meridionalis, Colossoma macropomum, Delia radicum, Drosophila nigrosparsa, Fontainea picrosperma, Helianthemum cinereum, Liomys pictus, Megabalanus azoricus, Pelteobagrus vachelli, Pleuragramma antarcticum, Podarcis hispanica type 1A, Sardinella brasiliensis and Sclerotinia homoeocarpa. These loci were cross-tested on the following species: Acipenser dabryanus, Barbus balcanicus, Barbus barbus, Barbus cyclolepis, Drosophila hydei, Drosophila melanogaster, Drosophila obscura, Drosophila subobscura, Fontainea australis, Fontainea fugax, Fontainea oraria, Fontainea rostrata, Fontainea venosa, Podarcis bocagei, Podarcis carbonelli, Podarcis liolepis, Podarcis muralis and Podarcis vaucheri.

Goubert, C., C. Josso, P. Louapre, A. M. Cortesero and D. Poinsot (2013). "Short- and long-range cues used by ground-dwelling parasitoids to find their host." Naturwissenschaften 100(2): 177-184.

Parasitoids of phytophagous insects face a detectability-reliability dilemma when foraging for hosts. Plant-related cues are easily detectable, but do not guarantee the presence of the host. Host-related cues are very reliable, but much harder to detect from a distance. Little is known in particular about the way coleopteran parasitoid females use these cues when foraging for a suitable place to lay their eggs. The question is of interest because, unlike hymenopteran larvae, coleopteran parasitoid larvae are highly mobile and able to forage for hosts on their own. We assessed whether females of the parasitoid rove beetle Aleochara bipustulata (L.) (Coleoptera: Staphylinidae) are attracted to plant (Swede roots, Brassica napus) and host-related cues [pupae of the cabbage root fly Delia radicum (L.) (Diptera: Anthomyiidae)]. In the field, A. bipustulata adult females were captured in selective pitfall traps containing pieces of roots damaged by D. radicum larvae, but not in traps containing pieces of healthy roots or D. radicum pupae. However, in the laboratory, the odour of D. radicum pupae attracted A. bipustulata females to mini-pitfalls. Video monitoring in the laboratory showed that foraging A. bipustulata females preferred a zone containing D. radicum pupae and larval tracks rather than one containing an extract of D. radicum-infested roots. Our results suggest a behavioural sequence where A. bipustulata females use plant-related cues at a distance, but then switch their preference to host-related cues at a close range. This would be the first observation of this behaviour in coleopteran parasitoids.

Gryganskyi, A. P., R. A. Humber, J. E. Stajich, B. Mullens, I. M. Anishchenko and R. Vilgalys (2013). "Sequential Utilization of Hosts from Different Fly Families by Genetically Distinct, Sympatric Populations within the Entomophthora muscae Species Complex." Plos One 8(8).

The fungus Entomophthora muscae (Entomophthoromycota, Entomophthorales, Entomophthoraceae) is a widespread insect pathogen responsible for fatal epizootic events in many dipteran fly hosts. During epizootics in 2011 and 2012 in Durham, North Carolina, we observed a transition of fungal infections from one host, the plant-feeding fly Delia radicum, to a second host, the predatory fly Coenosia tigrina. Infections first appeared on Delia in the middle of March, but by the end of May, Coenosia comprised 100% of infected hosts. Multilocus sequence typing revealed that E. muscae in Durham comprises two distinct subpopulations (clades) with several haplotypes in each. Fungi from either clade are able to infect both fly species, but vary in their infection phenologies and host-specificities. Individuals of the more phylogenetically diverse clade I predominated during the beginning of the spring epizootic, infecting mostly phytophagous Delia flies. Clade II dominated in late April and May and affected mostly predatory Coenosia flies. Analysis of population structure revealed two subpopulations within E. muscae with limited gene exchange. This study provides the first evidence of recombination and population structure within the E. muscae species complex, and illustrates the complexity of insect-fungus relationships that should be considered for development of biological control methods.

Josso, C., A. Le Ralec, L. Raymond, J. Saulais, J. Baudry, D. Poinsot and A. M. Cortesero (2013). "Effects of field and landscape variables on crop colonization and biological control of the cabbage root fly Delia radicum." Landscape Ecology 28(9): 1697-1715.

Agriculture intensification has deeply modified agroecosystems from field to landscape scales. To achieve successful pest control using natural enemies, understanding species interactions over all scales remains a challenge. Using the cabbage root fly as a model, we studied whether field and landscape characteristics influenced colonization and infestation of broccoli fields by the pest and its control by natural enemies. We also determined whether species of different trophic level or host specialization would respond to environmental characteristics at the same spatial extent. During a multiple-species and multiple-spatial extent study in northwestern France, we recorded pest colonization and infestation in 68 fields, collected associated natural enemies and assessed crop damages. In each field, we considered management practices and characterized the surrounding landscape in 50-500 m-wide buffers. Our main findings are that Delia radicum and its main natural enemies respond to both field and landscape characteristics. Semi-natural areas supported both crop colonization by pests and natural enemy action. The pest and its enemies differed in their responses to field or landscape variables. Landscape elements such as field banks favored the movement of the pest while impeding the movement of some natural enemies. Pest pressure did not increase with the neighboring density of Brassica crops. The presence of natural enemies did not reduce crop damage but reduced pest emerging rates. Finally, specialist parasitoids responded to the landscape at larger spatial extents than generalists. These results outline the complexity of improving pest control through landscape management.

Kruidhof, H. M., M. de Rijk, D. Hoffmann, J. A. Harvey, L. E. M. Vet and R. Soler (2013). "Effect of belowground herbivory on parasitoid associative learning of plant odours." Oikos 122(7): 1094-1100.

Root herbivores can influence both the performance and the behaviour of parasitoids of aboveground insect herbivores through changes in aboveground plant quality and in the composition of the plant's odour blend. Here we show that root herbivory by Delia radicum larvae did not influence the innate preferences for plant odours of the two closely related parasitoid species Cotesia glomerata and C. rubecula, but did affect their learned preferences, and did so in an opposite direction. While C. glomerata learned to prefer the odour of plants with intact roots, C. rubecula learned to prefer the odour of root-infested plants. The learned preference of C. glomerata for the odour of plants with intact roots matches our previously published result of its better performance when developing in P. brassicae hosts feeding on this plant type. In contrast, the relatively stronger learned preference of C. rubecula for the odour of root-infested plants cannot be merely explained by its performance, as the results of our present study indicate that D. radicum root herbivory did not influence the performance of C. rubecula nor of its host P. rapae. Our results stress the importance of assessing the influence of root herbivores on both innate and learned responses of parasitoids to plant odours.

Meyling, N. V., S. Navntoft, H. Philipsen, K. Thorup-Kristensen and J. Eilenberg (2013). "Natural regulation of Delia radicum in organic cabbage production." Agriculture Ecosystems & Environment 164: 183-189.

In a field experiment, we evaluated effects of three different organic white cabbage-cropping systems (O1, O2, O3) on the cabbage root fly, Delia radicum, and its egg predators and pupal parasitoids over 3 years. The three systems all complied with regulations for organic production, but varied in external nutrient input and N-recycling, and were compared to a conventionally farmed control. One organic system (O3) included an intercropped strip of green manure between crop rows. Oviposition by D. radicum was generally not reduced in organic cropping systems. However, higher pupae/egg ratios were observed in the conventional compared to all organic systems, indicating that immature survival from oviposition to pupation was reduced under all the three organic farming practices. In organic system O2 most small coleopteran predators were recorded, but predation on fly eggs was not significantly higher in organic treatments. Pupal parasitization rates ranged from 26.5% to 59.5%, but no significant differences among farming systems were found. Although reduced D. radicum survival could not be attributed solely to natural enemies, the results indicated that organic farming practices in general contribute to the suppression of belowground pests in cabbage production. (C) 2012 Elsevier B.V. All rights reserved.

Pierre, S. P., S. Dugravot, M. R. Herve, H. M. Hassan, N. M. van Dam and A. M. Cortesero (2013). "Belowground induction by Delia radicum or phytohormones affect aboveground herbivore communities on field-grown broccoli." Frontiers in Plant Science 4.

Induced plant defence in response to phytophagous insects is a well described phenomenon. However, so far little is known about the effect of induced plant responses on subsequently colonizing herbivores in the field. Broccoli plants were induced in the belowground compartment using (i) infestation by the root-herbivore Delia radicum, (ii) root application of jasmonic acid (JA) or (iii) root application of salicylic acid (SA). The abundance of D. radicum and six

aboveground herbivores displaying contrasting levels of host specialization were surveyed for 5 weeks. Our study showed that the response of herbivores was found to differ from one another, depending on the herbivore species, its degree of specialization and the root treatment. The abundance of the root herbivore D. radicum and particularly the number of emerging adults was decreased by both phytohormone treatments, while the number of D. radicum eggs was increased on conspecific infested plants. The root infestation exhibited moderate effects on the aboveground community. The abundance of the aphid Brevicoryne brassicae was strongly increased on D. radicum infested plants, but the other species were not impacted. Root hormone applications exhibited a strong effect on the abundance of specialist foliar herbivores. A higher number of B. brassicae and Pieris brassicae and a lower number of Plutella xylostella were found on JA treated plants. On SA treated plants we observed a decrease of the abundance of B. brassicae, Pi. rapae, and P xylostella. Surprisingly, generalist species, Mamestra brassicae and Myzus persicae were not affected by root induction treatments. Finally, root treatments had no significant effect on either glucosinolate (GLS) profiles of the heads or on plant quality parameters. These results are discussed from the perspective of below-aboveground interactions and adaptations of phytophagous insects to induced plant responses according to their trophic specialization level.

Rahman, M. M., S. Neupert and R. Predel (2013). "Neuropeptidomics of the Australian sheep blowfly Lucilia cuprina (Wiedemann) and related Diptera." Peptides 41: 31-37.

Insect neuropeptides are the most diverse and important group of messenger molecules that regulate almost all physiological processes, including behavior. In this study, we performed a combination of matrix assisted laser desorption ionization time of flight (MALDI-TOF) and electrospray ionization quadrupole time of flight (ESI-Q-TOF) mass spectrometry to analyze the peptidome of the brain and the neurohemal organs of the Australian sheep blowfly Lucilia cuprina and compared the data with those of related flies such as the gray flesh fly Sarcophaga (=Neobellieria) bullata; the cabbage root fly Delia radicum, the fruit fly Drosophila melanogaster, and the yellow fever mosquito, Aedes aegypti. Without counting low intensity signals of truncated peptides, 45 neuropeptides arising from 12 neuropeptide genes (adipokinetic hormone, CAPA-peptides, corazonin, extended FMRFamides, SIFamide, insect kinin, short neuropeptide F, NPLP-1 peptides, HUGIN-pyrokinin, sulfakinins, allatostatins A, putative eclosion hormone precursor peptide) were identified; sequences of extended FMRFamides were reported in a separate publication. The remarkable similarity of the peptidome of cyclorraphan flies, which contain a large number of ecologically important species, does not support the development of a species-specific neuropeptide-based insect pest control strategy. However, mass spectrometric approaches as shown here do not cover the entire peptidome or differences at the receptor level and it is possible that group-specific peptide ligands or receptors exist that escaped the detection. (c) 2013 Elsevier Inc. All rights reserved.

Tremblay, J., V. Myrand, A. Bouchard, S. Martinez and P. Lafontaine (2013). "Lutte contre la mouche du chou dans le rutabaga : évaluation de nouveaux insecticides et d'une nouvelle stratégie d'application afin de trouver une alternative au chlorpyrifos". CIEL - Centre de valorisation des plantes Lanaudière. PSIH11-2-535: 3 pages.

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Blackshaw, R. P., R. S. Vernon and R. Prasad (2012). "Reduction of Delia radicum attack in field brassicas using a vertical barrier." Entomologia Experimentalis Et Applicata 144(2): 145-156.

Insecticide options for controlling Delia radicum (L.) (Diptera: Anthomyiidae) in brassica crops are now limited, and alternatives are needed. Vertical mesh barriers impede females reaching, and ovipositing in, small-scale crops. We tested this pest management technique in a commercial crop to determine whether such barriers would also reduce dispersal of females at larger scales, and whether there was any detectable pattern to the spatial distributions of female D. radicum, eggs, and damage in a rutabaga crop [Brassica napabrassicae (L.) Mill (Brassicaceae)]. A mesh fence of 1.3m high with an externally facing 30-cm overhang was erected around the perimeter of a 2.7-ha field. Yellow sticky traps were positioned at 12 points outside and at 104 locations along transects inside the barrier to capture adult flies. Eggs were sampled from soil around 10 plants at 62 locations and damage was assessed at harvest using a subset of 38 of these locations. There was a substantial reduction (up to 96%) in the number of female flies caught per trap inside the fence compared with outside and a change in the male:female sex ratio from 0.36 outside to 0.92 inside. Female

numbers inside and outside were related and sampling date, trap location, and trap face explained significant proportions of the variance in both data sets. There was no relationship between the size of the population and the distance flies penetrated into the field or the proportion of flies recovered in the outer 10m. Female, egg, and damage counts were largely restricted to the perimeter of the field. Although eggs and damage were related, trap counts did not reflect their spatial distributions. Damage was related to oviposition in the later weeks leading up to harvest. We conclude that yellow sticky traps are an ineffective monitoring tool compared with egg sampling, exclusion barriers can reduce numbers of females reaching a crop, and the system has the potential to deliver reductions in damage and pest control costs at a commercial scale.

Crespo, E., C. A. Hordijk, R. M. de Graaf, D. Samudrala, S. M. Cristescu, F. J. M. Harren and N. M. van Dam (2012). "On-line detection of root-induced volatiles in Brassica nigra plants infested with Delia radicum L. root fly larvae." Phytochemistry 84: 68-77.

Plants emit various volatile organic compounds (VOCs) upon herbivore attack. These VOC emissions often show temporal dynamics which may influence the behavior of natural enemies using these volatiles as cues. This study analyzes on-line VOC emissions by roots of Brassica nigra plants under attack by cabbage root fly larvae. Delia radicum. Root emitted VOCs were detected using Proton-Transfer-Reaction Mass Spectrometry (PTR-MS) and Gas Chromatography-Mass Spectrometry (GC-MS). These analyses showed that several sulfur containing compounds, such as methanethiol, dimethyl sulfide (DMS), dimethyl disulfide (DMDS), dimethyl trisulfide (DMTS) and glucosinolate breakdown products, such as thiocyanates (TC) and isothiocyanates (ITC), were emitted by the roots in response to infestation. The emissions were subdivided into early responses, emerging within 1-6 h after infestation, and late responses, evolving only after 6-12 h. The marker for rapid responses was detected at m/z 60. The ion detected at m/z 60 was identified as thiocyanic acid, which is also a prominent fragment in some TC or ITC spectra. The emission of m/z 60 stopped when the larvae had pupated, which makes it an excellent indicator for actively feeding larvae. Methanethiol. DMS and DMDS levels increased much later in infested roots, indicating that activation of enzymes or genes involved in the production of these compounds may be required. Earlier studies have shown that both early and late responses can play a role in tritrophic interactions associated with Brassica species. Moreover, the identification of these root induced responses will help to design non-invasive analytical procedures to assess root infestations. (c) 2012 Elsevier Ltd. All rights reserved.

Dosdall, L. M., K. N. Harker, J. T. O'Donovan, R. E. Blackshaw, H. R. Kutcher, Y. Gan and E. N. Johnson (2012). "Crop Sequence Effects on Root Maggot (Diptera: Anthomyiidae: Delia spp.) Infestations in Canola." Journal of Economic Entomology 105(4): 1261-1267.

Strong market demand for canola, Brassica napus L., has prompted some western Canadian producers to increase the frequency of this crop in rotations with other crop species, but the impact of this practice on canola insect pests has not been determined. Here, we investigate 12 cropping sequences involving canola over a 3-yr period (2008-2010 inclusive) at five locations across western Canada. Cropping sequences varied from continuous production of two herbicide-tolerant canola varieties, to production in two of 3 yr, to canola production in one of the 3 yr. Treatments analyzed were the frequency and timing of canola within the rotational sequence. Damage by larvae of root maggots (Diptera: Anthomyiidae: Delia spp.) to canola taproots increased as the study progressed, particularly in 2010 after canola had been grown continuously for 3 yr. Yield declined with continuous canola production, and differences were greatest in 2010. At mean canola crop prices for 2010, the yield reduction from continuous production amounted to economic losses of approximately Can$282D-377/ha. Crop quality, in terms of oil and protein concentrations of harvested seed, was affected more by crop variety than cropping sequence. Crop sequence effects for root maggot damage, yield, and seed quality were relatively stable in the presence of environmental (location) variation. Results of our study suggest that continuous canola production could be unsustainable over the long-term even though market forces currently provide incentive for this practice.

Hummel, J. D., L. M. Dosdall, G. W. Clayton, K. N. Harker and J. T. O'Donovan (2012). "Ground Beetle (Coleoptera: Carabidae) Diversity, Activity Density, and Community Structure in a Diversified Agroecosystem." Environmental Entomology 41(1): 72-80.

Diversity and abundance of ground beetles (Coleoptera: Carabidae) can be enhanced in vegetable and field intercropping systems, but the complexity of polycultures precludes the application of generalized assumptions of

effects for novel intercropping combinations. In a field experiment conducted at Lacombe and Ellerslie, Alberta, Canada, in 2005 and 2006, we investigated the effects of intercropping canola (Brassica napus L.) with wheat (Triticum aestivum L.) on the diversity and community structure of carabid beetles, and on the activity density responses of individual carabid species. Shannon-Wiener diversity index scores and species evenness increased significantly as the proportion of wheat comprising total crop plant populations increased in one site-year of the study, indicating a positive response to enhanced crop plant species evenness in the intercrops, and in that same site-year, ground beetle communities in intercrops shifted to more closely approximate those in wheat monocultures as the percentage of wheat in the intercrops increased. Individual carabid species activity densities showed differing responses to intercropping, although activity densities of some potential root maggot (Delia spp.) (Diptera: Anthomyiidae) predators were greater in intercrops with high proportions of wheat than in canola monocultures. The activity density of Pterostichus melanarius (Illiger), the most abundant species collected, tended to be greater in canola monocultures than high-wheat intercrops or wheat monocultures. We conclude that intercrops of canola and wheat have the potential to enhance populations of some carabid species, therefore possibly exerting increased pressure on some canola insect pests.

Kergunteuil, A., S. Dugravot, A. Mortreuil, A. Le Ralec and A. M. Cortesero (2012). "Selecting volatiles to protect brassicaceous crops against the cabbage root fly, Delia radicum." Entomologia Experimentalis Et Applicata 144(1): 69-77.

Volatiles resulting from plantherbivore interactions play an important role in the behavioral decisions of phytophagous, predatory, and parasitoid insects and could be used for managing pest insects. However, to date and after about 40 years of research, documented studies on applications in the field remain extremely scarce. Delia radicum L. (Diptera: Anthomyiidae), the cabbage root fly, is a major pest of brassicaceous crops for which classical control strategies are currently lacking. Our previous studies showed that dimethyl disulfide (DMDS), a compound emitted by roots heavily infested by D. radicum larvae, was attractive for the flys main natural enemies and could lead to a reduction of 60% in number of eggs laid on treated plants in the field. As a follow-up of this work, we conducted another field study to select additional volatiles that could be used in a pushpull approach. Several synthetic herbivore-induced plant volatiles, selected on the basis of their potential action on the behavior of both the fly and its natural enemies, were placed in odor dispensers in experimental broccoli plots and their influence on oviposition by D. radicum and egg predation by ground-dwelling predators was assessed. Our results confirmed the role of DMDS in reducing D. radicum egg numbers on broccoli plants and revealed that (Z)-3-hexenyl acetate, a green leaf volatile released by recently damaged plants, strongly stimulated fly oviposition. Also, two of the compounds tested slightly modified predation activity of ground-dwelling predators: acetophenone decreased the proportion of predated patches, whereas methyl salicylate increased it. This study is a first step in designing a pushpull strategy to control the cabbage root fly.

Lepage, M. P., G. Bourgeois, J. Brodeur and G. Boivin (2012). "Effect of Soil Temperature and Moisture on Survival of Eggs and First-Instar Larvae of Delia radicum." Environmental Entomology 41(1): 159-165.

Edaphic factors such as soil temperature and moisture influence soil-dwelling insects, whose most vulnerable stages typically are eggs and young larvae. In this study, the survival of eggs and first-instar larvae of the cabbage maggot, Delia radium. L., was measured under laboratory conditions after exposure to a range of soil temperatures and moistures. When eggs were exposed to constant temperature (20 similar to 29 degrees C) and humidity (5-200% [wt:wt]), temperature had no significant effect on survival, whereas humidity < 25% [wt:wt] caused egg mortality. The gradual exposure of eggs to high temperatures resulted in low mortality below 33 degrees C, but < 5% of eggs survived at 40 degrees C. When first-instar larvae were exposed to constant temperature (17-29 degrees C) and humidity (5-100% [wt:wt]), both factors as well as their interaction had a significant effect on larval survival, which was nil at 5% (wt:wt) for all temperatures but increased from 21.9 to 42.8% at 17 degrees C and from 34.1 to 55.0% at 29 degrees C, for soil moisture contents of 15% and 100% (wt:wt), respectively. Eggs of D. radicum are resistant to low soil moisture and high temperature conditions. Larval survival tends to increase with an increase in soil temperature and moisture. It is suggested that soil temperature be integrated into insect development simulation models instead of air temperature, to build more effective models for cabbage maggot management.

Nilsson, U., A. Eriksson, B. Ramert and P. Anderson (2012). "Male and female Trybliographa rapae (Hymenoptera: Figitidae) behavioural responses to food plant, infested host plant and combined volatiles." Arthropod-Plant Interactions 6(2): 251-258.

Many parasitoids use volatiles produced by plants as important cues during their food and host search process. We investigated the attraction of the parasitic wasp Trybliographa rapae Westwood (Hymenoptera: Figitidae) to volatiles emitted from plants infested by the cabbage root fly Delia radicum L. (Diptera: Anthomyiidae), as well as to volatiles from a nectar food plant. Behavioural choice tests showed that male parasitoids were not attracted to any volatiles from plants infested by D. radicum or from nectar plants, while females showed clear attraction to both volatile sources. Young females were more attracted to combined volatiles of host and food plants over those from only the host plant, whereas older females showed no differences in attraction to the two odour sources. This suggests that intercropping attractive flowers with host plants could potentially be used to recruit newly emerged parasitoids from surrounding fields while older parasitoids invest more energy in host location than in additional food search. Volatiles from a whole infested plant were chosen over those emitted from separated above- and below-ground parts from infested plants. It is important to consider the availability of both energy and host resources for parasitoids when designing an eco-compatible management of a vegetable crop system.

Nilsson, U., L. M. Rannback, P. Anderson and B. Ramert (2012). "Herbivore response to habitat manipulation with floral resources: a study of the cabbage root fly." Journal of Applied Entomology 136(7): 481-489.

Biological control of pest insects can be improved by providing natural enemies with additional food resources such as floral nectar within the production field. However, herbivores may also benefit from this practice. The aim of this 3-year field study was to investigate if dill and buckwheat, aimed as food resources for natural enemies, could increase the densities of the cabbage root fly, Delia radicum L. (Diptera: Anthomyiidae), a severe pest on crucifers. Differences in egg density, numbers of pupae and sex ratio were compared between cabbage plots with or without flowers. Habitat manipulation by intercropping flowering plants with cabbage did not increase the overall D.similar to radicum egg density in our 3-year study, and there were no significant differences in egg numbers between treatments in any year. No effect on the fecundity of D.similar to radicum was observed, most likely because of the high mobility and feeding behaviour of the female flies, combined with high abundance and diversity of other food sources around the fields during this period. Despite equal egg numbers, fewer pupae were found in plots with flowers than without in one of three studied years. This finding suggests that natural enemies attacking larvae and pupae of D.similar to radicum were either more abundant or efficient in cabbage plots with flowers.

Pierre, P. S., S. Dugravot, A. M. Cortesero, D. Poinsot, C. E. Raaijmakers, H. M. Hassan and N. M. van Dam (2012). "Broccoli and turnip plants display contrasting responses to belowground induction by Delia radicum infestation and phytohormone applications." Phytochemistry 73: 42-50.

Induced responses to insect herbivory are a common phenomenon in the plant kingdom. So far, induced responses have mostly investigated in aerial plant parts. Recently it was found that root herbivore may also elicit both local and systemic responses affecting aboveground herbivores and their natural enemies. Using broccoli (Brassica oleracea subsp. italica L) and turnip (Brassica rapa subsp. rapa L.), two cultivated brassicaceaous plants differing in their chemistry and morphology, we analysed the local and systemic induced responses triggered by Delia radicum L. damage, JA and SA application. We also assessed whether the root induction treatments affected D. radicum larval performance. Both D. radicum damage and JA induced changes in glucosinolate and sugar content as well as affected D. radicum performance, while SA application did not. Despite the uniform chemical responses, the effect on larval performance on broccoli and turnip plants was very different. On broccoli, JA root treatment reduced herbivore performance, whereas in turnips the same treatment enhanced it. JA- and D. radicum-induced responses followed similar patterns, which suggests that the JA signalling pathway is involved in root-induced responses to larval feeding. Glucosinolate induction cannot fully explain the differences found in the performance of D. radicum on the different species. Changes in other resistance factors might significantly contribute to the induced resistance in these brassicaceaeous species as well. (C) 2011 Elsevier Ltd. All rights reserved.

van Dam, N. M., D. Samudrala, F. J. M. Harren and S. M. Cristescu (2012). "Real-time analysis of sulfur-containing volatiles in Brassica plants infested with root-feeding Delia radicum larvae using proton-transfer reaction mass spectrometry." Aob Plants.

Background and aims Plants damaged by herbivores emit a variety of volatile organic compounds (VOCs). Here we used proton-transfer reaction mass spectrometry (PTR-MS) as a sensitive detection method for online analysis of herbivore-induced VOCs. Previously, it was found that Brassica nigra plants emit several sulfur-containing VOCs when

attacked by cabbage root fly (Delia radicum) larvae with m/z 60 as a marker for the formation of allylisothiocyanate from the glucosinolate sinigrin. We tested the hypothesis that m/z 60 emission occurs only in plants with sinigrin in their roots. Additionally, we tested the hypothesis that methanethiol, dimethylsulfide and dimethyldisulfide are only emitted after larval infestation. Methodology Proton-transfer reaction mass spectrometry was used to track sulfur-containing VOCs from six different species of Brassica over time. The roots were either artificially damaged or infested with cabbage root fly larvae. Glucosinolate profiles of the roots were analysed using high-pressure liquid chromatography and compared with VOC emissions. Principal results Brassica nigra, B. juncea and B. napus primarily emitted m/z 60 directly after artificial damage or root fly infestation. Sulfide and methanethiol emissions from B. nigra and B. juncea also increased after larval damage but much later (6-12 h after damage). Brassica rapa, B. oleracea and B. carinata principally emitted methanethiol after artificial and after larval damage. Brassica oleracea and B. carinata showed some increase in m/z 60 emission after larval damage. Comparison with root glucosinolate profiles revealed that sinigrin cannot be the only precursor for m/z 60. Conclusions The principal compound emitted after root damage is determined by the plant species, and not by damage type or root glucosinolate composition. Once determined, the principal compounds may be used as markers for identifying damaged or infested plants. Further analyses of plant enzymes involved in the breakdown of sulfur compounds is needed to reveal the origin of sulfur-containing VOCs from plants.

Zoephel, J., W. Reiher, K. H. Rexer, J. Kahnt and C. Wegener (2012). "Peptidomics of the Agriculturally Damaging Larval Stage of the Cabbage Root Fly Delia radicum (Diptera: Anthomyiidae)." Plos One 7(7).

The larvae of the cabbage root fly induce serious damage to cultivated crops of the family Brassicaceae. We here report the biochemical characterisation of neuropeptides from the central nervous system and neurohemal organs, as well as regulatory peptides from enteroendocrine midgut cells of the cabbage maggot. By LC-MALDI-TOF/TOF and chemical labelling with 4-sulfophenyl isothiocyanate, 38 peptides could be identified, representing major insect peptide families: allatostatin A, allatostatin C, FMRFamide-like peptides, kinin, CAPA peptides, pyrokinins, sNPF, myosuppressin, corazonin, SIFamide, sulfakinins, tachykinins, NPLP1-peptides, adipokinetic hormone and CCHamide 1. We also report a new peptide (Yamide) which appears to be homolog to an amidated eclosion hormone-associated peptide in several Drosophila species. Immunocytochemical characterisation of the distribution of several classes of peptide-immunoreactive neurons and enteroendocrine cells shows a very similar but not identical peptide distribution to Drosophila. Since peptides regulate many vital physiological and behavioural processes such as moulting or feeding, our data may initiate the pharmacological testing and development of new specific peptide-based protection methods against the cabbage root fly and its larva.

Ahmed, N., I. Ahman, J. E. Englund and E. Johansson (2011). "Effect on radish pests by application of insecticides in a nearby spring oilseed rape field." Journal of Applied Entomology 135(3): 168-176.

Chemical control of insect pests is often necessary to ensure high yields of field crops. The aim of the present study was to study whether field pesticide use influences amount of pest damage in neighbouring garden crops. Spring oilseed rape, OSR (Brassica napus L.), was established in Southern Sweden as an example of an agricultural field crop. One half of the OSR field was treated with insecticides to control flea beetles (Phyllotreta spp., Chrysomelidae) and pollen beetle (Meligethes aeneus Fab., Nitidulidae). Radish (Raphanus sativus L.) was used as an example of a common garden crop and it was sown as four replications at three different distances and on four occasions during the season. Care was taken to protect the radish plots from pesticide due to wind drift during applications. Damage to the radish by flea beetle and cabbage root fly (Delia radicum L., Anthomyiidae) along with unspecified leaf damage was recorded. Significantly lower damage by flea beetles was found on cotyledons of radish adjacent to the insecticide treated side of the OSR field compared to the untreated side in radishes from the first sowing. Unspecified damage to true leaves was also less abundant on radishes at the treated side of the OSR field as compared to the untreated side, in all three of the radish harvests analysed. However, radish plot distance from the OSR field did not influence leaf damage. Root fly damage rates in radish did not differ significantly between those adjacent to the treated and untreated sides of the OSR. Damage rates were, however, higher in the radish plots closest to the OSR field in the first sowing, which coincides with the appearance of the first ovipositing females after overwintering as pupae elsewhere. Generally, insecticide treatment in the agricultural field appeared to influence overall damage in the neighbouring garden crop, despite the fact that the garden crop was protected against wind drift of the insecticides during applications.

Audsley, N., H. J. Matthews, R. E. Down and R. J. Weaver (2011). "Neuropeptides associated with the central nervous system of the cabbage root fly, Delia radicum (L)." Peptides 32(3): 434-440.

The peptidome of the central nervous system of adult cabbage root fly, Delia radicum (L) was investigated using matrix assisted laser desorption ionization time of flight mass spectrometry (MALDI-TOF MS). Over twenty neuropeptides were identified from three different tissue sources, the combined brain/suboesophageal ganglion (SOG), the retrocerebral complex, and the thoracic-abdominal ganglion (TAG). A number of peptides were identified in all three tissues, including allatostatins, short neuropeptide F-like peptides, corazonin, a pyrokinin, and a myosuppressin. Adipokinetic hormone was restricted to the retrocerebral complex. Other peptides, including FMRFamides and sulfakinins were detected only in the brain/SOG and TAG. Some peptides, notably myoinhibitory peptides and tachykinins, which have been identified in other fly species, were not detected in any tissue sample. This study has structurally characterized for the first time, the neuropeptides from adult D. radicum. Crown Copyright (C) 2010 Published by Elsevier Inc. All rights reserved.

Fortier, A. M. and S. Balagué (2011). "Évaluation de l'efficacité de différents modes d'application du Delegate (spinétorame) pour lutter contre la mouche du chou dans le radis.". Compagnie de recherche Phytodata Inc. PSIH10-2-335: 2 pages.

http://www.mapaq.gouv.qc.ca/SiteCollectionDocuments/Recherche_Innovation/Legumesdechamp/PROJETNO335.pdf

Nilsson, U., L. M. Rannback, P. Anderson, A. Eriksson and B. Ramert (2011). "Comparison of nectar use and preference in the parasitoid Trybliographa rapae (Hymenoptera: Figitidae) and its host, the cabbage root fly, Delia radicum (Diptera: Anthomyiidae)." Biocontrol Science and Technology 21(9): 1117-1132.

This study investigated differences in flower preferences between the parasitoid Trybliographa rapae Westwood (Hymenoptera: Figitidae) and its host, the economically important pest of cruciferous crops, the cabbage root fly, Delia radicum L. (Diptera: Anthomyiidae). The data obtained were used to suggest selective food plants in conservation biological control programmes for control of D. radicum. The attraction of both insect species to floral odours emitted from nine different plant species, their ability to access nectar from four of these species and the effect of the most promising plant species on insect longevity were determined. Naive T. rapae females were significantly attracted to flower odours from Fagopyrum esculentum Moench. (Polygonaceae) and repelled by Coriandrum sativum L. (Apiaceae) and Borago officinalis L. (Boraginaceae). In addition, T. rapae gained weight when exposed to F. esculentum, Anethum graveolens L. (Apiaceae) and Lobularia maritima Desv. (Brassicaceae). In contrast, naive D. radicum females showed attraction to most of the flowers. The longevity of both T. rapae and D. radicum increased significantly when they were provided with flowering A. graveolens and F. esculentum. In addition to the laboratory studies, a semi-field experiment was made to study the impact of flowering F. esculentum on the ability of T. rapae to parasitise D. radicum larvae. Significantly more larvae were parasitised in cages where a floral resource was present. The findings are discussed in the context of a Brassica agroecosystem.

Pierre, P. S., S. Dugravot, A. Ferry, R. Soler, N. M. van Dam and A. M. Cortesero (2011). "Aboveground herbivory affects indirect defences of brassicaceous plants against the root feeder Delia radicum Linnaeus: laboratory and field evidence." Ecological Entomology 36(3): 326-334.

1. Belowground herbivory has recently been shown to disrupt the host location behaviour of aboveground parasitoids and thereby impact plants indirect defences. Reverse interactions, on the other hand, have received little attention so far. 2. Lab and field studies were conducted to examine whether the presence of the leaf herbivore Pieris brassicae Linnaeus on brassicaceous plants influences the response of Trybliographa rapae Westwood, a specialist parasitoid of the root feeder Delia radicum Linnaeus. 3. The present results show that the attraction of the parasitoid towards host-infested plants disappeared when these plants were also infested by P. brassicae. This absence of attraction was observed both when the complete odour blend or only undamaged leaves from damaged plants were offered, emphasising the role of systemically induced volatiles for host location in T. rapae. 4. Furthermore, the field study revealed that parasitism levels dropped from 30% on root-infested plants to 4% on double-infested plants. 5. The present study is the first to confirm that reduced attraction to host-infested plants as a result of simultaneous attack by below- and aboveground herbivores translates into lower levels of parasitism in the field.

Susurluk, I. A. (2011). "Potential of Steinernema feltiae (Rhabditida: Steinernematidae) as a biological control agent against the cabbage maggot Delia radicum (Diptera: Anthomyiidae) in oilseed rape." Turkish Journal of Agriculture and Forestry 35(4): 413-419.

Entomopathogenic nematodes (EPNs) in families Heterorhabditidae and Steinernematidae have considerable potential as biological control agents against soil-inhabiting insect pests. In the present study, the potential of Steinernema feltiae as a biological control agent against cabbage maggot (CM) Delia radicum (Diptera: Anthomyiidae), persistence of the nematode in areas infested by CM larvae, and foraging behavior of the nematode toward CM and/or oilseed rape roots were examined in the laboratory. The results of the laboratory experiment showed that more than 80% control was achieved against the last instars of D. radicum. Steinernema feltiae persisted in the soil in high numbers for 12 weeks in laboratory assays. The foraging behavior of S. feltiae in the presence of D. radicum larvae and oilseed rape roots, offered individually and in combination, was studied using a Y-tube olfactometer filled with silver sand (Humax. U.K., particle size: 300-400 mu m) at 8 and 15 degrees C. When insect larvae were present, more nematodes migrated toward the larvae at both temperatures.

Andreassen, L. D., U. Kuhlmann, J. W. Whistlecraft, J. J. Soroka, P. G. Mason, O. O. Akinremi and N. J. Holliday (2010). "Spring emergence of Canadian Delia radicum and synchronization with its natural enemy, Aleochara bilineata." Canadian Entomologist 142(3): 234-249.

To characterize time of spring emergence following post-diapause development, Delia radicum (L.) (Diptera: Anthomyiidae) from Saskatchewan, Manitoba, and southwestern Ontario were collected in fall, maintained over winter at 1 degrees C, then transferred to higher constant temperatures until adult emergence. At each location there were "early" and "late" phenotypes. Truncated normal models of temperature dependency of development rate were fitted for each phenotype from each location. We provide the first evidence of geographic variation in the criteria separating these phenotypes. Separation criteria and models for early and late phenotypes at the two prairie locations, approximately 700 km apart, were indistinguishable, but differed from those for Ontario. Prairie phenotypes developed more slowly than Ontario phenotypes, and more prairie individuals were of the late phenotype. Poor synchronization of spring emergence could impair predation of D. radicum eggs by adult Aleochara bilineata Gyllenhal (Coleoptera: Staphylinidae). Aleochara bilineata from Manitoba were reared and development rates modelled as for D. radicum. Models of development rates for the two species, when combined with simulated soil temperatures for two prairie locations, suggest that emergence of adult A. bilineata is well synchronized with availability of D. radicum eggs in prairie canola.

Bjorkman, M., P. A. Hamback, R. J. Hopkins and B. Ramert (2010). "Evaluating the enemies hypothesis in a clover-cabbage intercrop: effects of generalist and specialist natural enemies on the turnip root fly (Delia floralis)." Agricultural and Forest Entomology 12(2): 123-132.

The relative importance of the resource concentration hypothesis and the enemies hypothesis was investigated for the turnip root fly Delia floralis in a cabbage-red clover intercropping system compared with a cabbage monoculture. Delia floralis egg densities were measured as well as the activity-densities of generalist predators in a field experiment during two growing seasons. In the second year, a study of egg predation with artificially placed eggs was conducted, in addition to a predator exclusion experiment, to estimate total predation during the season. Parasitization rates were estimated from samples of pupae. Delia floralis oviposition was greater in the monoculture during both years. The predator activity-densities differed between treatments and study years. The known natural enemies of Delia spp., Bembidion spp. and Aleochara bipustulata showed a strong response to a cultivation system with higher activity-densities in the monoculture. The response, however, appeared to be caused primarily by habitat preferences and not by D. floralis egg densities. The reduction in the number of D. floralis pupae in the intercropping may be explained by a disruption in oviposition behaviour caused by the presence of clover because neither predation, nor parasitization rates differed between cultivation systems.

Hamback, P. A., M. Bjorkman and R. J. Hopkins (2010). "Patch size effects are more important than genetic diversity for plant-herbivore interactions in Brassica crops." Ecological Entomology 35(3): 299-306.

2. This paper examines the effect of intraspecific genetic diversity within Brassica fields on two Brassica specialists, cabbage root fly, and diamondback moth, and on a parasitoid attacking diamondback moths. Genetic diversity was

manipulated both in a replacement and an additive design. 3. Both herbivore densities and parasitism rates were higher in smaller plots, with limited responses to increased within-plot diversity. All species showed variable densities across genotypes, and preference hierarchies were species specific. 4. Responses to plot size in root flies scaled with the diameter-to-area ratio, suggesting that patch detectability affected local density, whereas responses by diamondback moths and parasitoids deviated from this ratio. These species differences could be traced to differences in the residence time within patches, where diamondback moths typically spend longer and more variable time periods in patches than root flies. 5. The lack of response to genetic diversity by both herbivores suggests that egg-laying rates are affected by decisions on the plant and not by attraction from a distance, neither to the plant itself nor the patch. Patterns of differential attack may then be due to different acceptability for studied genotypes. 6. Future theories on insect responses to spatial heterogeneity should focus on species traits and how traits interact with information landscapes in the field.

Hummel, J. D., L. M. Dosdall, G. W. Clayton, K. N. Harker and J. T. O'Donovan (2010). "Responses of the parasitoids of Delia radicum (Diptera: Anthomyiidae) to the vegetational diversity of intercrops." Biological Control 55(3): 151-158.

Several natural enemies regulate populations of root maggots (Delia spp.) (Diptera: Anthomyiidae) in canola (Brassica napus L.) in western Canada, among them the rove beetles Aleochara bilineata Gyllenhal and Aleochara verna Say (Coleoptera: Staphylinidae) and the hymenopteran Trybliographa rapae West-wood (Hymenoptera: Figitidae). Intercrops of canola and wheat (Triticum aestivum L.) can be part of an integrated pest management strategy to reduce damage by Delia spp. to canola. We investigated several intercropping regimes of canola and wheat to determine effects on parasitism of Delia radicum (L.) and activity densities of adult A. bilineata and A. verna. Studies were conducted over four site-years in central Alberta, Canada in 2005 and 2006. Mean parasitism rates of D. radicum puparia by A. bilineata ranged from 7.27% to 81.69%. Increasing proportions of wheat in intercrops significantly reduced parasitism by A. bilineata in one site-year. Parasitism of D. radicum by T. rapae was not affected by intercropping; mean parasitism rates were between 2.17% and 14.55%. In one site-year combined parasitism by all parasitoids significantly increased with increasing canola as a proportion of total crop plant populations. Pitfall trap collections of adult A. bilineata increased with increasing proportions of canola in some site-years. Collections of A. verna adults were low relative to A. bilineata and were largely unaffected by intercropping. Although canola-wheat intercrops do not appear to favour parasitism of D. radicum, reductions in canola root damage by Delia larvae in intercrops, reported previously, suggest that canola-wheat intercrops may nevertheless be favourable as a crop protection strategy.

Malchev, I., R. Fletcher and L. Kott (2010). "Breeding of rutabaga (Brassica napus var. napobrassica L. Reichenb.) based on biomarker selection for root maggot resistance (Delia radicum L.)." Euphytica 175(2): 191-205.

Cabbage root maggot (Delia radicum) is the most devastating and persistent pest for rutabaga (Brassica napus var. napobrassica) in all production areas in Canada. With the deregistration of terbufos (Counter(A (R))) to combat maggot attack, only chlorpyrifos (Lorsban(A (R))), an organophosphorous pesticide, remains and extensive use could lead to insecticide resistance. An unprotected crop would lead to serious domestic and export losses. Root maggot resistance from canola, that originated from the weedy crucifer, Sinapis alba, was transferred to rutabaga by standard hand crossing. A population of doubled haploids was developed from the F1s and screened in a high pressure root maggot rutabaga production field. Resistant and susceptible isolines were identified from different crossing groups and these isoline pairs were used to develop a biochemical selection protocol based on HPLC profiles where glucosinolates can be present as an aid to resistance breeding. Fourteen peaks in the HPLC profile were identified as markers and predictably varied between the more resistant and more susceptible lines. The 3-4 leaf stage was identified as the ideal stage for tissue extraction for profiling which is close to the stage when gravid female maggot flies seek host plants for oviposition utilizing olfactory signals from the host. Olfactory signals for Delia commonly are isothiocyanates which are volatile break down products of glucosinolates. The peaks in the HPLC profiles identified as markers for resistance contain glucosinolates and may be partially responsible for the plant-insect interaction. A predictive model is proposed as an aid to breeders for the development of root maggot resistant rutabaga lines.

Andreassen, L. D., U. Kuhlmann, P. G. Mason and N. J. Holliday (2009). "Host range testing of a prospective classical biological control agent against cabbage maggot, Delia radicum, in Canada." Biological Control 48(2): 210-220.

The introduction of a European natural enemy, Aleochara bipustulata L. (Coleoptera: Staphylinidae), is being considered for control of cabbage maggot, Delia radicum (L) (Diptera: Anthomyiidae) in canola in Canada, and the host specificity of this pupal parasitoid must first be studied. Contemporary guidelines were used to select 18 species of Diptera to represent non-target species taxonomically related or ecologically similar to reported hosts of A. bipustulata, or beneficial species. No-choice tests were used to determine which of the 18 species are within A. bipustulata's fundamental host range, and whether puparial structure or mass or duration of pupal development influence their acceptability and suitability as hosts. Five species were consistently suitable as hosts, and these were either relatively small or were taxonomically closely related to the target host. The probability that a puparium would be entered by a parasitoid larva was greatest for small puparia, but was unaffected by pupal duration. The probability of completing parasitoid development once a puparium was entered was influenced by both puparial mass and duration of pupal development. Pitfall traps to assess habitat associations caught A. bipustulata adults in a variety of crop habitats but none were caught in forests. Host range and habitat data are used to argue that there is little risk of parasitism to beneficial taxa. Non-target species taxonomically closely related to the target D. radicum or with small puparia may fall within the fundamental host range of A. bipustulata. However, risk to many of these species may be minimal because of the habitat preferences of the parasitoid and its cues for host-finding and recognition. (C) 2008 Elsevier Inc. All rights reserved.

Eyre, M. D., D. Labanowska-Bury, J. G. Avayanos, R. White and C. Leifert (2009). "Ground beetles (Coleoptera, Carabidae) in an intensively managed vegetable crop landscape in eastern England." Agriculture Ecosystems & Environment 131(3-4): 340-346.

Four fields (three organic and one conventionally managed) in an intensive vegetable producing landscape in eastern England were sampled for ground beetles in 2005 and 2006, using pitfall traps, to investigate species activity and species assemblage distribution within five crop and three field margin types. In addition, non-crop ditch sites were also sampled. Three species assemblages in the fields were strongly related to crop type, with two others consisting of non-crop sites, one dominated by field margins, the other by ditch sites, Species activity and richness in fields were also strongly, and significantly, associated with crop type, with most in organic Brassica crops (cauliflower, cabbage, broccoli), less in organic leeks and least in conventional calabrese. Some species were significantly more active in weedier fields but others preferred more open ground. Considerably more species were recorded from first-year planted field margins, with fewest species active in unplanted margins. Activity was also relatively low in densely vegetated second-year margins. There appeared to be little relationship between species activity in the margins and that in the crop fields. Ground beetle species are important for the predation of cabbage root fly eggs in Brassica Crops, especially in organic fields. In order to enhance and maximise appropriate ground beetle species activity and predation within vegetable fields, it is likely that management within both fields and margins would be required, as well as some method for increasing movement of predators from margins into fields. (C) 2009 Elsevier B.V. All rights reserved

Ferry, A., S. Le Tron, S. Dugravot and A. M. Cortesero (2009). "Field evaluation of the combined deterrent and attractive effects of dimethyl disulfide on Delia radicum and its natural enemies." Biological Control 49(3): 219-226.

Delia radicum (L 1758) is a major pest of cabbage crops in northern Europe. Due to more constraining laws relating to insecticide use, new strategies to control this pest are urgently needed. Manipulating insect behavior through infochemicals is a promising approach. The recent identification of dimethyl disulfide (DMDS) as a compound that both attracts the main predators of D. radicum and inhibits oviposition by the fly gives a challenging opportunity to develop such strategy. The aim of the present study was to confirm such potential of DMDS, in the field. Through the 8 weeks of the first egg laying peak of the fly we assessed, the potential of artificially increasing the levels of this molecule in the close vicinity of broccoli plants to 1/attract predators, 2/stimulate predatory activity and 3/limit damage done by the fly. Despite a lower number of D. radicum eggs as food resource, DMDS effectively increased predator catches in treated plots (119 Aleochara bilineata (Gyllenhal, 1810) caught in treated plot, while only 21 in control plots). However, damages done by the fly were of the same magnitude order in treated plots than in control ones. Number of D. radicum larvae and pupae recovered in plant roots were similar, despite the important decrease in eggs laid. This result, together with the observation that the numbers of eggs predated in artificial patches were lowered in the presence of the molecule, seems to indicate that increasing DMDS amounts disturbed the foraging activity of the fly predators.

Consequences of these findings for the future of DMDS use in crop protection against D. radicum are discussed. (C) 2009 Published by Elsevier Inc.

Hamback, P. A., M. Bjorkman, B. Ramert and R. J. Hopkins (2009). "Scale-dependent responses in cabbage herbivores affect attack rates in spatially heterogeneous systems." Basic and Applied Ecology 10(3): 228-236.

Herbivorous insects face a dilemma when selecting suitable hosts in a complex environment, and their sensory capability may often reduce the female capacity for proper selection. As a consequence, eggs are often deposited on inferior hosts, affecting both insect and host plant fitness. We examined the attack rates of three cabbage herbivores in monocultures and biculture plots of different Brassica oleracea genotypes, with different spatial heterogeneity. The main goals of the study were to improve our understanding of the spatial scales involved in herbivore search processes and to examine the possibility of using spatial heterogeneity for manipulating pest attack rates in cabbage cropping systems. The results showed that the host selection behaviour of the small white butterfly (Pieris rapae) was strongly dependent on spatial heterogeneity. The difference in egg density between plant genotypes was larger when contrasting plants were growing in close proximity than in monoculture. This suggests that P. rapae is able to differentiate among genotypes from a small distance, while selection is compromised at larger spatial scales. The two other herbivores in the study (Mamestra brassicae and Delia radicum) did not respond to heterogeneity at any spatial scale, but showed a constant preference hierarchy. This suggests that host selection in these species occurs after direct plant contact. The difference in species' responses to spatial heterogeneity has consequences both for selection gradients in natural communities and for the potential to reduce pest attack in polyculture systems. (C) 2008 Gesellschaft fur Okologie. Published by Elsevier GmbH. All rights reserved.

Hummel, J. D., L. M. Dosdall, G. W. Clayton, K. N. Harker and J. T. O'Donovan (2009). "Effects of Canola-Wheat Intercrops on Delia spp. (Diptera: Anthomyiidae) Oviposition, Larval Feeding Damage, and Adult Abundance." Journal of Economic Entomology 102(1): 219-228.

Reductions in oviposition and subsequent damage by root maggots (Diptera: Anthomyiidae, Delia spp.) to brassicaceous crops in the presence of nonhost plants has been demonstrated, but such investigations have not been conducted using intercrops of species commonly grown in the large-scale agricultural production systems of western Canada. A field experiment was conducted at three sites in Alberta, Canada, in 2005 and 2006 to determine interactions between root maggots and the various proportions of canola (Brassica napus L.) making up the total crop plant populations in intercrops with wheat (Triticum aestivum L.). The effect of a neonicotinoid seed treatment also was investigated. Root maggot damage to canola taproots decreased with increasing proportions of wheat in the intercrops. The presence of wheat in the intercrops had little effect on root maggot adult abundance in any single site-by-year combination or when data were combined over all sites and years, with different Delia species and sexes responding differently. Similarly, per plant root maggot egg populations were unaffected by intercropping, although egg populations were reduced on a per unit land area basis in intercrops compared with monocultures. Insecticidal seed treatment did not affect root maggot egg populations or canola root damage. Variable abundances and phenologies of the principal root maggot species infesting canola at different sites and years may influence their responses to canola-wheat intercrops. Intercropping canola and wheat may provide an opportunity for reducing crop damage from root maggot attack without compromising environmental sustainability.

Leger, C. and E. Riga (2009). "Evaluation of Marigolds and Entomopathogenic Nematodes for Control of the Cabbage Maggot Delia radicum." Journal of Sustainable Agriculture 33(2): 128-141.

The susceptibility of Delia radicum, cabbage maggot (CM), first instar larvae to fresh tissue extracts of two marigolds (Tagetes erecta and T. patula), the entomopathogenic nematode Steinernema feltiae, and a combination of them, was evaluated under laboratory and glasshouse conditions. In the laboratory, CM larvae were susceptible to marigold fresh tissue extracts; the root extracts were the most effective. Fresh root tissue extracts of non-flowering and flowering T. erecta caused 28% and 84% CM mortality, and T. patula caused 65% and 100% CM mortality, respectively. The nematodes caused up to 46% CM mortality at a concentration of 300 IJs/larva. In the glasshouse, up to 95% reduction of CM was achieved when cabbage plants, infected with CM eggs, were treated with fresh root extracts from either Tagetes species. Combination treatments with Tagetes and S. feltiae were also effective. Fresh tissue extracts of Tagetes spp. and S. feltiae show potential as control agents of D. radicum.

Soler, R., S. V. Schaper, T. M. Bezemer, A. M. Cortesero, T. S. Hoffmeister, W. H. Van der Putten, L. E. M. Vet and J. A. Harvey (2009). "Influence of presence and spatial arrangement of belowground insects on host-plant selection of aboveground insects: a field study." Ecological Entomology 34(3): 339-345.

1. Several studies have shown that above- and belowground insects can interact by influencing each others growth, development, and survival when they feed on the same host-plant. In natural systems, however, insects can make choices on which plants to oviposit and feed. A field experiment was carried out to determine if root-feeding insects can influence feeding and oviposition preferences and decisions of naturally colonising foliar-feeding insects. 2. Using the wild cruciferous plant Brassica nigra and larvae of the cabbage root fly Delia radicum as the belowground root-feeding insect, naturally colonising populations of foliar-feeding insects were monitored over the course of a summer season. 3. Groups of root-infested and root-uninfested B. nigra plants were placed in a meadow during June, July, and August of 2006 for periods of 3 days. The root-infested and the root-uninfested plants were either dispersed evenly or placed in clusters. Once daily, all leaves of each plant were carefully inspected and insects were removed and collected for identification. 4. The flea beetles Phyllotreta spp. and the aphid Brevicoryne brassicae were significantly more abundant on root-uninfested (control) than on root-infested plants. However, for B. brassicae this was only apparent when the plants were placed in clusters. Host-plant selection by the generalist aphid M. persicae and oviposition preference by the specialist butterfly P. rapae, however, were not significantly influenced by root herbivory. 5. The results of this study show that the presence of root-feeding insects can affect feeding and oviposition preferences of foliar-feeding insects, even under natural conditions where many other interactions occur simultaneously. The results suggest that root-feeding insects play a role in the structuring of aboveground communities of insects, but these effects depend on the insect species as well as on the spatial distribution of the root-feeding insects.

Stadler, E. and K. Reifenrath (2009). "Glucosinolates on the leaf surface perceived by insect herbivores: review of ambiguous results and new investigations." Phytochemistry Reviews 8(1): 207-225.

Herbivorous insects identify their host plants either by structural features, chemical cues, or a combination. Some insects probe the host leaf prior feeding or oviposition, other species use olfactorial cues or compounds somewhere on the surface. Insects attacking Brassicaceae are no exception, some are attracted and stimulated by volatile isothiocyanates (ITC), many others depend fully on the non-volatile glucosinolates (GS) for host-plant recognition and acceptance. Since most insects have no access to the leaf interior investigators concluded that GS must be present on the leaf surface and ITC in the headspace. However, peelings of mechanically removed surface waxes were devoid of measurable amounts of GS, whereas solvent surface extractions revealed a correlation between stomatal conditions and GS concentrations. Both observations lead to the conclusion that the presence of GS on the top leaf surface is rather unlikely. In the experimental part we show that a chloroform/methanol/water (2: 1: 1 vol/vol/vol) solvent leaf extract contains GS and, in addition, thia-triaza-fluorenes (TTF), other oviposition stimulants of the cabbage root fly, Delia radicum. Electrophysiological investigations showed that both, GS and TTF stimulated specific receptor neurones of the fly. We suggest that these compounds probably originated from deeper leaf layers and that herbivorous insects may penetrate the wax layer and perceive the stimulating compounds in deeper layers or through the stomata.

Balog, A., V. Marko and L. Ferencz (2008). "Patterns in distribution, abundance and prey preferences of parasitoid rove beetles Aleochara bipustulata (L.) (Coleoptera : Staphylinidae, Aleocharinae) in Hungarian agroecosystems." North-Western Journal of Zoology 4(1): 6-15.

The abundance, habitat preference, seasonal dynamics and prey preferences of parasitoid rove beetles Aleochara bipustulata (L.) (Coleoptera: Staphylinidae: Aleocharinae) were investigated in 16 Hungarian agricultural fields. Aleochara bipustulata was the 7(th) most frequent species in the cumulative samples, and widely occurred in woodland areas of mountains with medium height. The species has no particular soil preferences and its activity density was high in conventionally treated crops. Under laboratory conditions we observed that the adults may consume up to five root maggot larvae (Delia radicum) per day. Laboratory studies revealed that adults are often cannibalistic, eating their own eggs. Adults also consume other fly pests as D. platura and D. florilega. Aleochara bipustulata consumed significantly more D. radicum than D. platura and D. florilega. Aleochara bipustulata may be important biological control agent against Delia species in Hungarian agricultural fields because of its widespread distribution, high host specificity and host acceptance, and a development time which is well synchronised with its host.

Bjorkman, M., R. J. Hopkins and B. Ramert (2008). "Combined Effect of Intercropping and Turnip Root Fly (Delia floralis) Larval Feeding on the Glucosinolate Concentrations in Cabbage Roots and Foliage." Journal of Chemical Ecology 34(10): 1368-1376.

The effects of plant competition and herbivory on glucosinolate concentrations in cabbage root and foliage were investigated in a cabbage-red clover intercropping system. Cabbage plants were grown under different competitive pressures and with varying degrees of attack by root-feeding Delia floralis larvae. Glucosinolate concentrations in cabbage were affected both by intercropping and by D. floralis density. Glucosinolate concentrations in foliage generally decreased as a response to intercropping, while the responses to insect root damage of individual glucosinolates were weaker. Root glucosinolates responded more strongly to both intercropping and egg density. Total root glucosinolate concentration decreased with clover density, but only at high egg densities. Increased egg density led to opposite reactions by the indole and aliphatic glucosinolates in roots. The responses of individual root glucosinolates to competition and root damage were complex and, on occasion, nonlinear. Reduced concentrations of several glucosinolates and the tendency towards a decrease in total concentration in cabbage foliage caused by intercropping and larval damage suggest that competing plants or plants with root herbivory do not allocate the same resources as unchallenged plants towards sustaining levels of leaf defensive compounds. This could also be true for root glucosinolate concentrations at high egg densities. In addition, the results suggest that changes occurring within a structural group of glucosinolates may be influenced by changes in a single compound, e.g., glucobrassicin (indol-3-ylmethyl) in foliage or sinigrin (2-propenyl) in roots.

Broatch, J. S., L. M. Dosdall, R. C. Yang, K. N. Harker and G. W. Clayton (2008). "Emergence and Seasonal Activity of the Entomophagous Rove Beetle Aleochara bilineata (Coleoptera: Staphylinidae) in Canola in Western Canada." Environmental Entomology 37(6): 1451-1460.

Aleochara, bilineata Gyllenhal (Coleoptera: Staphylinidae) is an important natural enemy of root maggots (Delia spp.) (Diptera: Anthomyiidae), which are serious pests of brassicaceous crops in North America and Europe. Adults of A. bilineata feed on eggs and larvae of root maggots, and A. bilineata larvae parasitize Delia spp. pupae. Emergence and seasonal activity patterns of A. bilineata were investigated during 2003-2005 in canola (Brassica rapa L. and Brassica napus L.) in central Alberta, Canada, in relation to degree-day (DD) accumulations and Julian date. Captures of A. bilineata adults from pitfall traps within emergence cages situated over canola stubble from the previous year indicated that approximate to 428,493, and 455 DD (soil base 5.57 degrees C) and 187,189, and 180 Julian days were required for 50% emergence in 2003, 2004, and 2005, respectively (3-yr mean = 185.1 +/- 2.8 Julian days [SEMI). Captures of A. bilineata adults from pitfall traps placed in current canola crops determined that 50% levels of activity density required 379 DD and 180 Julian days in 2004. A logistic model that described the relationship of degree-days and Julian days with emergence of adult beetles was appraised, and good correspondence was evident between predicted and observed cumulative emergence patterns. Emergence and seasonal activity periods of A. bilineata in canola were well synchronized with occurrence of preimaginal life stages of its principal hosts, Delia radiacum (L.) and Delia platura Meigen, with beetle emergence beginning shortly after the onset of root maggot oviposition.

Dalthorp, D. and A. J. Dreves (2008). "Spatio-temporal ecology and management of cabbage maggot." Environmental Entomology 37(2): 409-418.

This. study analyzes the spatio-temporal dispersion patterns of the cabbage maggot (Delia radicum L.) (Diptera: Anthomyiidae) infestation in rutabagas and turnips in Oregon and suggests ways to exploit the spatial and temporal ecology of the cabbage maggot to improve management of the pest. The patchy distribution of cabbage maggots arises from a combination of first-order effects driven by spatial heterogeneity and second-order effects driven by spatial auto-correlation. The intensity of cabbage maggot infestations varied from year to year. Within a given year, damage rates tended to be higher in rutabagas than turnips, in crops planted earlier in the season, and in fields hear nurseries and houses. Nonsignificant first-order effects included soil texture, distance from river, proximity to maggot sources (other than cultivated fields), type of vegetation on field borders, field manager, field area, and perimeter. Second-order effects were processes intrinsic to the population and would give rise to patchiness even in a homogeneous environment. For example, adults may be attracted to others of their species or eggs may be deposited in batches. The locations of patches arising from second-order effects cannot be predicted from knowledge of environmental covariates. However, cabbage maggot does not tend to disperse far, and existing patches tend to give

rise to other patches nearby at a later time. We found elevated damage rates in spring fields planted near fields that were heavily damaged the previous fall and in fields planted late in the season near fields that had heavy damage early in the season.

van Leur, H., C. E. Raaijmakers and N. M. van Dam (2008). "Reciprocal interactions between the cabbage root fly (Delia radicum) and two glucosinolate phenotypes of Barbarea vulgaris." Entomologia Experimentalis Et Applicata 128(2): 312-322.

The cabbage root fly, Delia radicum L. (Diptera: Anthomyiidae), has a life cycle with spatially separated components: adults live and oviposit above ground, whereas larvae feed and pupate below ground. Oviposition choice is affected by shoot glucosinolates. However, little is known about below-ground plant defence against D. radicum. Here, we investigate the effect of glucosinolates on oviposition preference and performance of D. radicum, using two naturally occurring heritable chemotypes of Barbarea vulgaris R. Br. (Brassicaceae) with different glucosinolate profiles: BAR-type plants (the most common and genetically dominant glucosinolate profile, dominated by glucobarbarin) and NAS-type plants (the recessive phenotype, dominated by gluconasturtiin). Performance was studied by applying 10 neonate D. radicum larvae per plant and measuring pupal biomass after 18 days. There was no difference in retrieval, but pupae had a higher biomass after development on BAR-type plants. On average, BAR-type plants received 1.8 times more eggs than NAS types, but this difference was not statistically significant. In a separate experiment, we compared the physiological response of both chemotypes to D. radicum feeding. Infestation reduced root and shoot biomass, root sugar and amino acid levels, and shoot sugar levels. Except for shoot sugar levels, these responses did not differ between the two chemotypes. Shoot or root glucosinolate profiles did not change on infestation. As glucosinolate profiles were the only consistent difference between the chemotypes, it is likely that this difference caused the reduced biomass of D. radicum pupae on NAS-type plants. In an experimental garden, plants were heavily infested by root flies, but we found no differences in the percentage of fallen-over flower stalks between the chemotypes. Overall, we found more pupae in the soil near BAR-type plants, but this was not statistically significant. The results of the performance experiment suggest that BAR-type plants may be more suitable hosts than NAS-type plants.

Ferry, A., S. Dugravot, T. Delattre, J. P. Christides, J. Auger, A. G. Bagneres, D. Poinsot and A. M. Cortesero (2007). "Identification of a widespread monomolecular odor differentially attractive to several Delia radicum ground-dwelling predators in the field." Journal of Chemical Ecology 33(11): 2064-2077.

Dimethyl disulfide (DMDS) was identified as a major volatile constituent of Brassica napus roots heavily infested by Delia radicum, the cabbage root fly. Attractiveness of this widespread compound was tested in the field in a naturally complex odorous environment. By using an original setup especially designed for ground dwelling beetles, different concentrations of the pure molecule as well as attractiveness of the natural blend emitted by the rotten part of infested roots were tested simultaneously. The use of general linear model (GLM) statistics permitted us to finely discriminate the responses among the different treatments. The main predators of D. radicum (i.e., two staphylinids Aleochara bilineata and Aleochara bipustulata and carabid beetles of the genus Bembidion) were significantly attracted by DMDS, but responded in different ways to the natural blend and to the different concentrations tested. The dose-response curves were similar for the two staphylinids. However, whereas A. bilineata was more attracted by the natural volatile blend than by its preferred DMDS concentration, A. bipustulata was attracted as much by the natural blend as by its preferred DMDS concentration. Carabid beetles exhibited a different response. They were not attracted by the natural blend, but responded to a wider range of DMDS concentrations that included low concentrations that did not attract the staphylinid beetles. These results are discussed according to the potential resources searched by each taxon studied and their specificity for the resources. The possible use of DMDS for enhancing biological control of D. radicum is mentioned.

Goubault, M., A. M. Cortesero, D. Poinsot, E. Wajnberg and G. Boivin (2007). "Does host value influence female aggressiveness, contest outcome and fitness gain in parasitoids?" Ethology 113(4): 334-343.

Intraspecific competition for resources is common in animals and may lead to physical contests. Contest outcomes and aggressiveness can be influenced by the resource holding potential of contestants but also by their perception of the resource value (RV). Competitors may assess resource quality directly (real RV) but may also estimate it according to their physiological status and their experience of the habitat quality (subjective RV). In this article, we studied contests between females of the solitary parasitoid Pachycrepoideus vindemmiae Rondani (Hymenoptera: Pteromalidae) when exploiting simultaneously a host, a Delia radicum L. (Diptera: Anthomyiidae) pupa. We tested the effect of factors

modifying host value on the occurrence of agonistic behaviours, contest outcomes and host exploitation. The factors tested were: the quality of the previous habitat experienced by females, female egg load, host parasitism status and the stage reached by the owner female in her behavioural oviposition sequence. Females successfully protected their host against intruders during its exploitation, but not after oviposition, and their aggressiveness did not seem to be influenced by their perception of the RV. The fact that the host is subsequently parasitized by the opponent females appears to mainly depend on the host selectiveness of females.

Hemachandra, K. S., N. J. Holliday, P. G. Mason, J. J. Soroka and U. Kuhlmann (2007). "Comparative assessment of the parasitoid community of Delia radicum in the Canadian prairies and Europe: A search for classical biological control agents." Biological Control 43(1): 85-94.

As a precursor to a classical biological control programme for Delia radicum in spring-seeded ("summer") canola (oilseed rape) in Canada, communities of parasitoids of D. radicum in summer canola in Canada were compared with those in brassica vegetables and several types of canola in Europe. Weekly samples of immature D. radicum were collected from sites in Canada and Europe and reared individually to determine identity and importance of parasitoids. On both continents, the most frequently encountered parasitoids were the larval-pupal parasitoid Trybliographa rapae and the pupal parasitoid Aleochara bilineata. In Canada, Aleochara verna was common at some sites, and in Europe, Aleochara bipustulata was common at some sites. Parasitoid communities were separated primarily by the relative importance of T rapae and A. bilineata in puparial samples: in Canada, the ratio of A. bilineata parasitism to that of T rapae was higher than in Europe. The negative correlation of these species may be related to the degree of synchrony of A. bilineata parasitism with its host. In Canada, A. bilineata parasitism occurred early relative to host availability and this timing is deleterious to T rapae already within the host. In Europe, T rapae was favored during multiparasitism because A. bilineata parasitism was synchronized with, or delayed, relative to its host's availability. The only important parasitoid in Europe that was not found in Canada was A. bipustulata, which most frequently occurred in summer canola in Europe, suggesting that it could be suited to the same crop in Canada. Consequently, A. bipustulata is being considered as a candidate biological control agent.

Hemachandra, K. S., U. Kuhlmann, P. G. Mason and N. J. Holliday (2007). "Spatial patterns of Trybliographa rapae parasitism of Delia radicum larvae in oilseed rape and cauliflower." Journal of Applied Entomology 131(5): 338-346.

Trybliographa rapae (Westwood) is an important parasitoid of Delia radicum (L.). Parasitism of D. radicum larvae by T. rapae in relation to host density on canola (oilseed rape) and cauliflower roots was examined at 10 field sites in Germany and Switzerland. For roots with host larvae, the proportion of roots with one or more parasitized hosts increased with increasing host density. However, for these infested roots, the parasitism of individual larvae was not consistently related to host density. When considering only roots on which there were parasitized larvae and the opportunity for multiple attacks, the proportion of larvae that were parasitized decreased with increasing host density in the field locations, and in a cage study under controlled conditions. A model of patch-finding and number of attacks by female parasitoids suggests that patch-finding is density-dependent, but that low attack rate and interference effects limit numbers of attacks to three or less per visit to a host patch; the reduced number of attacks per visit leads to the inverse relationship of larval parasitism with host density in the host patches visited. The interplay of the density-dependent and inversely density-dependent processes appears to be responsible for the inconsistency of density dependence of overall larval parasitism in this and previous studies. In the laboratory, adult female T. rapae parasitized hosts at <= 4 cm deep in soil, but not at 6 cm deep. From the depth distribution of larval feeding sites in the field, we infer that between 4% and 20% of Delia larvae may be in a physical refuge from T. rapae parasitism, which may have a stabilizing influence on the host-parasitoid interaction.

Parsons, C. K., P. L. Dixon and M. Colbo (2007). "Relay cropping cauliflower with lettuce as a means to manage first-generation cabbage maggot (Diptera : Anthomyiidae) and minimize cauliflower yield loss." Journal of Economic Entomology 100(3): 838-846.

First-generation cabbage maggot, Delia radicum (L.) (Diptera: Anthomyiidae), can cause extensive damage to newly transplanted brassica crops. This study investigated the use of relay cropping, a form of intercropping that involves overlapping two crops in the same field for a short period, as a means to 1) reduce first-generation D. radicum egg numbers by disrupting female host finding and 2) minimize yield loss by reducing the time that crops overlap. Because

of the high incidence of two other Delia species, Delia platura (Meigen) and Delia florilega (Zetterstedt), treatment effects on these insects also were considered. In both years of the study (2003 and 2004), there were fewer D. radicum eggs collected from the base of cauliflower, Brassica oleracea variety botrytis, plants relay cropped with lettuce, Lactuca sativa L., than in monoculture. D. platural D. florilega also laid fewer eggs on cauliflower in the relay crop than in monoculture in 2003, but in 2004 the opposite was true, there were more D. platura / D. florilega eggs laid on the relay-cropped cauliflower. After peak D. radicum oviposition, the lettuce was harvested. Cauliflower curd weights and diameters were comparable between treatments in both years. Plant loss because of D. platura / D. florilega feeding in the 2004 relay-cropped plots resulted in reduced yields in these plots compared with the monoculture. Although further investigation is needed into the effects of relay cropping on other pests within this system, this is the first study to demonstrate that relay cropping can reduce egg laying by D. radicum at the scale studied while minimizing competition between component crops for key resources.

Riley, K. J., U. Kuhlmann, P. G. Mason, J. Whistlecraft, L. J. Donald and N. J. Holliday (2007). "Can mustard seed meal increase attacks by Aleochara spp. on Delia radicum in oilseed rape?" Biocontrol Science and Technology 17(3): 273-284.

Responses to mustard seed meal of two parasitic beetles, Aleochara bipustulata and A. bilineata, were assessed by measuring levels of parasitism of Delia radicum puparia and of root damage to oilseed rape, and by pitfall trapping of the beetles. Levels of parasitism and trap catches of A. bipustulata were higher in meal-treated plots than in untreated control plots; however, there were no significant effects on A. bilineata, numbers of D. radicum in roots or on levels of root damage. Olfactometry confirmed the absence of response by A. bilineata and showed that A. bipustulata is attracted to volatiles released by dry or wet mustard seed meal. From GC - MS, the most abundant volatiles from mustard seed meal were limonene and structurally-similar compounds. These results are discussed with respect to mechanism of attraction, the host finding cues used by the major parasitoids of D. radicum, and the value of mustard seed meal for enhancing biological control.

Soler, R., T. M. Bezemer, A. M. Cortesero, W. H. Van der Putten, L. E. M. Vet and J. A. Harvey (2007). "Impact of foliar herbivory on the development of a root-feeding insect and its parasitoid." Oecologia 152(2): 257-264.

The majority of studies exploring interactions between above- and below-ground biota have been focused on the effects of root-associated organisms on foliar herbivorous insects. This study examined the effects of foliar herbivory by Pieris brassicae L. (Lepidoptera: Pieridae) on the performance of the root herbivore Delia radicum L. (Diptera: Anthomyiidae) and its parasitoid Trybliographa rapae (Westwood) (Hymenoptera: Figitidae), mediated through a shared host plant Brassica nigra L. (Brassicaceae). In the presence of foliar herbivory, the survival of D. radicum and T. rapae decreased significantly by more than 50%. In addition, newly emerged adults of both root herbivores and parasitoids were significantly smaller on plants that had been exposed to foliar herbivory than on control plants. To determine what factor(s) may have accounted for the observed results, we examined the effects of foliar herbivory on root quantity and quality. No significant differences in root biomass were found between plants with and without shoot herbivore damage. Moreover, concentrations of nitrogen in root tissues were also unaffected by shoot damage by P. brassicae larvae. However, higher levels of indole glucosinolates were measured in roots of plants exposed to foliar herbivory, suggesting that the development of the root herbivore and its parasitoid may be, at least partly, negatively affected by increased levels of these allelochemicals in root tissues. Our results show that foliar herbivores can affect the development not only of root-feeding insects but also their natural enemies. We argue that such indirect interactions between above- and below-ground biota may play an important role in the structuring and functioning of communities.

Soler, R., J. A. Harvey and T. M. Bezemer (2007). "Foraging efficiency of a parasitoid of a leaf herbivore is influenced by root herbivory on neighbouring plants." Functional Ecology 21(5): 969-974.

Root feeding insects can influence foliar quality of the host plant, which can affect the development and behaviour of leaf herbivores and parasitoids. Thus far, such interactions have been reported in situations where root and leaf associated organisms share a host-plant. We tested whether root herbivory influences searching behaviour of an above-ground parasitoid when the foliar feeding host of the parasitoid and the root herbivore are feeding on different plants. We manipulated the proportion of 25 plants (ranging from 0 to 1) exposed to root herbivory by Delia radicum (neighbouring-plants). Five additional plants were infested above-ground with Pieris brassicae larvae (host-infested

plants) and were placed in-between the neighbouring plants. We then released females of the parasitoid Cotesia glomerata which attacks P. brassicae and studied foraging efficiency of the parasitoid. Overall, parasitoids located more host-infested plants during the maximum allowed searching time, and found their hosts about three times faster when neighbouring plants were exposed to root herbivory, than when neighbouring plants were not infested with D. radicum. Similar results were found when the host-infested plants were also exposed to root herbivory. Our results show that the interaction between an above-ground foliar feeding insect and its parasitoid can be influenced by the presence of non-host herbivores feeding on the roots of neighbouring conspecific plants.

Soler, R., J. A. Harvey, A. F. D. Kamp, L. E. M. Vet, W. H. Van der Putten, N. M. Van Dam, J. F. Stuefer, R. Gols, C. A. Hordijk and T. M. Bezemer (2007). "Root herbivores influence the behaviour of an aboveground parasitoid through changes in plant-volatile signals." Oikos 116(3): 367-376.

It is widely reported that plants emit volatile compounds when they are attacked by herbivorous insects, which may be used by parasitoids and predators to locate their host or prey. The study of herbivore-induced plant volatiles and their role in mediating interactions between plants, herbivores and their natural enemies have been primarily based on aboveground systems, generally ignoring the potential interactions between above and belowground infochemical- and food webs. This study examines whether herbivory by Delia radicum feeding on roots of Brassica nigra (black mustard) affects the behaviour of Cotesia glomerata, a parasitoid of the leaf herbivore Pieris brassicae, mediated by changes in plant volatiles. In a semi-field experiment with root-damaged and root-undamaged plants C. glomerata prefers to oviposit in hosts feeding on root-undamaged plants. In addition, in a flight-cage experiment the parasitoid also prefers to search for hosts on plants without root herbivores. Plants exposed to root herbivory were shown to emit a volatile blend characterized by high levels of specific sulphur volatile compounds, which are reported to be highly toxic for insects, combined with low levels of several compounds, i.e. beta-farnesene, reported to act as attractants for herbivorous and carnivorous insects. Our results provide evidence that the foraging behaviour of a parasitoid of an aboveground herbivore can be influenced by belowground herbivores through changes in the plant volatile blend. Such indirect interactions may have profound consequences for the evolution of host selection behaviour in parasitoids, and may play an important role in the structuring and functioning of communities.

Valantin-Morison, M., J. M. Meynard and T. Dore (2007). "Effects of crop management and surrounding field environment on insect incidence in organic winter oilseed rape (Brassica napus L.)." Crop Protection 26(8): 1108-1120.

Many organic farmers hesitate to grow winter oilseed rape (WOSR), despite its usefulness for crop rotations and animal fodder, because it is attacked by many insects, which are difficult to control without chemical treatments. In a geographically broad network of farmer's fields, we analysed the effect of various crop management factors and of the surrounding field environment on a large range of insects known to damage WOSR: root maggot (Delia radicum L.), cabbage stem flea beetle (Psylliodes chrysocephala L.), rape stem weevil (Ceuthorhynchus napi Gyl) and pollen beetle (Meligethes aeneus F.). Our results confirm the effect of sowing date, plant density and soil tillage regime on root maggot attacks and cabbage stem flea beetle larva infestation. Early sowing tended to increase root maggot damage whereas it was associated with a lower level of attack of cabbage stem flea beetle. High plant density tended to decrease the damage or the attack of all insects. We show that nitrogen availability in the soil affect cabbage stem flea beetle, stem weevil levels and pollen beetle damage: the negative effect of soil nitrogen content on pollen beetle damage may be related to the significant effect of nitrogen on plant vigour and, therefore, to the compensation of pollen beetle damage on new racemes. If all insects were considered together, the proportion of land under WOSR in the region and the surrounding environment had a significant effect on pest occurrence. In regions with a high proportion of land under WOSR, the proportion of plants attacked by root maggot and pollen beetle tended to increase. Conversely, regions with high proportions of land under WOSR tended to have a smaller proportion of plants with cabbage stem flea beetle larvae or damage, whatever the environment surrounding the field. For almost all the pests considered, the fields displaying the most severe pest attacks in regions with more than 1.2% WOSR were bounded by trees, hedges and bushes. Conversely, in regions with a lower percentage of land under WOSR, woodland around the field reduced the occurrence of pest attacks.

Broatch, J. S., L. M. Dosdall, G. W. Clayton, K. N. Harker and R. C. Yang (2006). "Using degree-day and logistic models to predict emergence patterns and seasonal flights of the cabbage maggot and seed corn maggot (Diptera : Anthomyiidae) in Canola." Environmental Entomology 35(5): 1166-1177.

Seasonal flight activity periods and emergence phenologies of the cabbage maggot, Delia radicum L., and the seedcorn maggot, Delia platura (Meigen), were studied from 2002 to 2004 in canola, Brassica rapa L. and Brassica napus L., in central Alberta, Canada, in relation to degree-days and Julian-days. D. radicum was univoltine in canola. Peak emergence occurred after an accumulation of 345.8 +/- 79.4 DD, and 50% flight activity required accumulation of 324.5 +/- 46.8 DD (soil base 4 degrees C). D. platura was bivoltine in canola. Peak emergence of the first generation required 339.5 DD, and the second generation required 594.5 +/- 38.9 DD (soil base 3.9 degrees C). Peak flight activity occurred after accumulation of 255.0 +/- 74.2 and 639.9 +/- 69.4 DD for the first and second generations, respectively. A logistic model was used to describe the relationship of degree-days and Julian-days with emergence patterns of adult flies and predicted that 10, 50, and 95% emergence of D. radicum required 213.7 +/- 39.9, 324.5 +/- 46.8, and 467.2 +/- 46.3 DD, respectively. Logistic analysis predicted that 50% emergence of the first generation of D. platin-a required an average of 255.0 +/- 74.2 DD, and the second generation required 526.8 +/- 66.6, 639.9 +/- 69.4, and 952.8 +/- 77.0 DD for 10, 50, and 95% emergence, respectively. Determination of the temporal patterns of abundance of D. radicum and D. platura has potential application for pest management because it can help ensure that phenologies of candidate agents for biocontrol are synchronous with those of the pests they are targeted to control.

Dreves, A. J., D. Dalthorp, A. G. Stone and G. Fisher (2006). "Spring emergence and seasonal flight of Delia radicum L. (Diptera : Anthomyiidae) in western Oregon." Environmental Entomology 35(2): 465-477.

Field research was conducted to describe and characterize spring emergence and seasonal flight activity of the cabbage maggot, Delia radicum L. (Diptera: Anthomyiidae), in relationship to degree-day accumulations. Turnip and rutabaga fields were monitored in the northern Willamette Valley in western Oregon from 2001 through 2004. Spring emergence from overwintering puparia was monitored using emergence cages. A bimodal spring emergence pattern was observed, with approximate to 70% of the Spring Population emerging in an early peak in late March, 2 mo before a later peak near the end of May. The mean degree-day accumulations at 10, 50, and 95% of spring emergence using a lower and upper developmental threshold of 4.3 and 30 degrees C beginning I January had corresponding degree-day values of 200 +/- 50.2 (8 March), 330 +/- 22.2 (4 April), and 762 +/- 60.1 (28 May), respectively. Seasonal flight activity was monitored using yellow water traps. Spring flight patterns mirrored the bimodal emergence patterns but with a delay of 3 d to 5 wk between emergence and detection of flies in the water traps. The mean degree-day accumulations recorded from the beginning to the end of spring flight had corresponding degree-day values of 303 +/- 61.5 (31 March) to 839 +/- 51.9 (4 June). Fly activity was lower over the summer from the beginning Of June until the end of August (2,138 +/- 82.3 DD). A fall flush of activity was observed each year beginning in late August to early September and extending through October (2,860 +/- 170.6 DD).

Gouinguene, S. P. D., T. Poiger and E. Stadler (2006). "Eggs of cabbage root fly stimulate conspecific oviposition: Evaluation of the activity and determination of an egg-associated compound." Chemoecology 16(2): 107-113.

Previous studies indicated the presence of antennally-active compounds in extracts of eggs laid by female cabbage root flies, Delia radicum, that stimulated oviposition by conspecific females. We confirmed that previously laid D. radicum eggs stimulated oviposition by other D. radicum females, in a dose-dependent manner. Methanol extracts of conspecific eggs stimulated oviposition by females D. radicum, whereas egg extracts of D. antiqua and Psila rosae had no effect. Electrophysiological recordings from the tarsal sensilla of D. radicum females indicated that neurones of the C-5 sensillum responded to the egg extracts from both D. radicum and D. antiqua, but not P. rosae. Chemical analysis revealed that the extract of eggs from D. radicum contained the thia-triaza-fluorene compound, 1,2-dihydro-3-thia-4,10,10b-triaza-cyclopenta[.a.]fluorene-1-carboxylic acid (CIF-1), an oviposition stimulant found previously only in cruciferous plants. Another potentially active component has yet to be identified.

Gouinguene, S. P. D. and E. Stadler (2006). "Comparison of the egg-laying behaviour and electrophysiological responses of Delia radicum and Delia floralis to cabbage leaf compounds." Physiological Entomology 31(4): 382-389.

The behaviour and the sensitivity of adult cabbage root fly, Delia radicum and turnip root fly, Delia floralis are compared with host-plant extracts and isolated crucifer compounds previously identified as oviposition stimulants for

D. radicum. The oviposition behaviour of both species is similar; 7-10-day-old females are stimulated to lay eggs by the methanol extract of cauliflower leaves that contains thia-triaza-fluorenes (CIF) as well as glucosinolates. The glucosinolate fraction is mainly composed of glucobrassicin, which alone stimulate both fly species to lay eggs. The C-5 and D-3,D-4 sensilla on the prothoracic tarsae of newly-emerged D. radicum contain neurones sensitive to the glucosinolate fractions tested and to glucobrassicin, whereas the CIF specifically stimulate a neurone in the C-5 sensillum. By contrast, newly-emerged D. floralis respond less to glucosinolates, especially to glucobrassicin, and have sensitive neurones to CIF in other sensilla than D. radicum. Recordings are also made from the longest sensilla present on the labellum because they are apparently sensitive to glucosinolates. By contrast to earlier investigations, no remarkable phasic-tonic responses of these neurones are seen. The two species are difficult to discriminate visually, have the same host plants, show identical host-selection behaviour, apparently respond to the same physical and chemical properties of their host-plants, but have a clearly different distribution of receptor neurones in the tarsal sensilla.

Johansen, T. J. and R. Meadow (2006). "Population differences in emergence of Brassica root flies (Diptera : Anthomyiidae)." Environmental Entomology 35(5): 1161-1165.

Accurate timing of pest control measures requires a good understanding of the emergence pattern of the specific pest populations. In 1999-2000, pupae of the cabbage maggot, Delia radicum L., and the turnip maggot, D. floralis Fallen, were collected in the autumn from nine widespread locations in Norway (58-70 degrees N). After diapause development during winter, emergence was studied in a climate chamber at 18 degrees C. The time to 50% emergence was < 2 wk for all populations of D. radicum, and the emergence period (time elapsed between 10 and 90% emergence) was similar to 4 d on average. The results indicated uniform and early emerging populations of this species. D. floralis, however, had much later emergence, with a wide range of emerging biotypes. The time to 50% emergence of D.floralis varied from 5 to 10 wk between populations. Moreover, the emergence period varied between 2 and 7 wk for the different populations, indicating mixtures of differently emerging biotypes. The ecological basis for the diverging emergence patterns is discussed.

Lukwinski, A. T., J. E. Hill, G. G. Khachatourians, S. M. Hemmingsen and D. D. Hegedus (2006). "Biochemical and taxonomic characterization of bacteria associated with the crucifer root maggot (Delia radicum)." Canadian Journal of Microbiology 52(3): 197-208.

The crucifer root maggot, Delia radicum, is an important pest of cruciferous crops; however, little is known about its digestive biochemistry or resident gut microbiota. A culturing approach was used to survey the types of microorganisms associated with eggs, midgut, and faeces of larvae feeding on rutabaga. All bacteria isolated from the midgut and faecal materials were Gram-negative bacilli. Nine types of culturable bacteria were identified within the midgut based on analysis of 60 kDa chaperonin sequences and were generally gamma-Proteobacteria, primarily Enterobacteriaceae. Carbohydrate utilization patterns, select biochemical pathways, and hydrolytic enzymes were examined using the API (R) system for each of the nine groups, revealing an exceptionally broad metabolic and hydrolytic potential. These studies suggest that resident alimentary tract microorganisms have the potential to contribute to host nutrition directly as a food source as well as by providing increased digestive potential.

Prowse, G. M., T. S. Galloway and A. Foggo (2006). "Insecticidal activity of garlic juice in two dipteran pests." Agricultural and Forest Entomology 8(1): 1-6.

1 Botanical products excluding pyrethroids constitute a small, but growing portion of the U.K. pesticides market. With increasing legislative pressure upon chemical pesticides such as organophosphates, interest in this sector is increasing steadily. 2 Garlic Allium sativum L. juices and extracts form the basis of several commercially available pest control products, but the performance of these products is variable, possibly due to lack of quality control upon batches of materials in the manufacturing process. 3 Some garlic products designed for use in the food industry are subjected to rigorous batch-control to ensure organoleptic consistency. We studied the insecticidal efficacy of a commercially produced food grade garlic juice using two target dipteran pests, Delia radicum (L.) and Musca domestica L. 4 Exposure of the two species to different concentrations of garlic juice revealed variability in insecticidal effect across life stages. LC50 values recorded for D. radicum were: eggs (7-day exposure) 0.8%; larvae (24-11 exposure) 26.4%; larvae (48-h exposure) 6.8%; and adults (24-h exposure) 0.4%. LC50 values recorded for M. domestica were: eggs (7-day exposure)

1.6%; larvae (24-h exposure) 10.1%; larvae (24-h exposure) 4.5%; and adults (24-h exposure) 2.2%. 5 Mortality rates caused by the garlic juice were comparable with those obtained with the organophosphate pesticide Birlane (R), indicating parity of effect at various concentrations depending on life stage. 6 We conclude that this product may provide an effective, naturally-derived insecticide for use in agricultural systems against dipteran pests.

van Dam, N. M. and C. E. Raaijmakers (2006). "Local and systemic induced responses to cabbage root fly larvae (Delia radicum) in Brassica nigra and B-oleracea." Chemoecology 16(1): 17-24.

Feeding by belowground herbivores may induce systemic changes in shoot defence levels that affect the performance of above ground herbivores and higher trophic levels. In this paper two wild Brassica species, B. nigra and B. oleracea were experimentally infested with 10 larvae of the cabbage root fly, Delia radicum. Plant dry masses and glucosinolate levels in shoots, main roots, and fine roots were determined at 3, 7, 12 and 14 days after infestation and compared to those of control plants. The systemic response in the leaves differed between plant species. In B. nigra shoot glucosinolate levels in D. radicum infested plants steadily increased with time until they were almost twice those of controls 14 days after infestation. B. oleracea plants infested with D. radicum did not show significant changes in shoot glucosinolate levels within 14 days, which may be due to the unexpected poorer performance of D. radicum on this species. Both plant species showed a local increase in indole glucosinolates in the main roots, which are the preferred feeding site of D. radicum larvae. B. oleracea plants however showed a stronger (1.9 - 4.7 times) increase in indole glucosinolate levels than B. nigra (1.5 - 2.6 times). The increase in indole glucosinolates in B. nigra main roots, was counterbalanced by a significant decrease in aromatic glucosinolate levels. These differences in local responses to D. radicum feeding between the two species may have contributed to the slower growth rates of the larvae on B. oleracea. D. radicum feeding did not result in altered glucosinolate levels in the fine roots in either plant species. The differences in glucosinolate induction patterns between the summer annual B. nigra and the perennial B. oleracea are discussed in the light of their different life histories.

(2005). "Evaluation of entomopathogenic nematodes and green manures for control of cabbage maggot, Delia radicum." Journal of Nematology 37(3): 379-379.

Biron, D. G., D. Coderre, S. Fournet, J. P. Nenon, J. Le Lannic and G. Bolvin (2005). "Larval respiratory systems of two anthomyiid files, Delia radicum and Delia antiqua (Diptera : Anthomyiidae)." Canadian Entomologist 137(2): 163-168.

The first-instar larvae of Delia radicum (L.) and Delia antiqua (Meigen) enter host plants to feed in galleries. These galleries can be filled by a liquid resulting from the putrefaction of the host. In this study, we show that D. radicum and D. antiqua larvae have a metapneustic respiratory system in the first instar and an amphipneustic respiratory system in the second instar, as observed in the majority of cyclorrhaphous Diptera. In addition, we observed four spatulate, ramified structures on the postabdominal spiracles in all three larval instars. We propose that these structures facilitate gas exchange (CO2 and O-2), especially in the first-instar larvae when they feed in liquid-filled galleries.

Bruck, D. J., J. E. Snelling, A. J. Dreves and S. T. Jaronski (2005). "Laboratory bioassays of entomopathogenic fungi for control of Delia radicum (L.) larvae." Journal of Invertebrate Pathology 89(2): 179-183.

Laboratory soil bioassays were performed at economic field rates for in-furrow (3.85 x 10(6) spores/g dry soil) and broadcast (3.85 x 10(5) spores/g dry soil) applications with three isolates of Metarhizium anisopliae (F52, ATCC62176, and ARSEF5520) and one isolate of Beauveria bassiana (GHA). All isolates tested were infective to second instar Delia radicum (L.). The conditionally registered M. anisopliae isolate (F52) performed best killing an average of 85 and 72% of D. radicum larvae at the high and low concentration, respectively. The mean LC50 and LC95 of F52 against second instar D. radicum was 2.7 x 10(6) and 1.8 x 10(8) spores/g dry soil, respectively. The use of F52 in an integrated management program is discussed. (c) 2005 Elsevier Inc. All rights reserved.

Chandler, D. and G. Davidson (2005). "Evaluation of entomopathogenic fungus Metarhizium anisopliae against soil-dwelling stages of cabbage maggot (Diptera : Anthomyiidae) in glasshouse and field experiments and effect of fungicides on fungal activity." Journal of Economic Entomology 98(6): 1856-1862.

The effect of two isolates of the entomopathogenic fungus Metarhizium anisopliae (Metchnikoff) Sorokin (389.93 and 392.93) on root-feeding stages of cabbage root fly, Delia radicum (L.), was studied under glasshouse and field

conditions. In glasshouse studies, the effect of drenching a suspension of conidia (concentration I X 10(8) ml(-1), 40 ml per plant, applied on four occasions) onto the base of cabbage plants infested with D. radicum eggs was compared with mixing conidial suspension into compost modules (concentration I X 10(8) ml(-1), 25 ml per plant) used to raise seedlings. Drench application reduced the mean number of larvae and pupae recovered per plant by up to 90%, but the compost module treatment had no statistically significant effect. Both application methods reduced the emergence of adult flies from pupae by up to 92%. Most conidia applied as a drench application remained in the top 10-cm layer of compost. Applications of the fungicides iprodione and tebuconazole, which are used routinely on brassica crops, were compatible with using M. anisopliae 389.93 against D. radicum under glasshouse conditions, even though these fungicides were inhibitory to fungal growth on SDA medium. In a field experiment, drench applications of M. anisopliae 389.93 to the base of cauliflower plants at concentrations of 1 X 10(6) to I X 10(8) conidia ml(-1) did not control D. radicum populations, although up to 30% of larval cadavers recovered supported sporulating mycelium. Drench applications often exhibited considerable lateral movement on the soil surface before penetrating the ground, which may have reduced the amount of inoculum in contact with D. radicum larvae.

Felkl, G., E. B. Jensen, K. Kristiansen and S. B. Andersen (2005). "Tolerance and antibiosis resistance to cabbage root fly in vegetable Brassica species." Entomologia Experimentalis Et Applicata 116(1): 65-71.

Four accessions of the wild species Brassica fruticulosa Cyrillo (Brassicaceae) were studied in order to identify its tolerance and antibiosis resistance to the cabbage root fly, Delia radicum L. (Diptera: Anthomyiidae), in comparison to a widely cultivated cauliflower cultivar and a rapid cycling Brassica oleracea L. line. Antibiosis was prominent, as the insects reared on resistant accessions showed reduced individual pupal weight, total pupal weight, adult dry weight, and the longest average fly eclosion time. Host plant resistance, however, did not affect the sex ratio of adult flies. A study of the root architecture of plants with and without root fly inoculation revealed differences in the structure within B. oleracea accessions. A long main root and a high number of lateral roots appeared to be important characteristics for a Brassica type, with a higher tolerance level to cabbage root fly attack.

Gouinguene, S., H. R. Buser and E. Stadler (2005). "Host-plant leaf surface compounds influencing oviposition in Delia antiqua." Chemoecology 15(4): 243-249.

Delia antiqua (Diptera: Anthomyiidae) females lay eggs between the leaves of onion plants or in the soil around the base of the plants, then the maggots feed on the onion bulb and roots causing rapid secondary infection by fungi and bacteria. It is well known that the first sensory modality used by the onion fly is vision, therefore the shape (vertical narrow cylinders) and colour (yellow) of the plant play a crucial role in the recognition of a potential host plant. In the past it has been shown that n-dipropyl disulfide (Pr2S2), a typical component of onion volatiles, is an important chemical host plant cue. We extracted host leaf surface to verify if Pr2S2 is the major chemical oviposition stimulant and to determine if other as yet unknown substances may play a role in host-plant selection. We confirmed that the females laid more eggs around onion plants with leaves than when only the onion bulb was present and that the odour of chopped onion stimulates oviposition. Extraction of the surface of onion leaves revealed that only the apolar fraction contained substances that stimulate egg-laying in D. antiqua. GC-EAD analysis indicated that a minor constituent, Pr2S2, is perceived by the olfactory receptor on the antennae of the onion fly females. This confirmed the importance of Pr2S2 as oviposition stimulant. Contact with the polar fraction did not stimulate egg-laying behaviour in this Delia species. We discuss the oviposition strategy of D. antiqua in comparison with its closely related species, D. radicum, in which the oviposition behaviour is stimulated mainly through contact with the cabbage leaf surface and only partially by the host volatiles.

Gouinguene, S. P. D. and E. Stadler (2005). "Comparison of the sensitivity of four Delia species to host and non-host plant compounds." Physiological Entomology 30(1): 62-74.

The behavioural facilitation hypothesis, tested in the present study, suggests that evolution of host-plant shifts by phytophagous insects is based on the preadaptation of insects to the chemistry of potentially novel plant hosts. Thus, closely-related insects should have similar sensitivities to compounds that are shared by different host plants. The chemoreception is investigated for four phytophagous flies, Delia radicum, Delia floralis, Delia antiqua and Delia platura (Diptera, Calyptratae: Anthomyiidae), belonging to the same genus but developing mainly on different plant families, with particular secondary plant compound profiles. In addition, the carrot fly, Psila rosae, an acalyptrate Diptera, is

included as an unrelated species that is associated with completely different host plants. For the comparison, the known oviposition stimulants of the cabbage root fly (glucobrassicin, sinalbin, sinigrin and a thia-triaza-fluorene compound; CIF-1) present on the cabbage leaf surface were chosen. Responses from prothoracic tarsal sensilla are recorded to contact stimulation in a dose-dependent manner. Among the different flies tested, only D. radicum responds to all the compounds. By contrast, D. floralis is only sensitive to CIF-1, and not specifically on the C-5 sensillum, a finding that is in conflict with previously published results. This discrepancy is possibly an indication of the variability among flies originating from different cultures or habitats. With the exception of sinigrin at high concentration, the various compounds tested do not stimulate D. antiqua or D. platura. However, the carrot fly appears to be completely insensitive to sinigrin even at the highest tested concentration of 10(-1) M. The responses of the contact-chemoreceptor neurones to the selected compounds therefore provide little evidence of common sensitivities that would explain host shift in Delia species and specialization at the physiological level. The wide divergence within closely-related species and rearing cultures appears to indicate that the sensitivity and distribution of sensory receptor neurones is very variable on an evolutionary scale.

Hemachandra, K. S., N. J. Holliday, J. Klimaszewski, P. G. Mason and U. Kuhlmann (2005). "Erroneous records of Aleochara bipustulata from North America: an assessment of the evidence." Canadian Entomologist 137(2): 182-187.

Aleochara bipustulata (L., 1761) (Coleoptera: Staphylinidae) is a Palearctic species and a natural enemy of the cabbage root maggot, Delia radicuin (L., 1758) (Diptera: Anthomyiidae). It has been identified as a candidate for introduction to Canada for classical biological control of D. radician. Recent taxonomic studies assert that A. bipustulata is absent from the Nearctic; however, there are numerous publications reporting the presence of the species in North America. We examined voucher material relating to these publications and additional museum specimens labeled as A. bipustulata. In addition, we reared Aleochara spp. from D. radician puparia collected in the Canadian prairie provinces. Specimens that, based on external anatomy, could be A. bipustulata were definitively identified using characters of the genitalia. All of the 141 museum specimens labeled A. bipustulata were found to be Aleochara verna Say, 1836. A total of 811 individuals of Aleochara spp. were reared from D. radicum puparia; of these, 690 were Aleochara bilineata Gyllenhal, 1810, 121 were A. verna, and none were A. bipustulata. We have found no evidence that A. bilnistulata occurs in North America.

Jhee, E. M., R. S. Boyd and M. D. Eubanks (2005). "Nickel hyperaccumulation as an elemental defense of Streptanthus polygaloides (Brassicaceae): influence of herbivore feeding mode." New Phytologist 168(2): 331-343.

No study of a single nickel (Ni) hyperaccumulator species has investigated the impact of hyperaccumulation on herbivores representing a variety of feeding modes. Streptanthus polygaloides plants were grown on high- or low-Ni soils and a series of no-choice and choice feeding experiments was conducted using eight arthropod herbivores. Herbivores used were two leaf-chewing folivores (the grasshopper Melanoplus femurrubrum and the lepidopteran Evergestis rimosalis), a dipteran rhizovore (the cabbage maggot Delia radicum), a xylem-feeder (the spittlebug Philaenus spumarius), two phloem-feeders (the aphid, Lipaphis erysimi and the spidermite Trialeurodes vaporariorum) and two cell-disruptors (the bug Lygus lineolaris and the whitefly Tetranychus urticae). Hyperaccumulated Ni significantly decreased survival of the leaf-chewers and rhizovore, and significantly reduced population growth of the whitefly cell-disruptor. However, vascular tissue-feeding insects were unaffected by hyperaccumulated Ni, as was the bug cell-disruptor. We conclude that Ni can defend against tissue-chewing herbivores but is ineffective against vascular tissue-feeding herbivores. The effects of Ni on cell-disruptors varies, as a result of either variation of insect Ni sensitivity or the location of Ni in S. polygaloides cells and tissues.

Marazzi, C. and E. Stadler (2005). "Influence of sulphur plant nutrition on oviposition and larval performance of the cabbage root fly." Agricultural and Forest Entomology 7(4): 277-282.

1 Oilseed rape plants (Brassica napus) (L.) (Brassicaceae) were grown under different levels of sulphur supply and tested for the oviposition preference and larval performance of cabbage root flies Delia radicum (L.) (Diptera: Anthomyiidae). 2 Adult females laid more than three-fold as many eggs on control S-n (normal field concentration) than on sulphur-free So plants. By contrast, no significant difference was observed between control and double normal concentration (S+) plants. 3 The larval performance was evaluated using three additional, intermediate sulphur levels between So and Sn, and the plants were infected with equal numbers of eggs. The percentage pupation at the end of larval feeding ranged

from 6% (S-o) to 32% (S-n or S+) and the average number of pupae, or of emerging flies, was significantly correlated with sulphur application. 4 The weight of emerging males and females was correlated with plant sulphur supply. 5 The duration of development from eggs to adult emergence was approximately 2 days longer in females than in males. Females originating from plants with a normal or higher sulphur supply tended to emerge 1-2 days earlier.

Morley, K., S. Finch and R. H. Collier (2005). "Companion planting-behaviour of the cabbage root fly on host plants and non-host plants." Entomologia Experimentalis Et Applicata 117(1): 15-25.

Six-hundred individual female cabbage root flies (Delia radicum L.) (Diptera: Anthomyiidae) were each observed for 20 min under laboratory conditions to record how they behaved after landing on a host or a non-host plant. Fly movements were recorded on host plants [cabbage -Brassica oleracea var. capitata (Cruciferae)] and non-host plants [clover -Trifolium subterraneum L. (Papilionaceae)] surrounded by bare soil and on cabbage surrounded by clover. The most frequently observed behaviours made by the flies were (1) hops/spiral flights and (2) walks/runs. In the bare soil situation, the 50 individual flies observed in each treatment made 66 hops/spiral flights on the cabbage and 94 on the clover. When the two plants were tested together the movements were not additive as, instead of the expected 160 hops/spiral flights in the mixed plant treatment, the flies made 210 hops/spiral flights when they landed initially on cabbage but only 130 when they landed initially on clover. Few of the flies that landed initially on clover moved onto the host plant, even though the host plant was only a few centimetres away. The duration of the individual walks and runs made by the cabbage root flies were similar on both the host and non-host plants. The only differences were the numbers of walks/runs made and the time the flies remained inactive. On the host plants, the females made four walks/runs, each of about 12 s duration, interspersed by rest periods that totalled 1.5 min. In contrast, on the non-host plants the females made 10 walks/runs, each of about 9 s duration, interspersed by rest periods that totalled 7 min. Therefore, after landing on a plant, the flies, on average, left the host plant after 2.25 min and the non-host plant after 8.5 min. Our conclusion is that the protracted time spent on the non-host plants is the mechanism that disrupts insects from finding host plants in diverse plantings. Hence, the flies were arrested by non-host plants rather than being repelled or deterred as suggested in earlier studies.

Soler, R., T. M. Bezemer, W. H. Van der Putten, L. E. M. Vet and J. A. Harvey (2005). "Root herbivore effects on above-ground herbivore, parasitoid and hyperparasitoid performance via changes in plant quality." Journal of Animal Ecology 74(6): 1121-1130.

1. Plants and insects are part of a complex multitrophic environment, in which they closely interact. However, most of the studies have been focused mainly on bi-tritrophic above-ground subsystems, hindering our understanding of the processes that affect multitrophic interactions in a more realistic framework. 2. We studied whether root herbivory by the fly Delia radicum can influence the development of the leaf feeder Pieris brassicae, its parasitoid Cotesia glomerata and its hyperparasitoid Lysibia nana, through changes in primary and secondary plant compounds. 3. In the presence of root herbivory, the development time of the leaf herbivore and the parasitoid significantly increased, and the adult size of the parasitoid and the hyperparasitoid were significantly reduced. The effects were stronger at low root fly densities than at high densities. 4. Higher glucosinolate (sinigrin) levels were recorded in plants exposed to below-ground herbivory, suggesting that the reduced performance of the above-ground insects was via reduced plant quality. Sinigrin contents were highest in plants exposed to low root fly densities, intermediate in plants exposed to high root fly densities and lowest in plants that were not exposed to root herbivory. 5. Our results show, for the first time, that root herbivory via changes in plant quality can reduce the performance of an above-ground multitrophic level food chain. This underlines the importance of integrating a broader range of above- and below-ground organisms to facilitate a better understanding of complex multitrophic interactions and interrelationships.

van Dam, N. M., C. E. Raaijmakers and W. H. van der Putten (2005). "Root herbivory reduces growth and survival of the shoot feeding specialist Pieris rapae on Brassica nigra." Entomologia Experimentalis Et Applicata 115(1): 161-170.

Plants may respond to herbivore attacks by changing their chemical profile. Such induced responses occur both locally and systemically throughout the plant. In this paper we studied how Brassica nigra (L.) Koch (Brassicaceae) plants respond to two different root feeders, the endoparasitic nematode Pratylenchus penetrans Cobb (Tylenchida: Pratylenchidae) and the larvae of the cabbage root fly Delia radicum L. (Diptera: Anthomyiidae). We tested whether the activities of the root feeders affected the survival and development of the shoot feeding crucifer specialist Pieris rapae (L.) (Lepidoptera: Pieridae) via systemically induced changes in the shoots. Overall, P. rapae larvae grew slower and

produced fewer pupae on plants that were infested with root feeders, especially on plants infested with P. penetrans. This effect could not be attributed to lower water or protein levels in these plants, as the percentage of water in the controls and root infested shoots was similar, and protein content was even higher in root infested plants. Both glucosinolate as well as phenolic levels were affected by root feeding. Initially, glucosinolate levels were the lowest in root infested plants, but on P. penetrans infested plants they increased more rapidly after P. rapae started feeding than in controls or D. radicum infested plants. Plants with D. radicum feeding on their roots had the highest phenolic levels at all harvest dates. Our results indicate that root feeding can significantly alter the nutritional quality of shoots by changes in secondary metabolite levels and hence the performance of a specialist shoot feeder.

Bonsall, M. B., M. P. Hassell, P. M. Reader and T. H. Jones (2004). "Coexistence of natural enemies in a multitrophic host-parasitoid system." Ecological Entomology 29(6): 639-647.

1. This study explored the temporal and spatial aspects of coexistence over many generations in a multispecies host-parasitoid assemblage. 2. The long-term 1 interaction between the cabbage root fly, Delia radicum (Diptera: Anthomyiidae), and two of its natural enemies, Trybliographa rapae (Hymenoptera: Fitigidae) and Aleochara bilineata (Coleoptera: Staphylinidae), in a cultivated field at Silwood Park over 19 years was explored. 3. Although time series showed that the populations were regulated, the impact of the natural enemies was highly variable. Within-year determinants showed that the spatial response of the specialist parasitoid, T. rapae, was predominantly independent of host density while A. bilineata acted simply as a randomly foraging generalist parasitoid. 4. These findings are compared and contrasted with an earlier investigation of the same system when only the first 9 years of the time series were available. This study demonstrated the potential of long-term field studies for exploring hypotheses on population regulation, persistence, and coexistence.

Collier, R. H. and S. Finch (2004). Forecasting attacks by pest insects of cruciferous crops.

The timing of pest insect attacks can vary greatly from region to region and from year to year. A simulation method, based on rates of insect development, has been developed for forecasting the timing of insect attacks on cruciferous crops. The method is based on using a fixed number of individuals from one generation to the next and simulates the timing of events in the life cycle of the pests rather than their population dynamics. Forecasts produced for the cabbage root fly, the bronzed-blossom beetle and various species of Lepidoptera have been validated using pest monitoring data. Forecasts can be generated on either a regional basis from standard meteorological data, or on a local basis from air and soil temperatures collected by participating growers.

Dixon, P. L., J. R. Coady, D. J. Larson and D. Spaner (2004). "Undersowing rutabaga with white clover: impact on Delia radicum (Diptera : Anthomyiidae) and its natural enemies." Canadian Entomologist 136(3): 427-442.

The cabbage maggot, Delia radicum (L.), is a serious pest of cruciferous crops in temperate regions of North America and Europe. The effects of undersowing rutabaga, Brassica napus L. subsp. rapfera Metzg. (Brassicaceae), with white clover, Trifolium repens L. (Leguminosae), on second-generation cabbage maggot and its natural enemies were studied in Newfoundland in 1997 and 1998. in 1997, totals of 1311 and 724 eggs were recovered from bare and undersown plots, respectively. More eggs were present in bare plots than undersown plots on various specific dates. In 1997, rutabagas front bare plots weighed more than those from undersown plots, although damage ratings were similar, suggesting that competition, not cabbage maggot feeding, caused the yield differences. In 1998, there were few cabbage maggots present and little damage or yield reduction in either treatment. Similar numbers of cabbage maggot pupae were extracted and reared front each treatment in each year. In 1997, of the pupae reared from undersown plots, 48% produced cabbage maggot flies, 14% produced parasitic Hymenoptera, and 8% produced Aleochara bilineata Gyllenhal (Coleoptera: Staphylinidae); 19% of the pupae from bare plots produced cabbage maggot flies, 8% produced parasitic Hymenoptera, and 36% produced A. bilineata. More A. bilineata were captured in pitfall traps in bare plots than in undersown plots. The effect of clover on carabid beetles was species specific. There were more Bembidion lampros (Herbst) and Amara bifrons (Gyllenhal) in bare plots in 1997, and more Pterostichus melanarius (Illiger) in undersown plots in both years. Despite consistently lower egg numbers in undersown plots than in bare plots, the numbers of pupae in the two treatments were similar at the end of the season. We speculate that this may be due to differential density-dependent mortality of immature stages of cabbage maggot caused by predators and parasitoids.

Fournet, S., N. Astier, A. M. Cortesero and D. G. Biron (2004). "Influence of a bimodal emergence strategy of a Dipteran host on life-history traits of its main parasitoids." Ecological Entomology 29(6): 685-691.

1. Among a great diversity of other strategies, insects have evolved polymodal emergence patterns that can increase survival in the face of annual variations in environmental conditions. Delia radicum L. (Diptera: Anthomyiidae) is a polyvoltine pest that attacks several cultivated cruciferous species. At the time of emergence, most populations show a polymodal emergence of type A (i.e. all individuals that enter diapause in the same year terminate diapause the following growing season, and exhibit a bimodal emergence curve). This results in the occurrence of two sympatric phenotypes, early and late, which differ by the timing of adult emergence in both diapausing and non-diapausing generations. 2. In Brittany, D. radicum pupae can be heavily parasitised by three parasitoids, Aleochara bilineata Gyll. (Coleoptera: Staphylinidae), Aleochara bipustulata L., and Trybliographa rapae (Hymenoptera: Eucoilidae). As in all parasitoids species, the successful development of both Aleochara species and T. rapae larvae depends mainly on the amount and quality of the food provided by the host. 3. The relationship between early and late host phenotype and (i) the parasitism efficiency, (ii) emergence patterns, and (iii) host selection behaviour were investigated for the three parasitoid species. 4. Depending on parasitoid species and their different parasitism and development mode, the results reveal that host phenotype can influence (i) survival and development time in T. rapae, and (ii) survival in Aleochara species. Aleochara larvae did not appear to discriminate between early and late host pupae on the basis of phenotype, but rather selected them according to their developmental stage. Furthermore, it was discovered that the same phenological strategy occurred in T. rapae and in D. radicum. However, for D. radicum the results indicate that such a strategy has a cost as the longer development time of late host pupae results in a longer period of time favourable for parasitism.

Marazzi, C., B. Patrian and E. Stadler (2004). "Secondary metabolites of the leaf surface affected by sulphur fertilisation and perceived by the cabbage root fly." Chemoecology 14(2): 87-94.

Surrogate leaves treated with methanolic leaf surface extracts of Brassica napus L. (cv Express) plants that received three different sulphur fertilisation treatments showed even more marked differences by the oviposition choice of Delia radicum L. than the potted plants. This confirms that the oviposition preference of D. radicum is mediated by chemical compounds on the leaf surface and that the quality of host-plants in terms of their nutrition status can be perceived by the female insect. The oviposition data were positively correlated with the content of fractionated surface extracts containing either CIF ("cabbage identification factor"; 1,2-dehydro-3-thia- 4,10,10b-triaza-cyclopenta[.a.]fluorine-1-carboxylic acid) or glucosinolates. Electrophysiological recordings from the tarsal chemoreceptor sensilla C-5 and D-3,D-4 showed that receptor neurons react to glucosinolate- and CIF-fractions. We found that the chemosensory activity of specific glucosinolate- and CIF-receptor neurons corresponded with the respective behavioural activity in the oviposition choice assays. The responses of D. radicum to glucosinolates in the electrophysiological recordings studies corresponded to the observed oviposition preference on plants or artificial leaves characterised with an higher amount of glucosinolates on leave surfaces. The presented data suggested that CIF and glucosinolates are involved in host-plant preference of D. radicum and are perceived by tarsal chemoreceptors.

Marazzi, C. and E. Stadler (2004). "Arabidopsis thaliana leaf-surface extracts are detected by the cabbage root fly (Delia radicum) and stimulate oviposition." Physiological Entomology 29(2): 192-198.

Oviposition of the cabbage root fly, Delia radicum (Diptera, Anthomyiidae) is stimulated by leaf-surface extracts of Arabidopsis thaliana (L.) Heynh. (Brassicaceae) ecotype Columbia. The leaf surface of A. thaliana, similar to that of many other crucifers, contains glucosinolates and CIF ('cabbage identification factor'; 1,2-dehydro-3-thia-4,10,10b-triaza-cyclopenta[.a.]fluorene-1-carboxylic acid). These compounds stimulate receptor neurones of the tarsal sensilla of D. radicum whereas additional, unknown compounds are detected by other receptor neurones.

Nielsen, O. and H. Philipsen (2004). "Recycling of entomopathogenic nematodes in Delia radicum and in other insects from cruciferous crops." Biocontrol 49(3): 285-294.

Larvae of Delia radicum Linnaeus (Diptera: Anthomyiidae) were exposed to Steinernema feltiae Filipjev (Rhabditida) to study the ability of the nematodes to fulfill their life cycle (recycle) in this host. In addition, the recycling of Steinernema and Heterorhabditis (Rhabditida) species was studied in larvae of the following insects: Meligethes spp. Stephens

(Coleoptera: Nitidulidae), Dasyneura brassicae Winnertz (Diptera: Cecidomyidae), Ceutorrhynchus assimilis Paykull, C. pallidactylus Marsham (Coleoptera: Curculionidae) and Mamestra brassicae Linnaeus (Lepidoptera: Noctuidae). All larval instars of D. radicum were studied (larvae live and pupate in soil) whereas the final instars of the remaining insects were studied (larvae only pupate in soil). On average, the following numbers of infective juveniles were produced in the different hosts: 1,200-1,400 in C. assimilis; 700-1,300 in Meligethes spp. and 47,000 in M. brassicae. In D. radicum, around 400 infective juveniles were produced on average in the smallest larvae and around 3,500 in the largest larvae. The highest number of nematodes recorded in a D. radicum larva (third instar) was 9,500 infective juveniles. The number of nematodes produced in D. radicum cadavers was positively related to the size of the insect host, but large variation was observed.

Nielsen, O. and H. Philipsen (2004). "Occurrence of Steinernema species in cabbage fields and the effect of inoculated S-feltiae on Delia radicum and its parasitoids." Agricultural and Forest Entomology 6(1): 25-30.

1 Seven organically grown cabbage fields were surveyed for entomopathogenic nematodes in the autumn by baiting. Nematodes were obtained from three fields with bait larvae infection ranging from 1.3-4.0%. 2 Inoculation of Steinernema feltiae (Rhabditida: Steinernematidae) in the spring increased bait larvae infection to 16.0-32.0%. 3 Four different species were found (Steinernema affine, Steinernema biconutum, S. feltiae and Steinernema C1). 4 The number of Delia radicum (L.) (Diptera: Anthomyiidae) puparia was significantly reduced at plants where S. feltiae had been inoculated. 5 Delia radicum parasitoids were also affected by S. feltiae. The results indicated that Aleochara species (Coleoptera: Staphylinidae) were more negatively affected than Trypliographa rapae (Westw.) (Hymenoptera: Cynipidae).

Nielsen, O. and H. Philipsen (2004). "Seasonal population dynamics of inoculated and indigenous steinernematid nematodes in an organic cropping system." Nematology 6: 901-909.

This study was based on naturally occurring and inoculated populations of steinernematid nematodes. The nematode populations were monitored in spring and autumn in 2 consecutive years in an organic cropping system and changes in population size were related to the presence of potential insect hosts. Nematode populations were estimated in terms of nematode incidence (percentage of positive soil samples) by using Tenebrio molitor larvae as bait. The population of naturally occurring nematodes (Steinernema affine and S.feltiae) was generally low (0-17% incidence for S. affine and 0-18% incidence for S.feltiae). Inoculated S.feltiae established well in half of the plots where inoculation had been performed and reached incidences of 87%. Establishment of inoculated nematodes, and population dynamics in general, was clearly influenced by the presence of insect hosts. In crops with high densities of potential hosts (Sitona lineatus in pea and partly Delia radicum in cabbage), nematode incidence increased from spring to autumn, whereas nematode incidence remained unchanged or decreased when few hosts were present (in barley, carrots, alfalfa and leek).

Prasad, R. P. and W. E. Snyder (2004). "Predator interference limits fly egg biological control by a guild of ground-active beetles." Biological Control 31(3): 428-437.

We examined whether predator interference could prevent effective conservation biological control of Delia spp. flies, important pests of cole crops, by an assemblage of carabid and staphylinid beetles. In laboratory feeding trials we found that the smaller (<1 cm) beetle species common at our site readily ate dipteran eggs, while the most common large carabid species, Pterostichus melanarius, rarely did. However, P. melanarius did eat several of the smaller beetle species. We conducted two field experiments where we manipulated immigration rates of the ground predator guild and then measured predation on fly eggs. Predation rates were consistently higher in cages where predators were added at ambient densities, compared to cages where ground predators were removed. However, in the second field experiment, when we quadrupled predator immigration rates neither beetle activity-density nor predation rate increased. High immigration rate plots had a higher proportion of P. melanarius in the predator community, compared to plots with beetles added at ambient densities, suggesting that P. melanarius was reducing activity-densities of the smaller beetles, perhaps through intraguild predation. Thus, tactics to improve the biological control of Delia spp. by conserving generalist predators, such as providing in- or extra-field refuges, could be thwarted if the primary predators of fly eggs, small carabids and staphylinids, are the targets of intraguild predation by also-conserved larger predators.

Soroka, J. J., L. M. Dosdall, O. O. Olfert and E. Seidle (2004). "Root maggots (Delia spp., Diptera : Anthomyiidae) in prairie canola (Brassica napus L. and B-rapa L.): Spatial and temporal surveys of root damage and prediction of damage levels." Canadian Journal of Plant Science 84(4): 1171-1182.

Soroka, J. J., Dosdall, L. M., Olfert, O. O. and Seidle, E. 2004. Root maggots (Delia spp., Diptera: Anthomyiidae) in prairie canola (Brassica napus L. and B. rapa L.): Spatial and temporal surveys of root damage and prediction of damage levels. Can. J. Plant Sci. 84: 1171-1182.

The levels of infestation and damage to canola taproots caused by crucifer-feeding root maggots (Delia spp.)(Diptera: Anthomyiidae) were determined through surveys of commercial crops across the canola growing regions of western Canada. Canola root damage caused by Delia spp. maggots was measured at the end of the season by determining the percentage of plants infested (PPI) per field and estimating average damage levels (DL, on a scale of O to 5) to taproots. Over the course of the survey, 2890 canola fields were sampled. Infestation by root maggots occurred wherever canola is grown in western Canada. In the study, 96% of the fields surveyed in Manitoba and Saskatchewan and 99.8% of the fields in Alberta showed evidence of root maggot feeding, with PPI much higher than in provincial surveys of a decade previously. Geographical ecoregion significantly affected both PPI and DL. The greatest amount of damage over the largest area was found in western and northwestern Alberta, although localized areas with severely damaged roots occurred along the northern edge of the entire Parkland ecoregion. Over the entire survey area, Brassica rapa L. roots had greater PPI and DL than B. napus L. roots, although species differences were not significant in Saskatchewan or Manitoba. Data from the survey were correlated with weather variables to develop a model predicting the levels of damage inflicted by root maggots to canola roots. Of the weather variables investigated, temperature, especially the average temperature in the preceding July and August, had the greatest influence on PPI and DL. The warmer the temperatures of the preceding July and August, the lower the PPI and DL in the current year. Likewise, previous year's July and August precipitation influenced PPI and DL negatively. Other weather parameters had little consistent influence on PPI and DI. The predictive model for PPI and DL, developed from the 1995-1998 survey data, incorporated canola species, ecoregion, previous July-August and September-October temperatures and precipitation. The validity of the model was assessed using a set of survey data collected in Alberta from 1981 to 1983. Regression equations of predicted results on actual results were significant. However, r(2) values for the regressions were low, in part because of the few ecoregions surveyed and the lack of canola species data recorded in the earlier survey, and because of the large increase in infestation levels since the earlier data were collected. The study is a first step in forecasting the effects of root maggots across a wide geographic area featuring many different canola production practices.

Biron, D. G., J. P. Nenon, D. Coderre and G. Boivin (2003). "Intra- and inter-specific variations on the chorionic ultrastructures of Delia eggs (Diptera : Anthomyiidae)." Annals of the Entomological Society of America 96(3): 245-249.

Three Nearctic and six Palearctic populations of Delia radicum L., two Palearctic populations of D. antiqua Meigen, and one Palearctic population of D. floralis Fallen were used to evaluate the range of intraspecific variation in the chorionic ultrastructures of the egg of D. radium, and to compare the chorionic ultrastructures of these eggs with those of the two other species. High variability in the mean size of the egg and hatching slit were found among populations of D. radicum. The D. radicum populations observed were not homogenous for quantitative variables but the qualitative variables showed less variability. Two patterns of antimicropylar poles were observed for D. radicum: the Random and Flower patterns. These two patterns were observed in all Nearctic populations and, among the Palearctic populations, only in the French and the English populations. The other Palearctic populations had only the Random or the Flower pattern. These results support the hypothesis that the North American populations originated from north-western Europe. Our results demonstrate that the three species, D. radicum, D. floralis (Fallen), and D. antiqua (Meigen), have specific chorion, micropyle, and antimicropyle patterns. The eggshell of D. radicum is more similar to that of D. floralis than that of D. antiqua.

Chen, S., J. Li, X. Han and M. Moens (2003). "Effect of temperature on the pathogenicity of entomopathogenic nematodes (Steinernema and Heterorhabditis spp.) to Delia radicum." Biocontrol 48(6): 713-724.

Susceptibility of last instar larvae of Delia radicum to Steinernema feltiae, S. carpocapsae, S. arenarium, Heterorhabditis megidis and H. bacteriophora was evaluated in the laboratory at 10degreesC, 15degreesC and 20degreesC. S. feltiae was the only species that killed the larvae at 10degreesC; S. carpocapsae, S. arenarium and H. megidis were effective at 15 - 20degreesC whereas H. bacteriophora killed the maggot only at 20degreesC. The temperature significantly affected the host searching ability of all tested species. Mobility was reduced at low temperatures. Significant effects of the host presence on nematode mobility were found for S. feltiae, S. arenarium and H. megidis but not for S. carpocapsae and H. bacteriophora. The dynamics of the attachment to and penetration into the host were monitored for S. feltiae at 10degreesC, 15degreesC or 20degreesC and for S. carpocapsae at 20degreesC. In the period of 6 - 30 hours after inoculation, S. carpocapsae attached in higher number at 20degreesC than did S. feltiae at all temperatures. At 20degreesC, S. carpocapsae penetrated the host only after 30 hours while S. feltiae penetrated already after 15, 9, 6 hours at 10degreesC, 15degreesC and 20degreesC, respectively.

Chen, S. L., X. Y. Han and M. Moens (2003). "Biological control of Delia radicum (Diptera : Anthomyiidae) with entomopathogenic nematodes." Applied Entomology and Zoology 38(4): 441-448.

Experiments evaluating the bio-control of the cabbage root maggot, Delia radicum, with entomopathogenic nematodes were conducted in the greenhouse and in the field. In the greenhouse better control was obtained with Steinernema feltiae than with S. arenarium, S. carpocapsae, Heterorhabditis megidis, and H. bacteriophora. Increasing doses of S. feltiae improved insect control; the best results were obtained with applications of 4,000 or 8,000 infective juveniles per plant. Applying S. feltiae eight days earlier or. eight days later than the inoculation of insect eggs or applying both at the same time did not give significant differences in D. radicum control. Field control of D. radicum with S. feltiae was not successful in early spring but improved in summer. The number of surviving insects and the cabbage damage were significantly reduced after applying S. feltiae in summer.

Collier, R. H., S. Finch and Bcpc (2003). The effect of increased crop diversity on colonisation by pest insects of brassica crops.

Many researchers have shown that the numbers of pest insects found on crop plants are reduced considerably when the crop is allowed to become weedy, when the crop is intercropped with another plant species, or when the crop is undersown with a living mulch. Laboratory and field-cage experiments were done to determine how undersowing brassica plants (Brassica oleracea spp., cabbage, cauliflower, Brussels sprout and Brassica chinensis) with subterannean clover (Trifolium subterraneum) affected host plant selection by eight pest insect species of brassica crops. Experiments were done also to determine the effect on egg-laying by the cabbage root fly (Delia radicum) on brassica plants surrounded with plant species other than clover. A total of 24 'companion' plant species were tested, including 1) bedding plants, to provide a different range of plant architectures and leaf colours; 2) weeds; 3) aromatic plants such as rosemary and thyme and 4) companion plant species such as marigold. After studying how pest insects behave in undersown brassica crops, we suggest it is simply the number of green objects surrounding the host plants that is the major factor that prevents the pest insects from finding their host-plants. Hence, increasing plant diversity within brassica crops should help considerably to reduce pest insect numbers.

Darvas, B. and A. Szappanos (2003). "Male and female morphology of some central european Delia (anthomyiidae) pests." Acta Zoologica Academiae Scientiarum Hungaricae 49(2): 87-101.

Based on male and female genitalia and chaetotaxy of legs, the authors give a key for the identification of some important Delia (Anthomyiidae) pests of vegetables. The article contains descriptions and drawings of male genitalia (D. antiqua, D. floralis, D. florilega, D. platura, D. radicum). The drawings and descriptions of female genitalia (D. antiqua, D. platura, D. radicum), are based on specimens from laboratory breeding.

Dosdall, L. M., G. W. Clayton, K. N. Harker, J. T. O'Donovan and F. C. Stevenson (2003). "Weed control and root maggots: making canola pest management strategies compatible." Weed Science 51(4): 576-585.

Early weed removal in canola gives the crop a competitive advantage over weeds and is therefore widely recommended for optimal crop production, but no studies have been undertaken previously to determine the effect of this practice on insect infestations. Four field experiments were conducted at Lacombe and Beaverlodge, AB, Canada, in 1999-2001 for a total of 10 site-years to determine the effect of time of weed removal on root maggot (Delia spp.) egg deposition and larval damage to taproots. The experiments also investigated the effects of other factors such as cultivar, seeding date, herbicide application rate, fertilizer rate and placement, and use of a nitrification inhibitor on root maggot damage and

oviposition. Damage to taproots and oviposition declined by approximately 6 and 23%, respectively, with a delay in weed removal from the two- to six-leaf stage of canola development. The effect of time of weed removal on root maggot damage and egg density sometimes varied with site and cultivar, but the main effect of time of weed removal was more prominent (smaller P values) than interactions wit site. The most plausible explanation for this effect relates to the behavioral sequence of events that precedes position in mated, gravid female flies. Heterogeneous environments, such as weedy backgrounds in canola plantings, minimize opportunities for females of Delia spp. to complete the behavioral sequence required for oviposition, leading to reduced infestation levels in weedy systems. However, yield improvements achieved with early weed removal exceeded the yield benefit derived by lowered root maggot pressure when weeds were removed later. Nevertheless, current efforts to reduce pesticide use in agriculture may promote broader adoption of cultural control strategies for weed and root maggot management. In some situations, it may then be appropriate to ameliorate root maggot damage by maintaining some weedy background.

Ester, A., H. de Putter and J. van Bilsen (2003). "Filmcoating the seed of cabbage (Brassica oleracea L. convar. Capitata L.) and cauliflower (Brassica oleracea L. var. Botrytis L.) with imidacloprid and spinosad to control insect pests." Crop Protection 22(5): 761-768.

Four field experiments were carried out between 1999 and 2001, to assess the protection against cabbage root fly larvae (Delia radicum), flea beetle (Phyllotreta nemorum and P. undulata), cabbage aphid (Brevicoryne brassicae) and caterpillars achieved in white cabbage and cauliflower crops by filmcoating the seed with insecticide. The plants were raised in trays of modules filled loosely with a peat-based potting compost. Batches of seed filmcoated with spinosad at five rates and imidacloprid at four rates, and also the combined products, were compared with a conventional post-planting treatment or with seed filmcoated with chlorpyrifos. Filmcoating with spinosad was ineffective at controlling flea beetle and cabbage aphid, whereas it gave a good control of cabbage root fly larvae and caterpillars at rates of 24 and 48 g a.i. per 100,000 seeds. Imidacloprid was ineffective at controlling cabbage root fly larvae and caterpillars whereas it gave a good control of flea beetle, and cabbage aphids at a rate of 70g a.i. per 100,000 seeds. Using high-quality seeds, there was no significant effect on the number of riable plants produced; however, imidacloprid reduced plant weight by 15% at the transplanting stage. The combined application of spinosad and imidacloprid as a filmcoating on seeds is an environmentally friendly alternative for protecting brassica crops against pests that occur frequently.

Finch, S., H. Billiald and R. H. Collier (2003). "Companion planting - do aromatic plants disrupt host-plant finding by the cabbage root fly and the onion fly more effectively than non-aromatic plants?" Entomologia Experimentalis Et Applicata 109(3): 183-195.

Brassica and Allium host-plants were each surrounded by four non-host plants to determine how background plants affected host-plant finding by the cabbage root fly (Delia radicum L.) and the onion fly [Delia antiqua (Meig.)] (Diptera: Anthomyiidae), respectively. The 24 non-host plants tested in field-cage experiments included garden 'bedding' plants, weeds, aromatic plants, companion plants, and one vegetable plant. Of the 20 non-host plants that disrupted host-plant finding by the cabbage root fly, fewest eggs (18% of check total) were laid on host plants surrounded by the weed Chenopodium album L., and most (64% of check total) on those surrounded by the weed Fumaria officinalis L. Of the 15 plants that disrupted host-plant finding in the preliminary tests involving the onion fly, the most disruptive (8% of check total) was a green-leaved variant of the bedding plant Pelargonium x hortorum L. H. Bail and the least disruptive (57% of check total) was the aromatic plant Mentha piperita x citrata (Ehrh.) Briq. Plant cultivars of Dahlia variabilis (Willd.) Desf. and Pelargonium x hortorum, selected for their reddish foliage, were less disruptive than comparable cultivars with green foliage. The only surrounding plants that did not disrupt oviposition by the cabbage root fly were the low-growing scrambling plant Sallopia convolvulus L., the grey-foliage plant Cineraria maritima L., and two plants, Lobularia maritima (L.) Desv. and Lobelia erinus L. which, from their profuse covering of small flowers, appeared to be white and blue, respectively. The leaf on which the fly landed had a considerable effect on subsequent behaviour. Flies that landed on a host plant searched the leaf surface in an excited manner, whereas those that landed on a non-host plant remained more or less motionless. Before taking off again, the flies stayed 2 - 5 times as long on the leaf of a non-host plant as on the leaf of a host plant. Host-plant finding was affected by the size (weight, leaf area, height) of the surrounding non-host plants. 'Companion plants' and aromatic plants were no more disruptive to either species of fly than the other plants tested. Disruption by all plants resulted from their green leaves, and not from their odours and/or tastes.

Jyoti, J. L., A. M. Shelton and J. Barnard (2003). "Evaluation of degree-day and Julian-day logistic models in predicting cabbage maggot (Diptera : Anthomyiidae) emergence and flight in upstate New York." Journal of Entomological Science 38(4): 525-532.

A 2 yr (1999-2000) study using water-pan traps in the field indicated four generations, including the spring generation, of cabbage maggot adults, Delia radicum (L.), in upstate New York. On average over the 2 yrs, an accumulation of 160.7 +/- 8.1 degree-days and 120 +/- 3 Julian-days was required for the first adult emergence of flies from overwintered puparia (spring generation). The emergence of 10% of the population required a mean accumulation of 176.6 +/- 3.8 degree days and 122.0 +/- 1.0 Julian days, 25% emergence required 204.2 +/- 2.3 degree days and 125.0 +/- 1.0 Julian days, 50% emergence required 251.3 +/- 3.5 degree-days and 129.3 +/- 1.5 Julian days, 75% emergence required 297.6 +/- 30.4 degree-days and 132.0 +/- 0.0 Julian days, and 95% emergence required 390.9 +/- 10.1 degree days and 141.0 +/- 3.0 Julian days. From the emergence of the first adult flies, the population required a mean accumulation of 449.2 +/- 1.4 degree days to complete the spring emergence. For complete emergence of flies, the F-1 generation required a mean accumulation of 508.4 +/- 32.9 degree days, the F-2 generation required 465.3 +/- 21.5 degree days and the F-3 generation required 399.1 +/- 3.1 degree days. With the help of a degree-days model, it is possible to predict fly emergence in the spring and succeeding generations. This model can help growers minimize insecticide use through better timing of treatments or adjustment of planting dates. In addition, this model will be useful in developing sampling plans and control strategies for immature stages of cabbage maggot.

Jyoti, J. L., A. M. Shelton and A. G. Taylor (2003). "Film-coating seeds with chlorpyrifos for germination and control of cabbage maggot (Diptera : Anthomyiidae) on cabbage transplants." Journal of Entomological Science 38(4): 553-565.

The cabbage maggot, Delia radicum (L.), is an important chronic pest of cabbage in the northern U.S. The maggots of this species cause damage to young plants by feeding on roots and stems, resulting in plant stand and yield losses or rendering the crop unmarketable. In New York, the nation's largest producer of cabbage, the most common control practice is to apply a drench or banded spray of chlorpyrifos at transplanting. As an alternative to this practice, we investigated the duration of insecticidal activity of chlorpyrifos film-coated seeds on cabbage transplants. Seeds of the cabbage var. 'Fresco F-1' were film-coated with chlorpyrifos at the rates of 0, 9.6, 19.2 or 28.8 g [Al]/kg seed and then examined for phytotoxic effects on germination in the laboratory as well as effectiveness against immature stages of D. radicum under greenhouse and field conditions. Chlorpyrifos film-coated seed treatments did not adversely affect germination in the laboratory tests when plants were grown with peat soil in transplant cell trays and provided significant plant protection against immature stages of cabbage maggot through several weeks after transplanting seedlings with associated soil under greenhouse and field conditions. These results agree with previous European studies showing the potential of seed treatments to reduce damage by D. radicum while at the same time dramatically reducing the amount of insecticide compared with a banded spray or drench application.

Nielsen, O. (2003). "Susceptibility of Delia radicum to steinernematid nematodes." Biocontrol 48(4): 431-446.

Isolates of different Steinernema species (S. affine, S. bicornutum, S. feltiae and Steinernema C1) were used in mortality assays with third instar larvae of Delia radicum (L.) (Diptera: Anthomyiidae). The nematode isolates had been obtained by baiting soil regularly grown with cabbage. One isolate (S. feltiae) was the result of a natural infection of a D. radicum puparium. The highest mortality (77%) was obtained with an isolate of S. feltiae (DK1). The isolate DK1 was also used in tests with all larval stages of D. radicum. Mortality around 60% was observed for second and third instar larvae, while first instar larvae showed very low or no susceptibility. Maximum mortality of second and third instar larvae was reached applying only 25 nematodes per larva. Observations of larvae that pupated revealed that some of these puparia contained nematodes. Experiments with hatching puparia showed that a high proportion was infected by nematodes if the flies were prevented from leaving nematode-containing soil. In addition to mortality, the ability of the nematodes to successfully reproduce in the insects was studied. It was found that the species S. feltiae and S. bicornutum reproduced in D. radicum larvae and adults with S. feltiae being the most successful.

Rousse, P., S. Fournet, C. Porteneuve and E. Brunel (2003). "Trap cropping to control Delia radicum populations in cruciferous crops: first results and future applications." Entomologia Experimentalis Et Applicata 109(2): 133-138.

This study evaluates the efficacy of a new approach to the control of Delia radicum populations. We suggest associating the primary crop with a trap crop that is expected to be more attractive to D. radicum females and to attract

and sustain their natural enemies such as Aleochara bilineata and A. bipustulata. Various cruciferous species were compared in terms of their preference for adult D. radicum females, and performance, as estimated by larval survival. Laboratory results were complemented by field experiments in which the selected trap crops were associated with broccoli plants. The following results were obtained. Of the six different cruciferous plant species tested, Delia radicum females showed a strong preference for Chinese cabbage, with turnip also being attractive. Following the laboratory results, turnip was chosen as a trap crop because it was easier to cultivate and presented good preference and performance. In the field experiments, Aleochara adults were present in higher numbers in plots associated with turnips than in pure broccoli plots. The presence of Aleochara adults in plots with turnips improved plant protection; as fewer broccoli plants were attacked, the attacked plants were less severely damaged, and more D. radicum pupae were parasitised than in pure broccoli plots. Delia radicum females did not lay fewer eggs on broccoli plants associated with turnips. Moreover, protection and parasitism were more effective in the rows closest to the central row of turnips, suggesting that Aleochara adults limit their activity to its immediate vicinity.

Biron, D. G., D. Coderre, G. Boivin, E. Brunel and J. P. Nenon (2002). "Genetic variability and expression of phenological and morphological differences in populations of Delia radicum (Diptera : Anthomyiidae)." Canadian Entomologist 134(3): 311-327.

In this study, survival to adult stage, duration of development of the immature stages, egg micromorphology, DNA polymorphism, and reproductive compatibility were measured for early- and late-emerging phenotypes of Delia radicum Linneaus to determine whether both phenotypes had evolved differences other than the duration of puparial development and to find the most likely genetic system controlling the expression of both phenotypes, Survival to adult stage was not significantly different between the early- and late-emerging phenotypes, Random amplified polymorphic DNA (RAPD) primers tested suggest that it is possible to distinguish an early-emerging fly from a late-emerging fly. Furthermore, the results suggest that the early- and late-emerging phenotypes differ not only in the timing of adult emergence but also in their egg structure (egg micromorphology) and in their larval and puparial mortality. These two phenotypes are not reproductively or ecologically isolated. The genetic system controlling the expression of early and late emergers in a population of D. radicum is probably an adaptive strategy reducing predator and parasitoid pressures, optimizing resource utilization, and ensuring survival of D. radicum during atypical winters. This strategy could eventually lead to temporal sympatric speciation if there are changes in a few key loci responsible for host plant selection and fitness on a new host.

de Jong, R. and E. Stadler (2002). "Did certain chemoreceptors for host plant stimuli in the cabbage root fly evolve as pheromone receptors?" Chemoecology 12(1): 61-64.

The cabbage root fly possesses highly specialised and extremely sensitive receptors for "CIF", a group of compounds present on cabbage leaves in very small amounts, and the strongest oviposition stimulants known. Here we present evidence that the same receptors are sensitive to a methanol extract of cabbage root fly eggs, which may contain the fly's host marking pheromone. Based on these results, the possible role of CIF in cabbage root fly behaviour and in cabbage plants is discussed.

Dixon, P. L., R. J. West, K. B. McRae and D. Spaner (2002). "Suitability of felt traps to monitor oviposition by cabbage maggot (Diptera : Anthomyiidae)." Canadian Entomologist 134(2): 205-214.

The effectiveness of felt egg traps to detect oviposition by the cabbage maggot, Delia radicum (L.), was studied under field conditions for cabbage, Brassica olcracea L. var. capitata L. (Brassicaceae), and rutabaga, Brassica napus L. var. napobrassica (L.) Reichenb. (Brassicaceae), in 1994 and 1995. The numbers of eggs laid on traps were compared with the numbers deposited in the soil next to the plant. Also, the incidence of oviposition (i.e., the percentage of samples with eggs) on soil and traps was compared. A total of 5160 eggs was collected from 5208 samples, but just 16% of all samples had eggs. For cabbage, early in the 1994 season, the incidence of oviposition in soil samples was double that on traps, and the number of eggs per sample was greater also. Oviposition incidence and the number of eggs per sample during the rest of the summer were similar. In the 1995 cabbage trial, the incidence of oviposition early in the season was again higher in soil samples than on traps, and there were fewer eggs per trap than per soil sample. For rutabaga, the number of eggs was similar using both methods early in the second generation, but from mid-August there were more eggs per trap than per soil sample. The incidence of oviposition in the rutabaga trial was similar on

traps and in soil through most of the experiment. In this study, felt traps did not adequately detect the timing of cabbage maggot oviposition in the critical early season.

Dosdall, L. M., R. C. Yang and P. M. Conway (2002). "Do applications of sulfur or sulfate influence infestations of root maggots (Delia spp.) (Diptera : Anthomyiidae) in canola?" Canadian Journal of Plant Science 82(3): 599-610.

While the importance of sulfur nutrition for the development of healthy stands of canola is well documented, the role of sulfur in the management of insect pest infestations has not previously been investigated in this crop. Field experiments were conducted at three sites in central Alberta in 1997 and 1998 to determine the influence of sulfur and sulfate applications on infestations of root maggots (Delia spp.) (Diptera: Anthomyiidae) in canola (Brassica rapa L.). Different formulations (granules, powder, prills, and sprays), application methods (either drilled in with the seed or top-dressed on the soil surface), and application rates were evaluated. To assess the degree of root maggot infestation, oviposition throughout the season and damage to taproots at the end of the season were monitored. Sulfur contents were analyzed from leaf samples collected mid-season and seed yields were measured from all treatment plots. Root maggot responses to the different sulfur treatments and application methods varied among years and sites, indicating that environmental factors have great importance in determining infestation levels by these pests, and the oxidation rate of elemental sulfur in soil. Sulfur formulation and application rate had significant effects on root maggot egg deposition and root damage for some sites and years, but even at high rates of application (112 kg ha(-1)) reductions in infestation levels were not substantial relative to the controls. While sulfur additions alone will not greatly reduce root maggot infestation levels in canola, growers should employ adequate sulfur nutrition for optimum crop health to enable plants to better compensate for damage by these pests.

Hegedus, D., M. O'Grady, M. Charnankhah, D. Baldwin, S. Gleddie, L. Braun and M. Erlandson (2002). "Changes in cysteine protease activity and localization during midgut metamorphosis in the crucifer root maggot (Delia radicum)." Insect Biochemistry and Molecular Biology 32(11): 1585-1596.

We show that differential localization and/or activation of two cysteine protease activities occur at the onset of dipteran midgut metamorphosis. A 26 kDa cysteine protease activity was associated specifically with midgut tissues of late third instar larvae. Starvation of mid third instar larvae simulated the onset of prepupation and resulted in loss of the 26 kDa protease activity. A cDNA clone encoding a cysteine protease, termed DrCP1, was isolated and shown to be highly similar to those from Sarcophaga peregrina and Drosophila melanogaster (DmCP1). DrCP1 mRNA was present in all developmental stages including eggs, larvae, pupae and adults, but was highly induced at the onset of the larval-pupal transition and thereafter. The DrCP1 protein is localized to the exterior of the midgut tissues during the onset of the prepupal transition period, possibly in response to ecdysone. Analysis of transcription factor binding sites associated with the DmCP1 promoter indicated that elements exist that allow for both ecdysone-mediated as well as tissue-specific regulation. Based upon these and other studies we propose: (1) that the expression, activity and localization of the DrCP1-like cysteine proteases are highly regulated throughout development; and, (2) that cysteine protease activities are involved in aspects of tissue reconstruction at the onset of and during metamorphosis.

Jensen, E. B., G. Felkl, K. Kristiansen and S. B. Andersen (2002). "Resistance to the cabbage root fly, Delia radicum, within Brassica fruticulosa." Euphytica 124(3): 379-386.

Fourteen accessions of the wild species Brassica fruticulosa were evaluated for resistance toward the cabbage root fly Delia radicum in comparison with a widely cultivated cauliflower cultivar and a rapid cycling Brassica oleracea line. The more resistant accession of B. fruticulosa had 60.6 percent plants escaping the attack, while only 2.6 percent of the cauliflower material survived. Larvae feeding on roots after inoculation with twenty D. radicum eggs per plant under glasshouse conditions effectively discriminated between both the two species and accessions within B. fruticulosa. Genetic determination of escape rate was high with 55.4 percent of total variation explained by genotypes, while average number of days without collapse and average number of days without symptoms showed genetic determination of 22.0 percent of total variation. All 11 diploid accessions of B. fruticulosa showed higher escape rates (14.7-60.6%) than the two B. oleracea cabbage lines (2.6 and 5.0%). The three tetraploid B. fruticulosa accessions formed an intermediate group with the B. fruticulosa ssp. glaberrima accession, having a higher escape rate (22.8%) than the accessions of B. fruticulosa ssp. mauritanica, and B. fruticulosa ssp. radicata (2.1 and 5.7%, respectively).

Accessions among the diploid B. fruticulosa group on average survived 15.1 to 18.4 days without collapse in the test, while the tetraploid accessions had on average 11.7 to 14.2 days without collapse and the two B. oleracea accessions survived on average only 11.5 and 11.7 days without collapse. Results are discussed with respect to the possible transfer of such resistance from the wild species into breeding material of cultivated types of Brassica vegetables.

Neveu, N., J. Grandgirard, J. P. Nenon and A. M. Cortesero (2002). "Systemic release of herbivore-induced plant volatiles by turnips infested by concealed root-feeding larvae Delia radicum L." Journal of Chemical Ecology 28(9): 1717-1732.

When attacked by herbivorous insects, many plants emit volatile compounds that are used as cues by predators and parasitoids foraging for prey or hosts. While such interactions have been demonstrated in several host-plant complexes, in most studies, the herbivores involved are leaf-feeding arthropods. We studied the long-range plant volatiles involved in host location in a system based on a very different interaction since the herbivore is a fly whose larvae feed on the roots of cole plants in the cabbage root fly, Delia radicum L. (Diptera: Anthomyiidae). The parasitoid studied is Trybliographa rapae Westwood (Hymenoptera: Figitidae), a specialist larval endoparasitoid of D. radicum. Using a four-arm olfactometer, the attraction of naive T. rapae females toward uninfested and infested turnip plants was investigated. T. rapae females were not attracted to volatiles emanating from uninfested plants, whether presented as whole plants, roots, or leaves. In contrast, they were highly attracted to volatiles emitted by roots infested with D. radicum larvae, by undamaged parts of infested roots, and by undamaged leaves of infested plants. The production of parasitoid-attracting volatiles appeared to be systemic in this particular tritrophic system. The possible factors triggering this volatile emission were also investigated. Volatiles from leaves of water-stressed plants and artificially damaged plants were not attractive to T. rapae females, while volatiles emitted by leaves of artificially damaged plants treated with crushed D. radicum larvae were highly attractive. However, T. rapae females were not attracted to volatiles emitted by artificially damaged plants treated only with crushed salivary glands from D. radicum larvae. These results demonstrate the systemic production of herbivore-induced volatiles in this host-plant complex. Although the emission of parasitoid attracting volatiles is induced by factors present in the herbivorous host, their exact origin remains unclear. The probable nature of the volatiles involved and the possible origin of the elicitor of volatiles release are discussed.

Stadler, E., R. Baur and R. de Jong (2002). "Sensory basis of host-plant selection: In search of the "fingerprints" related to oviposition of the cabbage root fly." Acta Zoologica Academiae Scientiarum Hungaricae 48: 265-280.

The oviposition preference of the cabbage root fly, Delia radicum (Diptera, Anthomyiidae), was studied using leaf surface extracts of 24 different plant species that covered the whole span of preference rankings. The oviposition data were related to the content of the extract fractions containing either the glucosinolates or CIF ("cabbage identification factor", 1,2-dihydro-3-thia-4,10,10b-triaza-cyclopenta[:a.]fluorene-l-carboxylic acid). We observed a significant correlation between oviposition preference and the leaf surface content of benzyl and indolyl glucosinolates, substances that belong to the most active stimulants in oviposition assays, and in electrophysiological recordings from the tarsal D(4,3)-sensilla. However, there was not a significant correlation between the extract fraction containing CIF and the recorded neural activity in the tarsal C(5)-sensillum containing the CIF sensitive neuron. When this lack of correlation was investigated it was revealed that the leaf surfaces of two unacceptable host plants, Capsella bursa-pastoris and Tropaeolum majus, contain inhibitory compounds. Our data strongly support the hypothesis put forward by T. JERMY that "fingerprints" (specific mixtures of stimulatory and inhibitory plant compounds) mediate host-plant selection.

Thomsen, L. and A. B. Jensen (2002). "Application of nested-PCR technique to resting spores from the Entomophthora muscae species complex: implications for analyses of hostpathogen population interactions." Mycologia 94(5): 794-802.

We developed new Entomophthora-specific primers for nested-PCR of the ITS II region to be used on in vivo material and combined it with RFLP. Resting spores from Scathophaga stercoraria (3 specimens), Delia radicum (9 specimens), Botanophila fugax (I specimen), and two syrphid host species, Platycheirus peltatus and Melanostoma mellinum (one specimen of each) were characterized genetically after analysis of RFLP-profiles of the PCR-products. The genetic characterization of the resting spore isolates was compared with twenty isolates of known primary conidial morphology (in vitro and in vivo) from the E. muscae species complex. The analysis allowed for the first time a separation of resting spore isolates into the species level, which is not possible only using morphological characters (diameter). Isolates

originating from different specimens of the same host taxa appeared to be strongly clonal even they were sampled at different localities in different years. Isolates morphologically belonging to E. muscae s. str. (e.g., including E. scatophagae) could be separated genetically further into sub-groups entirely depending on the host taxa; each fungal genotype, either present at the conidial stage or at the resting spore stage, is correlated with one host species. Furthermore, E. muscae s. str. originating from D. radicum proved to be much more closely related to E. scatophagae than to E. muscae s. str. originating from M. domestica. None of the resting spore isolates could be assigned to E. schizophorae. The nested-PCR approach accompanied by RFLP proved its usefulness for identification of resting spores and for more detailed studies clarifying host-pathogen specificity and interactions. It seems that different members of the E. muscae species complex are able to complete their life cycle in only one host species and, further, that each pathogen-host system is independent.

Willmott, D. M., A. J. Hart, S. J. Long, P. N. Richardson and D. Chandler (2002). "Susceptibility of cabbage root fly Delia radicum, in potted cauliflower (Brassica oleracea var. botrytis) to isolates of entomopathogenic nematodes (Steinernema and Heterorhabditis spp.) indigenous to the UK." Nematology 4: 965-970.

The susceptibility of larvae of the cabbage root fly (Delia radicum) to ten isolates of entomopathogenic nematodes was examined in a glasshouse experiment using cauliflower (Brassica oleracea var. botrytis) as the host plant. Steinernema affine Horticulture Research International (HRI) code 179 provided the highest level of control, killing approximately 46% of the cabbage root fly within 28 days. Two Heterorhabditis isolates (HRI code K122 and UK211) and Steinernema E1 and F1 (HRI code 194 and GWE63) did not give any significant control. In a second experiment, S. affine was applied against cabbage root fly larvae at 8000 to 64 000 nematodes per pot, and its performance was compared to identical dose applications of Nemasys(R), a commercial formulation of S. feltiae. Averaged over the four dose rates, S. affine controlled significantly more cabbage root fly (36%) than Nemasys(R) (10.4%).

Alix, A., A. M. Cortesero, J. P. Nenon and J. P. Anger (2001). "Selectivity assessment of chlorfenvinphos reevaluated by including physiological and behavioral effects on an important beneficial insect." Environmental Toxicology and Chemistry 20(11): 2530-2536.

Selectivity is an important factor in identifying candidate pesticides to be used in crop protection since it characterizes chemicals that, while being effective against target pests, exert an acceptable impact on the other components of the environment. Extrapolated to an integrated pest management (IPM) context, selectivity implies that candidate pesticides may preserve the ability of beneficial insects to significantly control target pest populations. In the present study, we assess the physiological selectivity of the organophosphate chlorfenvinphos, used to protect cruciferous crops against the cabbage root fly, Delia radicum (Diptera: Anthomyiidae), by investigating both the lethal and sublethal effects exerted on its main parasitoid Trybliographa rapae (Hymenoptera: Figitidae). The comparison of the median lethal doses showed that T. rapae was at least seven times less sensitive than D. radicum to chlorfenvinphos. However. longevity of parasitoids surviving a sublethal dose was reduced by half. The potential fecundity of females was decreased by 9.6 to 22.8%. Chlorfenvinphos also induced important behavioral changes in both sexes and reduced the chances for parasitoids to mate by more than 70%. While most behavioral changes were reversible, effects on mating and on fecundity were not. thereby suggesting long-term effects on the reproduction of the parasitoid. These cumulative effects of chlorfenvinphos would have dramatic consequences on the efficacy of parasitoids contacting such doses of chlorfenvinphos in the field and therefore there is question about the intrinsic selectivity of this insecticide.

Bligaard, J. (2001). "Binomial sampling as a cost efficient sampling method for pest management of cabbage root fly (Dipt., Anthomyiidae) in cauliflower." Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie 125(3): 155-159.

A binomial (presence-absence) sampling plan has been developed based on the relationship between the proportion of cauliflower plants having visible cabbage root By eggs (Delia radieum L.) exposed on the soil surface around the plant stein and the mean density of eggs per plant. The Kono-Sugino's model was fitted to a total of 125 population estimates, each based on 10 plant samples collected from cauliflower fields in 1994 and 1995 (P = 0.001: R-2 = 0.64). When the model was compared with an independent data set consisting of 39 population estimates collected in 1995, an analysis of covariance showed no significant differences between the regression lines. The efficiency of the binomial method was compared with absolute sampling in terms of relative precision and cost efficiency. The binomial method had a high coefficient of variation, RV approximate to 0.85, due to large biological error. In spite of this, binomial

sampling was more cost efficient than the applied soil sampling when between 10 and 30 plants were examined for the presence of visible eggs.

de Jong, R. and E. Stadler (2001). "Complex host marking in the cabbage root fly." Chemoecology 11(2): 85-88.
The cabbage root fly marks an oviposition site with two different chemical messages, Plants that were exposed to ovipositing flies are less acceptable than control plants, while sand particles that were closely associated with an actual oviposition site stimulate oviposition. By combining the information from these opposing messages, the cabbage root fly may be able to optimise the size of its egg clusters in relation to the food available for the larvae. The findings might account for the aggregated oviposition observed ill this species.

de Jong, R. and E. Stadler (2001). "Sensilla on cabbage root fly tarsae sensitive to egg-associated compounds." Chemoecology 11(3): 145-147.
We identified a tarsal sensillum that has a receptor neurone sensitive to a methanol extract of cabbage root fly eggs. This extract is known to act as an oviposition deterrent. The electrophysiologically active substance in the extract is probably not of host plant origin but a pheromone produced by adult flies.

Fournet, S., D. Poinsot, E. Brunel, J. P. Nenon and A. M. Cortesero (2001). "Do female coleopteran parasitoids enhance their reproductive success by selecting high-quality oviposition sites?" Journal of Animal Ecology 70(6): 1046-1052.
1. Female parasitoids that lay their eggs away from potential host insects are supposed to have only a minor influence on the fitness of their own progeny, as they do not select and evaluate directly the quality of hosts for their offspring. Aleochara bilineata Gyll. (Coleoptera: Staphylinidae) females oviposit near to cabbage plants infested by larvae of Delia radicum L. (Diptera: Anthomyiidae). Once the mobile A. bilineata larva emerges from the egg, it must then search the soil to find and select a suitable fly pupa. The beetle larvae have a limited time to found pupae and can only parasitize one host pupa during their lifetime. Moreover, because A. bilineata is a solitary parasitoid whether or not the host pupa is parasitized, has a strong influence on the successful development of the beetle larva. 2. We studied the oviposition behaviour of A. bilineata females in laboratory experiments in which females could choose between a range of several oviposition sites. 3. Our results reveal that A. bilineata females, like hymenopteran parasitoid females, show an adaptive oviposition behaviour in response to the quality of the oviposition site. The female beetles adapt their oviposition decisions and their clutch size based on information associated with the presence of a host. Furthermore, our results reveal that the Aleochara females can discriminate between specific cues related to the stage and parasitization status of the host. Such behaviours may greatly enhance the parasitization success of the larvae, and thereby female fitness.

Griffiths, D. W., N. Deighton, A. N. E. Birch, B. Patrian, R. Baur and E. Stadler (2001). "Identification of glucosinolates on the leaf surface of plants from the Cruciferae and other closely related species." Phytochemistry 57(5): 693-700.
Leaf-surface extracts prepared from 18 non-cultivated (wild) plant species, derived from the Capparidaceae, Cruciferae, Resedaceae and Tropaeolaceae were ranked for their ability to stimulate oviposition by the cabbage root fly, and analysed for glucosinolates. A total of 28 different glucosinolates were identified. A clear relationship was detected between the indolyl-, benzyl- and the total glucosinolate composition on the leaf surface and oviposition preference by cabbage root fly females. However, as the results are not fully explained by differences in leaf surface glucosinolates, other important oviposition deterrents and stimuli on the leaf surface of these wild crucifers must also be present. (C) 2001 Elsevier Science Ltd. All rights reserved.

Hoffmann, M. P., T. P. Kuhar, J. M. Baird, J. Gardner, P. Schwartz and A. M. Shelton (2001). "Nonwoven fiber barriers for control of cabbage maggot and onion maggot (Diptera : Anthomyiidae)." Journal of Economic Entomology 94(6): 1485-1491.
We investigated the use of nonwoven fiber barriers for control of cabbage maggot, Delia radicum (L.), and onion maggot, D. antiqua (Meigen). The barriers consist of arrangements of minute fibers loosely intertwined in "web" form. Results from a greenhouse experiment showed that manually applied graphite fibers placed at the base of broccoli plants reduced the number of D. radicum eggs by 64-98%, and that efficacy increased with greater fiber density. Using a melt extrusion process, we devised a method for on-site creation of nonwoven fibers of ethylene vinyl acetate (EVA). In field trials with broccoli and onion plants, EVA fibers significantly reduced the number of cabbage and onion maggots infesting plants. Fiber barriers provided comparable control to standard insecticide applications. The addition

of blue, yellow, red, or black pigments, as well as optical brighteners that absorb UV light did not enhance fiber efficacy. Incorporation of capsaicin olfactory repellent to EVA also did not enhance fiber efficacy. Nonwoven fiber barriers may offer an alternative to insecticides for control of cabbage maggot and onion maggot mid possibly other insect pests. Additional research is needed to improve the application process and to identify economically feasible and biodegradable compounds for fibers.

Jensen, A. B., L. Thomsen and J. Eilenberg (2001). "Intraspecific variation and host specificity of Entomophthora muscae sensu stricto isolates revealed by random amplified polymorphic DNA, universal primed PCR, PCR-restriction fragment length polymorphism, and conidial morphology." Journal of Invertebrate Pathology 78(4): 251-259.

The intraspecific variations of Entomophthora muscae s. str. associated with particular host species, Musca domestica and Delia radicum, sampled from different localities and different years in Denmark and the variation of E. muscae s. str. originating from different host taxa were investigated. The isolates were compared both by primary spore morphology and by three molecular methods: random amplified polymorphic DNA, universal primed PCR, and PCR-restriction fragment length polymorphism. Analyses of the different molecular data showed the same overall picture and separated E. muscae s. str. into two main groups with all the M. domestica isolates in one group and isolates from D. radicum, Coenosia tigrina, and Pegoplata infirma in the second group. E. muscae s. str. isolates from M. domestica also differ significantly from the rest of the E. muscae s. str. isolates with regard to the morphology of the primary conidia, which were bigger and contained significantly more nuclei per conidium. Several different E. muscae s. str. genotypes were documented and each type was restricted to a single host species, indicating a very high degree of host specificity at or below the level of the subfamily. (C) 2001 Elsevier Science (USA).

Jyoti, J. L., A. M. Shelton and E. D. Earle (2001). "Identifying sources and mechanisms of resistance in crucifers for control of cabbage maggot (Diptera : Anthomyiidae)." Journal of Economic Entomology 94(4): 942-949.

The cabbage maggot, Delia radicum (L.) is an important insect pest of cruciferous crops in upstate New York. This species causes considerable damage to seedlings and young plants by feeding on roots and stems, resulting in plant stand loss and yield loss. Five crucifer accessions (Brassica oleracea variety italica L., 'Green Comet'; B. oleracca L.,'Rapid Cycling' [Crucifer Genetics Cooperative 3-1]; B. olercea variety botrytis L., a standard cauliflower cultivar 'Amazing'; B, carinata L.; and Sinapis alba L., 'Cornell Alt 543') were evaluated to identify sources and mechanisms of resistance for D. radicum. Of the accessions tested, S. alba Cornell Alt 543 demonstrated reduced oviposition by D. radicum, reduced weights and survivorship of larvae, pupae or adults,and reduced damage to plants. Thus, S. alba Cornell Alt 543 could be a potential source for resistance to be bred into cruciferous crops for control of D. radicum.

Belyakova, N. A. and A. I. Anisimov (2000). "Frequency of chromosome rearrangements induced by various doses of X-irradiation in gametes of the cabbage root fly (Delia brassicae Bouche)." Russian Journal of Genetics 36(2): 116-119.

Chromosome rearrangements were isolated via crossing of F-1 offspring from X-irradiated male and female Delia brassicae with intact insects. An enhanced (more than 30%) rate of late embryonic lethality (LEL) in clutches was the primary criterion of rearrangements. When males alone were irradiated at 2.5, 5, and 15 Gy, a total of 7.8, 9.6, and 23.6% of their offspring, respectively, inherited semisterility. After irradiation of females alone, the LEL rate in F-1 was insignificant. Hybridization analysis of F-2 revealed 18 lines with autosomal inheritance of semisterility. Fourteen lines (43.7%) exhibited an increased rate of LEL linked to the male sex.

Biron, D. G., B. S. Landry, J. P. Nenon, D. Coderre and G. Boivin (2000). "Geographical origin of an introduced pest species, Delia radicum (Diptera : Anthomyiidae), determined by RAPD analysis and egg micromorphology." Bulletin of Entomological Research 90(1): 23-32.

The origin of introduction of the cabbage root fly, Delia radicum Linnaeus to the north-eastern coast of North America in the 19th century has been assumed to be from Europe. From that point of introduction, D. radicum gradually spread westward to occupy available ecological niches. DNA fingerprinting and egg micromorphology were used to determine the most likely geographical origin of the North American populations of this species. Forty-five informative RAPD loci obtained from ten primers and three criteria for egg micromorphology were studied. These characters indicated a common origin for the North American populations and a high similarity between populations from North America and north-western Europe. The results suggest a single entrance point of D. radicum into North America, probably via the

north-eastern coast (New York area) from north-western Europe. The implications of this study in assisting selection of natural enemies of this important agricultural pest are discussed.

Bomford, M. K., R. S. Vernon and P. Pats (2000). "Importance of collection overhangs on the efficacy of exclusion fences for managing cabbage flies (Diptera : Anthomyiidae)." Environmental Entomology 29(4): 795-799.

Fine nylon mesh fences (135 cm high) with varying lengths of downward-sloping collection overhangs were evaluated for efficacy in excluding the female cabbage flies Delia radicum (L.) from plots of radish, Raphanus sativus (L.). During three trials conducted in 1994 and 1995, fences without overhangs, fences with 12.5-cm overhangs, or fences with 50-cm overhangs were tested against fences with standard 25-cm overhangs and unfenced control plots. In fenced plots with standard 25-cm overhangs, the mean number of D radicum females caught on yellow sticky traps placed within plots was 85% less than those caught in corresponding control plots. The mean numbers of D. radicum females caught in fenced enclosures with no overhangs, 12.5-cm overhangs, or 50-cm overhangs; were 61, 67, and 94% less than those caught in corresponding control plots, respectively. The mean proportion of radishes damaged by D. radicum larvae inside enclosures with 25-cm overhangs was 62% less than in corresponding control plots. The mean proportions of radishes damaged inside fences with no overhangs, 12.5-cm overhangs, or 50-cm overhangs were 33, 59, and 81% less than those caught in corresponding control plots, respectively. Results are discussed in terms of defining an appropriate fence design for commercial use.

de Jong, R., N. Maher, B. Patrian, E. Stadler and T. Winkler (2000). "Rutabaga roots, a rich source of oviposition stimulants for the cabbage root fly." Chemoecology 10(4): 205-209.

Two recently identified compounds ("CIFs"), present on the leaf surface of Brassica oleracea (cabbage), are the strongest oviposition stimulants known for the cabbage root fly, Delia radicum. Cabbage leaves contain these compounds in extremely low concentrations, and the amount of CIFs obtained from purifying leaf extracts was so small that it limited further research. We were able to purify far more of these two compounds from the roots of Brassica napus var. napobrassica (rutabaga). Apart from being a richer source of CIFs, rutabaga roots are considerably easier to collect and process than leaves. In addition, we isolated and identified a new CIF compound from the roots that is also very active in stimulating oviposition in the cabbage root fly.

Dosdall, L. M., A. Good, B. A. Keddie, U. Ekuere and G. Stringam (2000). "Identification and evaluation of root maggot (Delia spp.) (Diptera : Anthomyiidae) resistance within Brassicaceae." Crop Protection 19(4): 247-253.

Current varieties of canola/oilseed rape, Brassica napus L. and Brassica rapa L., are susceptible to infestation by the root maggots Delia radicum (L.) and Delia floralis (Fallen) (Diptera: Anthomyiidae) in western Canada. Crop losses from root maggot infestations can be very significant, and infestation levels have increased substantially from 1983 to present. Although cultural and chemical strategies exist to reduce crop losses caused by root maggots, these methods are either not sufficiently effective or pose unacceptable environmental risk. This paper reports progress achieved to develop canola cultivars resistant to attack by root maggots as the most environmentally sustainable strategy for management of these pests. Twelve species of Brassicaceae, and many genotypes within species, were evaluated for levels of root maggot resistance, in addition to many intergeneric hybrids produced by crosses of Sinapis alba x B. napus. Sinapis alba had greatest resistance to infestation by root maggots among the Brassicaceae species evaluated, and five intergeneric hybrids had levels of resistance to root maggots that were similar to S. alba and were maintained from year to year. Low amounts of S. alba DNA were detected in the hybrids using genomic slot-blot analysis. These results indicate that a genetic basis for resistance to root maggot infestation exists in the Brassicaceae, and our research represents the first step toward introgression of genetic sources of root maggot resistance from related species into commercial canola varieties.

Eilenberg, J., P. H. Damgaard, B. M. Hansen, J. C. Pedersen, J. Bresciani and R. Larsson (2000). "Natural coprevalence of Strongwellsea castrans, Cystosporogenes deliaradicae, and Bacillus thuringiensis in the host, Delia radicum." Journal of Invertebrate Pathology 75(1): 69-75.

Adult cabbage root flies (Delia radicum) from three Danish localities were diagnosed microscopically for the natural prevalence of Strongwellsea castrans, Cystosporogenes deliaradicae, and Bacillus thuringiensis. C. deliaradicae was significantly coprevalent with S. castrans. B. thuringiensis sporangia were diagnosed in the hemolymph in two D.

radicum which were also infected with S. castrans and proved to belong to serovar aizawai and serovar balearica. The biological characterization of S. castrans proved that at 17.5 degrees C dies developed an abdominal hole 7.9 days (mean) after infection and that 5.7 days (mean) passed from the emergence of the hole to the death of the infected host. No mortality effect among D. radicum subjected to B. thuringiensis serovar aizawai, balearica, and kurstaki isolates was detected. RAPD with DNA proved that six B. thuringiensis serovar balearica isolates (all from the same fly) were indistinguisable. This indicates that proliferation of B. thuringiensis in the abdomen of an S. castrans-infected D. radicum may be due to just one genotype. The profiles of one isolated aizawai strain did not correspond to the profiles of other serovar aizawai strains used for comparison. The biological significance of the interaction between the involved pathogens is discussed. (C) 2000 Academic Press.

Fournet, S., J. O. Stapel, N. Kacem, J. P. Nenon and E. Brunel (2000). "Life history comparison between two competitive Aleochara species in the cabbage root fly, Delia radicum: implications for their use in biological control." Entomologia Experimentalis Et Applicata 96(3): 205-211.

This study evaluates the efficacy of Aleochara bilineata Gyll and Aleochara bipustulata L. (Coleoptera: Staphylinidae) as biological control agents against the cabbage root fly, Delia radicum L. (Diptera: Anthomyiidae). Biological and demographic characters are documented and comparisons made between the two species. The following results were obtained: (1) The reproductive potential and longevity of A. bipustulata females are significantly higher than those of A. bilineata. These differences are correlated with the biology and ecology of the hosts of both species. (2) Under laboratory conditions the rate of increase (r(m)) of both staphylinids species is significantly higher than that of the pest and their major competitor Trybliographa rapae West. (Hymenoptera:Figitidae). This may indicate that A. bilineata and A. bipustulata can be effective biological control agents. (3) Aleochara bilineata appears to be the most interesting biological control agent against D. radicum, because of its higher rate of increase, higher host specificity and host acceptance, and a development time which is well synchronised with that of its host. With its higher competitive ability, a population of A. bilineata may increase even if competition occurs. However, A. bipustulata presents interesting biocontrol characteristics, but the best strategy may be only to use the potential of its natural populations.

Ishikawa, Y., T. Yamashita and M. Nomura (2000). "Characteristics of summer diapause in the onion maggot, Delia antiqua (Diptera : Anthomyiidae)." Journal of Insect Physiology 46(2): 161-167.

Characteristics of summer diapause in the onion maggot, Delia antiqua, were clarified by laboratory experiments. Temperature was the primary factor for the induction of summer diapause in this species. The critical temperature for diapause induction was approximately 24 degrees C, regardless of the photoperiod. At 23 degrees C, the development of the diapausing pupae was arrested the day after pupariation, when about 7% of the total pupal development had occurred in terms of total effective temperature (degree-days). The most sensitive period for temperature with regard to diapause induction was estimated to be between pupariation and "pupation" (i.e., evagination of the head in cyclorrhaphous flies). Completion of diapause occurred at a wide range of temperatures (4-25 degrees C): The optimal temperature was approximately 16 degrees C, at which temperature only five days were required for diapause completion. The characteristics of summer diapause in D. antiqua are discussed in comparison with those of summer dormancy in a congener D. radicum and those of winter diapause in D. antiqua. (C) 2000 Elsevier Science Ltd. All rights reserved.

Jukes, A. A., R. H. Collier, S. Finch, G. Universiteit and G. Universiteit (2000). Evaluation of non-organophosphorus insecticides for controlling the cabbage root fly. The insecticide conundrum. 52nd International Symposium on Crop Protection, Pts I and Ii, Proceedings. 65: 167-173.

The need to find non-organophosphorus insecticides to control the cabbage root fly has never been so urgent. Of the six non-OF insecticides tested, fipronil was the most effective but cyromazine also showed promise. The other effective compound, carbofuran, is being withdrawn from use in the UK. Imidacloprid extended the period of development of the fly larvae and so should not be used, as it increased crop damage. Similarly, all three pyrethroid compounds tested, the soil-active tefluthrin and the two foliar-active compounds lambda-cyhalothrin and deltamethrin, did not kill larvae/adults of the cabbage root fly but appeared to kill beneficial organisms, as crop damage following such treatments was higher than on the untreated plants. One conundrum is that even if effective non-OF insecticides can be

found, the chemical manufacturers may not support such insecticides being applied to minor crops such as vegetable brassicas.

Klingen, I., R. Meadow and J. Eilenberg (2000). "Prevalence of fungal infections in adult Delia radicum and Delia floralis captured on the edge of a cabbage field." Entomologia Experimentalis Et Applicata 97(3): 265-274.

Brassiceye(R) traps baited with ethylisothiocyanate were modified and used to collect live adults of Delia radicum (L.) and Delia floralis (Fallen) (Diptera: Anthomyiidae) from the field to observe the prevalence of Entomophthora muscae (Cohn) Fresenius and Strongwellsea castrans Batko & Weiser. The traps were highly effective and selective for D. radicum and D. floralis. Of the flies identified, 98.4% in 1996 and 93.7% in 1997 were either D. radicum or D. floralis. In 1997 the maximum mean catch was as high as 82 flies per trap per day, and more than 80% of these were females. During both seasons E. muscae caused relatively high levels of mortality in adult populations of D. radicum and D. floralis. The fungus caused a total infection level of 17.9% in 1996 and 47.7% in 1997 with infection peaks of 82.4% in 1996 and 87.5% in 1997. Both years, a significant positive correlation was found between E. muscae prevalence and temperature. One infection peak was observed for S. castrans in 1996, and during that season the total S. castrans infection level was 18.0%. In 1997, the total S. castrans infection level was as low as 8.1%. There is no strong indication that the prevalence of E. muscae or S. castrans differs between either the fly species or sexes within species.

Kostal, V., R. Baur and E. Stadler (2000). "Exploration and assessment of the oviposition substrate by the cabbage root fly, Delia radicum (Diptera : Anthomyiidae)." European Journal of Entomology 97(1): 33-40.

Oviposition behaviour of Delia radicum is not only influenced by host plant duality but also by the duality of the substrate in which the plant grows. Direct behavioural observations showed that the females partition their visits to a host plant (cauliflower) into ovipositional bouts separated by exploration of the host plant surface. Ovipositional bouts were further partitioned into acts of egg deposition separated by exploration of the substrate. While the mean number of ovipositional bouts per visit (2.6), and eggs laid per egg deposition event (1.4) were stable, the mean number of egg deposition events per ovipositional bout significantly varied (from 2.1 to 7.3) with the duality of the substrate and the physiological state of the female (egg load). Ovipositing females adjusted the final number of eggs laid around the plant during the behavioural stage of substrate exploration. Additional experiments using plant surrogates treated with methanolic extract of Brassica leaves mounted in different substrates showed that: (a) the presence of living Brassica, Hordeum or Allium roots in a substrate enhances the number of eggs laid into this substrate, but females do not discriminate between the different plants; (b) females avoid both wet and dry substrates and prefer the substrates with a dry surface and moist particles directly accessible at a depth of about 5 mm; (c) substrates rich in organic matter are preferred to sand; (d) olfactory perception of volatile chemicals from the substrate must at least partially be responsible for the differences in oviposition in various substrates.

Meadow, R., J. D. Vandenberg and A. M. Shelton (2000). "Exchange of inoculum of Beauveria bassiana (Bals.) Vuill. (Hyphomycetes) between adult flies of the cabbage maggot Delia radicum L. (Diptera : Anthomyiidae)." Biocontrol Science and Technology 10(4): 479-485.

Adult cabbage maggots (Delia radicum L.) were exposed to dry conidia of isolates of several hyphomycetous fungi by placing them in a centrifuge tube containing conidia, then releasing them into small screened plastic cages. Mortality was assessed after 48, 120 and 160 h. A Beauveria bassiana isolate (P89 from Musca domestica) caused the highest mortality after 48 h, resulting in 100% mortality and 100% infection. Isolate L90 (B. bassiana) and one Metarhizium anisopliae isolate (ARSEF 2521) also caused fatal infection in more than 50% of the flies. To investigate exchange of inoculum, flies were placed in a small container with a dry powder formulation containing B. bassiana (Mycotrol(R)) on the bottom. The flies were removed to small screened cages containing untreated flies. This experiment confirmed the ability of flies to pass inoculum to other flies. In a similar experiment, one treated fly was placed in each cage with one untreated fly. When each fly died, one untreated fly was added to each cage after the dead fly was removed. This study showed that fly to fly transfer of fatal doses of inoculum was possible for a series of at least six flies. When female flies were exposed to the inoculum, then transferred to small cages containing males and an oviposition substrate, no eggs were laid. Further studies are being conducted to develop a system where flies attracted to a trap will be inoculated with the fungus and spread it to a field population.

Neveu, N., L. Krespi, N. Kacem and J. P. Nenon (2000). "Host-stage selection by Trybliographa rapae, a parasitoid of the cabbage root fly Delia radicum." Entomologia Experimentalis Et Applicata 96(3): 231-237.

Host-stage selection by Trybliographa rapae Westwood (Hymenoptera: Figitidae) was studied in choice and no-choice experiments in the laboratory. The parasitoid was able to reproduce in first, second, and third instars of the cabbage root fly, Delia radicum L. (Diptera: Anthomyiidae), but oviposition occurred more frequently in third instars when all three developmental stages were offered simultaneously. Oviposition in third instars increased the rate of development of offspring and their body size, but did not alter sex ratio. Results are discussed in the light of predictions made by the theory of optimal host acceptance.

Thomsen, L. and J. Eilenberg (2000). "Entomophthora muscae resting spore formation in vivo in the host Delia radicum." Journal of Invertebrate Pathology 76(2): 127-130.

The formation in vivo of Entomophthora muscae resting spores was investigated in the host, Delia radicum (cabbage root fly), by analysis of field data on the seasonal occurrence of E. muscae resting spores over 4 years. E. muscae resting spores in D. radicum were spherical with an average diameter of 39.4 mu m, and the average numbers produced were estimated at 5.7 x 10(4) resting spores/female cadaver. Resting spores were found only after midsummer in D. radicum and almost exclusively in females. The proportion of infected females with resting spores was negatively correlated with average weekly day length after midsummer. We did not detect any significant year effect; thus, the results support the hypothesis that the photoperiod is the most important abiotic factor controlling E. muscae resting spore formation in D. radicum. (C) 2000 Academic Press.

Biron, D. G., E. Brunel, J. P. Nenon, D. Coderre and G. Boivin (1999). "Preliminary survey of genetic determinism controlling the expression of the bimodal emergence of Delia radicum L-(Diptera : Anthomyiidae)." Annales De La Societe Entomologique De France 35: 104-108.

In horlarctic region, at the beginning of the growing season, many phytophagous insect species show a polymodal emergence in post-diapause against the unfavorable environmental conditions. Within the populations of Delia radicum, two biotypes are observed, early and late, which differ for the timing of adult emergence in diapausing and non-diapausing conditions. These biotypes cause a bimodal emergence of the adults. In this preliminary survey, in non-diapausing condition, we demonstrate that the bimodal emergence is controlled genetically, that the late biotype is recessive and that there is a significant maternal effect of late biotype on the mortality of the eggs. Also, our results also suggest that the females of late biotype have a similar average length of oviposition to those of early biotype.

Bligaard, J. (1999). "Damage thresholds for cabbage root fly Delia radicum (L.) in cauliflower assessed from pot experiments." Acta Agriculturae Scandinavica Section B-Soil and Plant Science 49(1): 57-64.

The influence of cabbage root fly [Delia radicum (L.)] on cauliflower dry matter production was investigated in three experiments during 1992 and 1993. Cauliflower plants grown outdoors in pots were inoculated with different numbers of cabbage root fly eggs, 1, 2, 3 or 4 weeks after transplanting as seedlings. A non-destructive Method was used to estimate dry matter production during the growing season. Regression analyses of plant dry matter against egg number demonstrated that control measures against cabbage root fly larvae are needed to protect young seedlings during the first 3-4 weeks after planting, whereas 100 eggs or more were required to cause a 5% reduction in mean plant dry matter when plants were inoculated 4 weeks after transplanting. Egg and larval mortality varied with means in the range from 47 to 61% and density-dependent larval mortality was demonstrated in two out of four combinations of experiment and inoculation time.

Bligaard, J., R. Meadow, O. Nielsen and A. Percy-Smith (1999). "Evaluation of felt traps to estimate egg numbers of cabbage root fly, Delia radicum, and turnip root fly, Delia floralis in commercial crops." Entomologia Experimentalis Et Applicata 90(2): 141-148.

The use of felt traps to estimate oviposition by the cabbage root fly, Delia radicum (L.), and turnip root fly, Delia floralis (Fall.), was compared with soil sampling at seven localities between 1992 and 1994 in Denmark and Norway. In all, 281 comparisons were made, based on 6800 samples. In 4.6% of these comparisons no eggs were found by either method. In 16% of the comparisons, 2.0 +/- 0.41 (+/- S.E.) eggs were found per soil sample and no eggs were found in felt traps, whereas in 0.7% of the comparisons 0.10 +/- 0.03 eggs were found per felt trap and no eggs in soil samples. When eggs were found using both methods, the ratio between soil sampling and felt traps varied from 13.1 +/- 3.2 when the

egg laying rate was very low to 1.8 +/- 0.2 at high egg laying rates. Regression analysis showed significant correlation between felt trap catches and soil sampling (P < 0.001), whereas locality did not influence felt trap efficiency (P=0.096). The influence of the physical conditions of felt traps, i.e., whether they were clean and dry, were analysed in a single year. Tentative action thresholds for control measures against cabbage root flies and turnip root flies were developed for cauliflower, Brassica oleracea, convar. botrytis (L.) Alef., var. botrytis, based on data from the literature and the present results.

Brown, P. E. and M. Anderson (1999). "Factors affecting ovipositor probing in Trybliographa rapae, a parasitoid of the cabbage root fly." Entomologia Experimentalis Et Applicata 93(2): 217-225.

The effect of allelochemicals from its host, the larva of the cabbage root fly, Delia radicum (L.) (Diptera: Anthomyiidae), and the host's food plant on the ovipositor probing response of the parasitoid Trybliographa rapae (Westw.) (Hymenoptera: Cynipidae) were investigated. Trybliographa rapae probed both cabbage root fly infested and uninfested swede (Brassica napus var. napobrassica), although significantly more wasps responded to infested swede. Antennal sensilla are likely to be the mediators of this response. The synomones and kairomones involved are extractable in water, diethyl ether and methanol. No response was observed to washed, starved cabbage root fly larvae. Wasps spent significantly longer searching infested swede than uninfested, although probing frequency remained constant. It is suggested that the initiation of probing in T. rapae is dependent on a threshold concentration of general synomones or host related synomones and kairomones, whereas time spent searching a particular area is dependent on the environment perceived by sensilla on the ovipositor.

Brunel, E., S. Fournet, P. Pedro and L. Renoult (1999). "Comparison of the development time at different temperatures of two Aleochara species, predator and parasitoid of the cabbage root fly." Annales De La Societe Entomologique De France 35: 71-76.

Two staphylinids, Aleochara bilineata Gyll. and A. bipustulata L., predator of eggs and parasites of the cabbage root fly pupae (Delia radicum L.), are observed in natural conditions in same proportion. To understand how these two sympatrical species can coexist and to bring some new data about their biology, the two staphylinids are reared at different temperature of 5, 9, 12, 17, 20, 24 et 35 degrees C in laboratory. Development time and mortality were analyzed. Penetration rate in pupae by larva is higher in A. bilineata than in A. bipustulata. The latter seems well tolerate low temperature. Development of the two staphylinids is effective and homogeneous between 12 et 24 DC. Optimum of development would be 17 degrees C for A. bilineata and 24 OC for A. bipustulata.

de Jong, R. and E. Stadler (1999). "The influence of odour on the oviposition behaviour of the cabbage root fly." Chemoecology 9(4): 151-154.

Host plant odours are known to be important in long-range host location by the cabbage root fly, whereas at short distances orientation is mainly visual. We show that olfaction also plays a significant role after a fly lands on a plant and before it moves down onto the soil to oviposit. Host plant acceptance by the cabbage root fly seems to result from a synergistic response to simultaneously perceived olfactory and contact chemostimulation.

Eilenberg, J. and V. Michelsen (1999). "Natural host range and prevalence of the genus Strongwellsea (Zygomycota : Entomophthorales) in Denmark." Journal of Invertebrate Pathology 73(2): 189-198.

The natural occurrence and host range of species of the insect pathogenic fungal genus Strongwellsea [Zygomycota: Entomophthorales] were studied by extensive sampling and examination of adult Diptera [Cyclorrhapha]. The host range for Strongwellsea spp. was significantly enlarged. Three families were documented as new hosts: Muscidae (three species), Calliphoridae (one species), and Sarcophagidae (one species). Further, within the family Anthomyiidae six new host species were recorded and three new host species were documented in the Fanniidae. Strongwellsea castrans was identified as the pathogen in the Anthomyiids, while records from Fanniidae belonged to S. magna. The records of S. magna were the first outside the type locality (California). Primary conidia morphology indicated that muscid and calliphorid species were infected by three undescribed species of Strongwellsea. For the sarcophagid fly, no conidia were encountered, so the Strongwellsea species could not be identified. The tested sampling methods had each different advantages. Sweep netting and diagnosis in situ gave the best opportunity to sample a high number of infected dipterans per time unit spend, while sweep netting followed by incubation in the laboratory was the only method for the documentation of resting spores. The prevalence of S. castrans in the cabbage root fly Delia radicum

was obtained by two methods: Samples collected by sweep net and incubated and water trap samples. Water trap captures gave higher prevalences of conidial infections than sweep-net captures. Measured prevalences of Strongwellsea spp. infections are therefore highly dependent on sampling method. The occurrence of resting spores of S. castrans in D. radicum was almost exclusively restricted to females and varied during the season. In samples from 1988 through 1993, no infected females in June contained resting spores, while 43.0% of the S. castrans-infected females from samples in August contained resting spores. During September and October, a decreasing proportion of S. castrans-infected D. radicum contained resting spores. The results document that species from the genus Strongwellsea are common fungal pathogens of adult flies from different families, occasionally with high prevalences. It also appears that the two described species of Strongwellsea, S. castrans and S. magna, have a range of dipterous host species that may always belong to a single family, Anthomyiidae and Fanniidae, respectively. Our data shows also that the host family Muscidae may be exploited by two new species of Strongwellsea. (C) 1999 Academic Press.

Ellis, P. R., D. A. C. Pink, N. E. Barber and A. Mead (1999). "Identification of high levels of resistance to cabbage root fly, Delia radicum, in wild Brassica species." Euphytica 110(3): 207-214.

Wild Brassica species and associated breeding lines were evaluated for their resistance to Delia radicum, the cabbage root fly, in the field in 1993 and in the field, glasshouse and laboratory in 1996. High levels of antibiosis resistance were discovered in the field in 1993 in Brassica fruticulosa, B. incana, B. villosa and B. spinescens and confirmed in the field in 1996 while two B. oleracea accessions and the susceptible control Brussels sprouts variety, 'Oliver', were highly susceptible. No D. radicum pupae were found in the soil around the roots of B. fruticulosa and B. spinescens at the end of the season. All the Brassica species were attractive to egg-laying by D. radicum in the field and in a laboratory experiment and therefore lacked antixenosis resistance. In a series of glasshouse experiments, Brassica species and breeding lines were inoculated with D. radicum eggs supplied from a laboratory culture and the effects of larval feeding on plants recorded. Brassica incana, B. fruticulosa and B. spinescens were highly resistant, most plants surviving, whilst B. macrocarpa and B. villosa were moderately resistant as were two F1 lines bred from a cross between B. macrocarpa and B. oleracea.

Fournet, S., L. Renoult, J. P. Nenon and E. Brunel (1999). "Super- and multiparasitism of Delia radicum L. (Diptera : Anthomyiidae), by two Aleochara species." Annales De La Societe Entomologique De France 35: 384-389.

The super and multiparasitim of D. radicum pupae by two Aleochara species have been studied. A. bilineata and A. bipustulata are naturally in competition for the exploitation of this host Our results show that the first instar larvae of the two coleoptera can discriminate between unparasitized pupae and parasitized pupae and more specifically, between pupae parasitized by a conspecific larvae and pupae parasitized by another species. Equally, they show that the choice of penetrating a parasitized pupa, is strongly influenced by the identity and the development stage of the first installed larva.

Hopkins, R. J., D. W. Griffiths, R. G. McKinlay and A. N. E. Birch (1999). "The relationship between cabbage root fly (Delia radicum) larval feeding and the freeze-dried matter and sugar content of Brassica roots." Entomologia Experimentalis Et Applicata 92(1): 109-117.

Five genotypes of swede (Brassica napus var. napobrassica), two genotypes of kale (B. oleracea var. acephala), and two genotypes of rape (B. napus var. napus) were each inoculated at the 8-10 true leaf stage with five cabbage root fly (Delia radicum) eggs. The percentage pupation after larval feeding on individual plant genotypes ranged from 45 to 78%, and the mean pupal weight from 6.5 to 13.0 mg. After 5 weeks, larval feeding damage had reduced root weight by up to 47%, compared with uninoculated plants. The dry matter content of undamaged roots was higher in the kales and rapes than in the swedes. Whilst the dry matter content of the rapes and swedes were not changed by D. radicum damage, that of the kales was elevated. The ethanol-soluble sugar content of the root was reduced in all cases by D. radicum larval damage. However, the effect of D. radicum damage on the concentrations of individual sugars (glucose, fructose and sucrose) was crop- and genotype-dependent. In the roots of kales and rapes, the glucose and fructose concentrations were either very low or unaffected by D. radicum damage, whilst both glucose and fructose were generally reduced in swede roots by D. radicum damage. The root sucrose concentration was either reduced or not significantly affected by D. radicum damage in all of the crop types tested. The percentage pupation and the mean

pupal weight of D. radicum were inversely correlated to root freeze-dried matter content. D. radicum pupal weight was positively correlated with root fructose, glucose and ethanol-soluble sugar contents.

Hurter, J., T. Ramp, B. Patrian, E. Stadler, P. Roessingh, R. Baur, R. de Jong, J. K. Nielsen, T. Winkler, W. J. Richter, D. Muller and B. Ernst (1999). "Oviposition stimulants for the cabbage root fly: isolation from cabbage leaves." Phytochemistry 51(3): 377-382.

Two compounds present on the surface of Brassica oleracea cv. botrytis leaves have been isolated and identified which stimulate very effectively oviposition in the cabbage root fly, Delia radicum and which are perceived by a specific receptor neuron in the tarsal sensillum C-5 of the female fly. Activity of extracts and chromatographic fractions were bioassayed, using oviposition experiments and mainly electrophysiological recordings from the CS tarsal contact chemoreceptor sensillum of female flies. Spectroscopic data indicate that the main compound is 1,2-dihydro-3-thia-4,10,10b-triaza-cyclopenta[.a.]fluorene-1-carboxylic acid, a novel compound related to Brassica phytoalexins like brassicanal C. It is accompanied by its glycine conjugate. (C) 1999 Elsevier Science Ltd. All rights reserved.

Kromp, B. (1999). "Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement." Agriculture Ecosystems & Environment 74(1-3): 187-228.

This review article an carabids in sustainable agro-ecosystems of the temperate Northern hemisphere presents a compilation of the available knowledge on the significance of carabids for natural pest control and the effects of cultivation methods (except pesticides) and landscape structural elements. Field carabids are species rich and abundant in arable sites, but are affected by intensive agricultural cultivation. For sampling, fenced pitfall trapping or pitfall trapping is recommended according to the type of study. Many of the assumed beneficial pest control activities of carabids are still based on laboratory feeding records. In the field, carabids have been demonstrated to reduce cereal and sugar beet aphid populations in their early colonization phase, mainly by foraging on aphids that have fallen from the vegetation. Egg predation on Dipteran eggs, e.g. the cabbage root fly, has been overestimated in earlier literature. Scattered data indicate carabidforaging on certain coleopteran pest larvae. In North America, some evidence has been found for control of pest lepidopterans. Larger carabids, e.g. Abax parallelepipedus, can effectively control slugs in greenhouses. Because of their spermophagous feeding habits, certain species of Harpalus and Amara could have some potential for biological weed control. As a result of their sensitive reaction to anthropogenic changes in habitat quality, carabids are considered of bioindicative value for cultivation impacts. Carabids seem to be negatively affected by deep ploughing and enhanced by reduced tillage systems. No negative effects have been found for mechanical weed control and flaming. Carabid recruitment is enhanced by proper organic fertilization and green manuring. Intensive nitrogen amendment might indirectly affect carabids by altering crop density and microclimate. Field carabid assemblages are not bound to a certain crop type, but shift in dominance according to the crop-specific rhythmicity of cultivation measures and changes in crop phenology and microclimate. Crop rotation effects could also be influenced by held-size dependent recolonization capability of carabids. They are enhanced by crop diversification in terms of monocrop heterogeneity and weediness as well as by intercropping and the presence of field boundaries, although corresponding increases in their pest reduction efficacy have not yet been evidenced. (C)1999 Elsevier Science B.V. All rights reserved.

Pats, P. and R. S. Vernon (1999). "Fences excluding cabbage maggot flies and tiger flies (Diptera : Anthomyiidae) from large plantings of radish." Environmental Entomology 28(6): 1124-1129.

The influence of a specially constructed insect exclusion fence on the number of cabbage maggot flies, Delia radicum (L), and tiger flies Coenosia tigrina (F.) (a predator of cabbage maggot flies) entering large plots of radish was determined. Plots with or without the exclusion fence or with an exclusion fence surrounded by a trap crop of radish were evaluated in a single growing season in 1995. Overall during the growing season, the mean cabbage fly catch per trap in the completely fenced plots was 90% fewer than in the unfenced control plots. Fewer cabbage flies were caught inside the completely fenced plots than inside the fence surrounded by a trap crop, suggesting that trap crops do not ultimately impede the movement of cabbage flies into fenced enclosures. The general pattern of trap catch of tiger flies in the various treatments was similar to that observed for cabbage flies. During the heaviest infestation of cabbage maggot flies, infestation was highest in the control plots (84.5%), followed by the fence + trap crop plots with 39.8% infested radishes, and the completely fenced plots with 24.7% infestation. The potential of exclusion fences for use in pest management Diagrams for Brassica crops is discussed.

Royer, L. and G. Boivin (1999). "Infochemicals mediating the foraging behaviour of Aleochara bilineata Gyllenhal adults: sources of attractants." Entomologia Experimentalis Et Applicata 90(2): 199-205.

Aleochara bilineata Gyll. (Coleoptera: Staphylinidae) adults feed on eggs and larvae of cabbage maggot, Delia radicum (L.) (Diptera: Anthomyiidae), and might be used to control this pest. We undertook tests in a Y-tube olfactometer to determine if infochemicals are involved in the food foraging behaviour of A. bilineata adults and to precisely determine the potential sources of stimuli. A. bilineata adults oriented toward the stimuli from both the food-plant of the prey (rutabaga: Brassica napus var. napobrassica (L.) Reichb.) and the prey-plant complex (rutabaga infested by cabbage maggot larvae), but adults significantly preferred the effluvia of infested to uninfested rutabaga in a choice test. The sources of infochemicals in the infested rutabaga were the cabbage maggot larvae themselves and their frass. However, in a choice test adults preferred the effluvia of the larvae to that of the damaged rutabaga from which those larvae were obtained. It is not expected that a generalist predator uses precise herbivore-derived signals in food foraging activity, but the preference of A. bilineata adults for the larval volatiles over frass volatiles may reflect the dependence of this species on dipteran pupae for reproduction.

Royer, L. and G. Boivin (1999). "Infochemicals mediating the forging behaviour of Aleochara bilineata Gyllenhal adults: source of attractants." Entomologia Experimentalis Et Applicata 90: 199-205.

Vanninen, I., H. Hokkanen and J. Tyni-Juslin (1999). "Screening of field performance of entomopathogenic fungi and nematodes against cabbage root flies (Delia radicum L. and D-floralis (Fall.); Diptera, Anthomyiidae)." Acta Agriculturae Scandinavica Section B-Soil and Plant Science 49(3): 167-183.

Finnish isolates of Beauveria bassiana (8 isolates), Metarhizium anisopliae (7), Tolypocladium sp. (2), Paecilomyces farinosus (2), P. fumosoroseus (1), Steinernema feltiae (3) and Bacillus thuringiensis ('Muscabac') were tested for efficacy against mixed populations of Delia radicum and D. floralis under field conditions in 1986-90. All pathogens were applied preventatively, the fungi as aqueous conidial or mycelial suspensions, dry conidia or dry mycelial powder. In only two of the nine experiments did B. bassiana or M. anisopliae give some control. In 1986, B. bassiana SF85-2 and Tolypocladium sp. SF85-4 (both at rate 1.2 x 10(9) conidia plant(-1)), and 'Muscabac' (25 g l(-1), 1 dl plant(-1)) reduced the number of pupae by 80%, 60% and 50%, respectively, as compared with untreated and chemical (isophenphos) controls. In 1990, M. anisopliae SF86-39 at rate 1.6 x 10(9) conidia plant(-1) and 1.5 x 10(8) CFU plant(-1) and S. feltiae SFS-22 (35 000 plant(-1)), increased the yield of cauliflower 2.2, 1.8, and 2.3-fold, respectively, as compared with the untreated control, but these yields were only 19%, 15% and 19% of those of the chemical (diazinon) control. Paecilomyces isolates were ineffective in the 1986 experiment in which they were included. Our results suggest that it is difficult to find efficient control agents among the fungal and nematode species tested for use as biopesticides against cabbage root flies, but that the potential of M. anisopliae against these pests deserves further study.

Vanninen, I., H. Hokkanen and J. Tyni-Juslin (1999). "Attempts to control cabbage root flies Delia radicum L,. and Delia floralis (Fall.) (Dipt., Anthomyiidae) with entomopathogenic fungi: laboratory and greenhouse tests." Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie 123(2): 107-113.

One laboratory and three greenhouse experiments were conducted to study the pathogenicity and efficacy of Finnish isolates of entomopathogenic hyphemycetous fungi against cabbage root flies. In Petri dishes, exposure to 1.5 x 10(10) spores of Metarhizium? anisopliae per dish caused 40-50% mortality of undifferentiated second- and third-stage larvae of Delia floralis, and 1 x 10(7) spores per dish caused 40-50% mortality of Delia indicum larvae. In one greenhouse test, 1 x 10(8) and 1 x 10(9) sports of M. anisopliae and Paecilomyces fumosoroseus reduced the root damage of head cabbage by 20-70% compared with untreated controls, although this was not accompanied by significant reductions in the number of pupae. Only M. anisopliae consistently grew out of larvae and pupae of D. floralis during incubation that followed their recovery from the soil at the end of an experiment testing different formulations of M. anisopliae and Beauveria bassiana, but the frequency of the latent infections of the pest by M. anisopliae was not associated with reduced severity of damage to seedlings of head cabbage.

Baur, R., E. Stadler, K. Monde and M. Takasugi (1998). "Phytoalexins from Brassica (Cruciferae) as oviposition stimulants for the cabbage root fly, Delia radicum." Chemoecology 8(4): 163-168.

Bacteria species known to induce the biosynthesis of crucifer-specific phytoalexins have earlier been shown to be associated with Delia flies. Eleven crucifer-specific phytoalexins and related synthetic compounds were applied on surrogate paper leaves and offered to cabbage root flies in oviposition assays. Since three of these compounds (methoxybrassinin, cyclobrassinin, brassitin) proved to be significantly stimulatory whereas the remaining metabolites had no effect, the reaction of the fly appears to be structure-specific. Inactive phytoalexins had no inhibitory effect on oviposition. 100 mu g of methoxybrassinin per surrogate leaf was as stimulatory as 0.05 gle (gram leaf equivalent) of a methanolic host-leaf (Brassica oleracea) extract. Thus the three active phytoalexins can explain only part of the activity of host-pant extracts but might induce a preference for infected plants.

Biron, D., X. Langlet, G. Boivin and E. Brunel (1998). "Expression of early and late-emerging phenotypes in both diapausing and non-diapausing Delia radicum L. pupae." Entomologia Experimentalis Et Applicata 87(2): 119-124.

The presence of early and late phenotypes of Delia radicum L. (Diptera: Anthomyiidae) has been attributed to the existence of differences in development after diapause. The criteria for the early phenotype is emergence in less than 20 days at 20 degrees C (320 DD above 4 degrees C) and more than 30 days at 20 degrees C (280 DD above 7 degrees C + 320 DD above 4 degrees C) for the late phenotype. The emergence pattern of 10 008 non-diapausing D. radicum pupae reared at 20 OC, L16:D8 and 60% r.h. showed an asymmetrical bimodal distribution similar to the emergence pattern of 477 (1994) and 326 (1995) diapausing pupae from the field. When reared individuals were segregated based on their emergence pattern and reared separately, the proportion of early phenotype increased from 61 to 96% in three generations, while the proportion of late phenotype stayed at 78 to 80% during three generations. These results indicate clearly that diapause is not necessary for the expression of the early and late phenotypes. The presence of these two phenotypes probably enables D. radicum to optimize the use of the available resources, to ensure that a sizeable proportion of the larval population enters diapause and to maintain its distribution throughout the holarctic region (35 to 68 degrees N).

Brown, P. E. and M. Anderson (1998). "Morphology and ultrastructure of sense organs on the ovipositor of Trybliographa rapae, a parasitoid of the cabbage root fly." Journal of Insect Physiology 44(11): 1017-1025.

The ovipositor of the parasitoid wasp Trybliographa rapae was examined by scanning and transmission electron microscopy. Characteristic peg-like sensilla with a cuticular ring at the base are found at the tip of the ventral valves, where they occur in a characteristic arrangement of triplets. The unusual basal structure probably protects the sensilla against damage during movement through the substrate and piercing of the host cuticle. These sensilla are each innervated by six dendrites, some of which have lamellated tips, generally considered to be characteristic of thermosensitivity. It is suggested that the remaining dendrites are gustatory, and as such probably respond to factors present in host haemolymph. A second type of peg-like sensillum is found on both the dorsal and the ventral valves. These are set in deep pits so that only the tip of the peg protrudes above the surface of the cuticle. These occur along the length of the ovipositor shaft and ultrastructural studies reveal the pegs to be innervated by a single mechanosensitive dendrite, probably monitoring the movement of the ovipositor through the substrate. (C) 1998 Elsevier Science Ltd. All rights reserved.

Brown, P. E., C. P. Frank, H. L. Groves and M. Anderson (1998). "Spectral sensitivity and visual conditioning in the parasitoid wasp Trybliographa rapae (Hymenoptera : Cynipidae)." Bulletin of Entomological Research 88(3): 239-245.

Spectral sensitivity of the wasp Trybliographa rapae (Westwood), a parasitoid of cabbage root fly larvae, was measured by the electroretinogram (ERG) technique and by a complimentary behavioural technique, to 15 selected wavelength bands from 340 to 670 nm. Peaks of electroretinogram sensitivity were found in the ultraviolet, blue and green-yellow regions of the spectrum. This corresponds to known classes of photoreceptor present in the Hymenoptera. Behavioural peaks of phototactic attraction were found in the ultraviolet and green-yellow regions, but not in the blue. No differences were observed between the sexes. We suggest that ultraviolet and green-yellow wavelengths initiated 'escape' and 'foliage' orientated behaviour respectively. Blue wavelengths appear to have a less specific function but may be important for colour discrimination. Blue wavelengths did, however, become significantly more attractive to female wasps after a pre-experimental conditioning period involving exposure to blue wavelengths in combination with swede infested with cabbage root fly larvae. Thus T. rapae has been demonstrated to show plasticity in its visually

motivated behaviour. This may prove advantageous in the development of an artificial egg collecting technique for this species.

Dosdall, L. M., L. Z. Florence, P. M. Conway and N. T. Cowle (1998). "Tillage regime, row spacing, and seeding rate influence infestations of root maggots (Delia spp.) (Diptera : Anthomyiidae) in canola." Canadian Journal of Plant Science 78(4): 671-681.

Infestations of root maggots (Delia spp.) (Diptera: Anthomyiidae) were assessed in Brassica rapa L. and Brassica napus L. grown under conventional and zero tillage regimes, at three row spacings (10, 20 and 30 cm) and three seeding rates (5.0, 7.5 and 10.0 kg ha(-1) or 120, 180 and 240 plants m(-2)). The studies were conducted during two growing seasons (1995 and 1996) at each of two sites in central Alberta. Root maggot infestations were assessed by determining the numbers of eggs laid per plant during the growing season and by larval feeding damage to canola taproots assessed at the end of the season. Seed yields of the treatment plots also were determined. Plants of B. rapa were significantly more susceptible to root maggot infestations than were plants of B. napus. Root maggot egg populations and root damage were generally greater with zero tillage than with conventional tillage. Plants grown at higher seeding rates (7.5 and 10.0 kg ha(-1)) usually had less root damage than plants grown at the lowest (5.0 kg ha(-1)) seeding rate, and canola grown at wider row spacings (20 and 30 cm) had less root damage and higher yields than canola grown at the narrowest spacing (10 cm). Response surface regression analyses determined that deposition of fewest root maggot eggs per plant, least root damage and maximum yields occurred at seeding rates ranging from 7 to 11 kg hal and at row spacings ranging from 17 to 25 cm. Even though canola grown in zero tillage had greater root maggot infestations than canola grown in conventional tillage, higher yields still occurred with zero tillage. Zero tillage is therefore an appropriate agronomic practice in areas infested by high populations of root maggots. Sowing B. napus rather than B. rapa, increasing seeding rates and widening row spacings are also appropriate cultural control practices for reducing clop damage from these pests.

Liburd, O. E., R. A. Casagrande and S. R. Alm (1998). "Evaluation of various color hydromulches and weed fabric on broccoli insect populations." Journal of Economic Entomology 91(1): 256-262.

We evaluated the potential for variously colored hydromulches (sprayed-on wood fibers plus adhesive) and weed fabric to suppress populations of the cabbage maggot, Delia radicum (L.), cabbage aphid, Brevicoryne brassicae (L.), and other insects in broccoli, Brassica oleracea L. Weed control also was evaluated. Commercial hydromulches were evaluated in their standard formulations or modified by adding corn starch, plaster of paris, lamp black, and latex blue or yellow paint. D. radicum populations were significantly lower in plots treated with hydromulch and blue paint than in unmulched control plots, This treatment was equal to or better than diazinon in suppressing D. radicum. B. brassicae populations were significantly higher in plots treated with hydromulch and yellow paint than in unmulched control plots. Weed fabric significantly reduced weed populations, but the levels of flea beetle Phyllotreta cruciferae (Goeze) in those plots were 6 times higher than in control plots. Early-season populations of D. radicum and B. brassicae could be suppressed simultaneously if the appropriate combinations of hydromulch and color were used.

Pats, P. and M. B. Isman (1998). "Effect of neem on adult longevity, oviposition and larval development of the cabbage fly, Delia radicum (L.) (Dipt., Anthomyidae)." Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie 122(2-3): 125-127.

Neem seed extract was evaluated at a concentration of 50 p.p.m. azadirachtin for potential oviposition deterrence, and for effects on larval survival, adult longevity and fecundity in the cabbage fly (Delia radicum). Oviposition was not deterred, nor was larval survival or fecundity affected. Adult longevity was not significantly reduced when neem seed extract was added to the diet.

Turnock, W. J., G. Boivin and R. A. Ring (1998). "Interpopulation differences in the coldhardiness of Delia radicum (Diptera : Anthomyiidae)." Canadian Entomologist 130(2): 119-129.

The cabbage root maggot, Delia radicum (L.), was introduced to North America in the mid-1800s, likely from northwestern Europe, and probably reached Quebec and British Columbia before 1885 and Manitoba by 1922. The mean temperature of crystallization (Tc) for overwintering pupae was -22.8 +/- 1.2 degrees C for the St-Jean-sur-Richelieu, Quebec, population and -23.8 +/- 0.7 degrees C for the Vancouver, British Columbia, population. The mean Tc for these two populations and for Winnipeg, Manitoba (-24.4 degrees C), Ascot, England (-22.8 degrees C), Tallinn, Estonia (-25.2 degrees C), and St. Petersburg, Russia (ca. -20 degrees C), did not show any relation to mean January

temperatures. These locations represent both temperate oceanic and temperate continental climates and a range of mean January temperatures from +4.6 to -17.7 degrees C. Survival of puparia from St-Jean-sur-Richelieu exposed to nonfreezing temperatures decreased as temperature decreased and exposure time lengthened. The parameters for the regression equations describing this relationship were similar to those describing the Winnipeg population, and both were more coldhardy than the Ascot population. The upper limit of the cold injury zone (ULCIZ) for the St-Jean-sur-Richelieu population was -12.7 degrees C and the lower limit of this zone (LLCIZ) was -27.6 degrees C. Coldhardy populations from temperate continental climates (St-Jean-sur-Richelieu, Winnipeg) showed a rate of decrease in survival with increased cold stress (lower temperature, longer exposure) within the cold injury zone which was much slower than in the less coldhardy population (Ascot). Thus, some individuals from the coldhardy populations would be physiologically capable of surviving exposure to temperatures below Tc, whereas in the Ascot population nonfreezing injury would kill all the overwintering puparia at a temperature (-19.6 degrees C) well above Tc (-22.8 degrees C). The observed survival of puparia from Vancouver, following various nonfreezing exposures, resembled more closely the calculated survival for these exposures when the equations describing the Ascot population were used than when the equations for Winnipeg or St-Jean-sur-Richelieu were used. The Ascot and Vancouver populations, both from temperate oceanic climates, are less coldhardy than the populations from St-Jean-sur-Richelieu and Winnipeg (temperate continental climates). The founder populations of D. radicum in North America, which probably originated in the temperate oceanic climates of northwestern Europe, have adapted to the colder temperate continental climates by increasing their ability to survive longer exposures to all temperatures within the cold injury zone and not by lowering Tc. Therefore, selection for coldhardiness in D. radicum must have operated on structures, processes, or physiological-biochemical mechanisms that help the organism to avoid or repair nonfreezing cold injury but not on those that determine Tc.

Vernon, R. S. and J. R. Mackenzie (1998). "The effect of exclusion fences on the colonization of rutabagas by cabbage flies (Diptera : Anthomyiidae)." Canadian Entomologist 130(2): 153-162.

A specially constructed fence was developed to exclude cabbage flies, Delia radicum (L.), from plantings of rutabaga. The number of first-flight female D. radicum caught on traps inside fenced enclosures declined linearly with fence height from 0 to 90 cm. Females caught in plots surrounded by a 90 cm high fence were 80.6 and 82.8% fewer than in open check plots in 1991 and 1992, respectively. The percentage of transplanted rutabagas killed by cabbage maggot in the 90 cm high enclosures was 1.4% in 1991 and 25.5% in 1992, compared with 11.8 and 84.5% in the open check plots, respectively. The mean damage index rating for rutabagas was severe in the open check plots but slight in the 90 cm high enclosures in 1991. Only 1.2% of rutabagas in the open check plots would have been of marketable grade in 1991, compared with 54% in the 90-cm enclosures. The mean damage rating was highest in the open check plots in 1992, but damage was also severe in all fenced plots due to the heavy infestation levels that year. The potential of exclusion fences for use in pest-management programs for rutabagas and other brassica crops is discussed.

Broatch, J. S. and R. S. Vernon (1997). "Comparison of water pan traps and sticky traps for monitoring Delia spp. (Diptera : Anthomyiidae) in canola." Canadian Entomologist 129(5): 979-984.

Yellow water pan traps and yellow sticky traps were used to collect Delia spp. flies in plots of canola, var. Tobin, for an entire growing season in the Peace River region of Alberta. At one or more times during the growing season, pan traps and;sticky traps captured Delia radicum (L.), Delia floralis (Fallen), Delia planipalpis (Stein), or Delia platura (Meigen). Numbers of males and females caught varied dramatically between the two trap styles, both within and between the various species. Prior to the onset of flowering, cumulative captures of each of the four Delia spp. in pan traps were all significantly lower than on sticky traps for females and males. From the onset of flowering until trapping ended on 17 August, cumulative captures of D. radicum, D. floralis, and D. planipalpis females were similar in pan traps and sticky traps. Sticky traps, however, remained significantly better than pan traps for trapping all Delia spp. males, as well as D. plarura females. Pan traps were more suitable than sticky traps for collecting intact specimens for positive identifications. Results indicate that a combination of sticky traps and pan traps should be used over an entire growing season when conducting initial surveys for Delia species in crops such as canola. In routine monitoring programs for Delia spp., sticky traps would be more efficacious early in the growing season and more practical than pan traps. The level of expertise required to accurately identify the Delia spp. complex in canola would be higher for sticky traps than for pan traps.

Damgaard, P. H., B. M. Hansen, J. C. Pedersen and J. Eilenberg (1997). "Natural occurrence of Bacillus thuringiensis on cabbage foliage and in insects associated with cabbage crops." Journal of Applied Microbiology 82(2): 253-258.

Bacillus thuringiensis was isolated from the phylloplane of organically grown cabbage in one field during two growth seasons (1992-93). The frequency of B. thuringiensis varied between 0.02 and 0.67 of the total B. cereus/ B. thuringiensis population, with an average of 0.11. Characterization of the B. thuringiensis isolates from foliage showed that the majority (64% of 150 isolates) belonged to serovar kurstaki, had bipyramidal crystals and toxicity towards Pieris brassicae and/or Trichoplusia. Other serovars were also found on the foliage but occurred at very low frequencies (one to three isolates of each serovar). Bacillus thuringiensis was also isolated from insects associated with the cabbage crop (Pieris rapae (Lep.), Delia radicum (Dip.), Syrphidae ribesii (Dip.) and Aleochara bilineata (Col.)), which were collected alive at different developmental stages in the same field. Serologically these isolates were assigned to the serovars kurstaki, aizawai, tochigiensis, colmeri and indiana/colmeri.

Degen, T. and E. Stadler (1997). "Foliar form, colour and surface characteristics influence oviposition behaviour of the carrot fly." Entomologia Experimentalis Et Applicata 83(1): 99-112.

Various leaf models made of paper were presented to carrot flies, Psila rosae (F.) (Diptera: Psilidae) in choice assays to investigate the effect of non-chemical plant traits on oviposition behaviour. The surrogate leaves differed in colour, shape, surface coating, size and stem length. In the presence of host-plant extracts, physical factors strongly influenced oviposition. Green, yellow and orange three-dimensional models similar in shape to host-plant leaves (pinnately or ternately compound or dissected) and with a thin cover of paraffin wax were most acceptable to the females. Egg-laying was not affected by leaf size, but was negatively correlated with stem length. The results obtained by testing models with simple leaf silhouettes were confirmed in an experiment using more lifelike imitations of real host and non-host leaves. The findings are discussed by an extensive review of similar studies in three other phytophagous Ay species (cabbage root fly, onion Ay, Hessian fly).

denOuden, H., D. P. W. Alkema, J. W. Klijnstra, J. Theunissen and J. J. deVlieger (1997). "Preference and non-preference experiments with aerial repellents against Delia radicum L. (Dipt., Anthomyiidae) in a wind tunnel." Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie 121(5): 275-279.

In wind tunnel experiments with Delia radicum the dosage increase efficiency of the repellent salicylaldehyde was studied under preference and non-preference conditions. In micro field experiments in the tunnel the influence of the repellent on oviposition was measured using different application methods. A concentration of about 43 ng salicylaldehyde/l of air reduced oviposition c. 80%.

Ester, A., F. vandeSteene and S. Drieghe (1997). "Effects of filmcoating Brussels sprouts seeds with various insecticides on the transport into the seedlings and on the control of cabbage root fly, Delia radicum (B)." Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection 104(1): 47-53.

Brussels sprouts seeds (Brassica oleracea L. var. gemmifera (D.C.) Schulz) were filmcoated in 1990 and 1991 with various doses of the insecticides chlorpyrifos, isofenphos and fonofos. The plants had been raised in modules. Different times after sowing, the amount of chlorpyrifos (filmcoating containing 28.8 g a.i./kg seed) and isofenphos (filmcoating containing 20 and 30 g a.i./kg seed) in the root and the stem, in the cotyledons and in the leaves was detected during 1991. No or little isofenphos was detected in the different parts of the seedlings, on the or-her hand, considerable concentrations of chlorpyrifos were detected in the root and the stem 48 and 56 days after sowing. Protection against cabbage root fly was assessed at a location with a high population density of cabbage root fly. Control of the cabbage root fly by a filmcoating containing chlorpyrifos 9.6 g a.i. per kg seed was as effective as treating each plant after transplanting. It is concluded that filmcoating with chlorpyrifos for the control of cabbage root fly enables the possibility for a large reduction in pesticide use without loss of control.

Finch, S. and M. Kienegger (1997). "A behavioural study to help clarify how undersowing with clover affects host-plant selection by pest insects of brassica crops." Entomologia Experimentalis Et Applicata 84(2): 165-172.

Laboratory and field-cage tests were done to determine how undersowing brassica plants (Brassica oleraceae L. and B. rapa L.) (Cruciferae) with subterranean clover (Trifolium subterraneum L.) (Papilionaceae) affected host-plant selection

by eight pest insect species of brassica crops. The pest species tested were Pieris rapae (Lepidoptera: Pieridae) (the small white butterfly), Pieris brassicae (Lepidoptera: Pieridae) (the large white butterfly), Delia radicum (Diptera: Anthomyiidae) (the cabbage root fly), Phaedon cochleariae (Coleoptera: Chrysomelidae) (the mustard beetle), Plutella xylostella (Lepidoptera: Yponomeutidae) (the diamond-back moth), Evergestis forficalis (Lepidoptera: Pyralidae) (the garden-pebble moth), Mamestra brassicae (Lepidoptera: Noctuidae) (the cabbage moth) and Brevicoryne brassicae (Hemiptera: Aphididae) (the cabbage aphid). In all tests, except two in which the brassica plants were about three times as high as the clover background, 39%-100% fewer of the pest insect stage monitored were found on host plants presented in clover than on those presented in bare soil. Contrary to claims supporting the 'enemies hypothesis', differences in colonization alone appeared sufficient to account for the lower numbers of insects found when host plants are undersown with clover. To be effective in reducing plant colonization, the clover must cover 50%, and preferably more, of the vertical profile of the crop plants. As clover used as an undersown crop often has to be cut to make it less competitive with the main brassica crop, temporal aspects of the condition of the clover during critical periods of pest activity need to be recorded carefully before concluding that undersowing does not produce the effect desired against certain pest species under field conditions. The effective clover barrier is like any other treatment, if it is not present at the appropriate time it cannot be expected to reduce pest insect numbers.

Helenius, J. (1997). "Spatial scales in ecological pest management (EPM): Importance of regional crop rotations." Biological Agriculture & Horticulture 15(1-4): 163-170.

The importance of spatial scales and landscape heterogeneity to insect populations is widely accepted in ecology and conservation biology. What are the applications to crop protection? Theoretically, insect pest species with certain characteristic metapopulation dynamics may effectively be managed by crop rotation, by applying the same tools as used in conservation. This strategy may in many cases necessitate regionally planned rotations that exceed single farm boundaries. The basic idea of pest management by regional crop rotation is presented, the theoretical background outlined and agroecological prerequisites discussed. Spatiotemporal patterns of both pest occurrence and the host crop field allocation in the landscape are important. For example, the required degree of isolation between host crop patches cannot be achieved with regionally covering major crops, e.g. cereals. The dispersal ability of the pest determines the overall spatial scale at which the rotation is practised. Recruitment from wild hosts must not be excessive. These aspects .re illustrated with example species, the cabbage root fly, Delia radicum a possible target for regional management, and the rape pollen beetle, Meligerhes aeneus, an unlikely target. Regional rotation and biological control are not conflicting strategies, as the crop-pest systems most promising for regional management are the least promising for biological control.

Hopkins, R. J., A. N. E. Birch, D. W. Griffiths, R. Baur, E. Stadler and R. G. McKinlay (1997). "Leaf surface compounds and oviposition preference of turnip root fly Delia floralis: The role of glucosinolate and nonglucosinolate compounds." Journal of Chemical Ecology 23(3): 629-643.

The role of leaf surface compounds influencing the oviposition of the turnip root By, Delia floralis, was investigated using bioassays and fractionation of leaf surface extracts from four Brassica genotypes. Polar leaf surface extracts contained between 65 and 175 nM/g leaf equivalent of glucosinolates. However, following fractionation it Was found that nonglucosinolates were the major stimuli for D. floralis oviposition. Electrophysiological studies of leaf surface extracts and their fractions were performed by using D. radicum, the cabbage root fly, as an analytical tool. The most behaviorally active fractions contained stimulatory compound(s) that had an activity profile identical to that previously described for recently discovered nonglucosinolate compounds. The role of leaf surface chemicals in influencing antixenotic resistance to D. floralis is discussed.

Johnsen, S. and A. P. Gutierrez (1997). "Induction and termination of winter diapause in a Californian strain of the cabbage maggot (Diptera: Anthomyiidae)." Environmental Entomology 26(1): 84-90.

Populations of the cabbage maggot, Delia radicum (L.), occur in the field during all seasons in coastal northern California because the climate is mild, hosts are available, and a percentage of the population does not enter diapause. Laboratory experiments on this population of the cabbage maggot showed the following 6 results: (1) criteria for diapause vary with the conditions that induce diapause, (2) the proportion of larvae entering diapause is highest at low temperatures across all photoperiods and at short photoperiods across all temperatures, (3) developmental times of

larvae producing diapause pupae were longer than for those producing nondiapause pupae, (4) rearing larvae at high temperatures and short photoperiods increased the diapause period for the pupal stage, (5) average pupal weights of diapause pupae (20.20 +/- 2.27 mg) (mean +/- SD) were higher than for nondiapause pupae (18.01 +/- 3.31), and (6) fresh pupae weighing <15.5 mg did not complete diapause. The results support previous findings that field populations of D. radicum are induced into winter diapause mainly by short photoperiods, whereas temperature has a lesser effect.

Johnsen, S., A. P. Gutierrez and J. Jorgensen (1997). "Overwintering in the cabbage root fly Delia radicum: A dynamic model of temperature-dependent dormancy and post-dormancy development." Journal of Applied Ecology 34(1): 21-28.

1. Emergence data on adult Delia radicum from overwintering dormant pupae were used to develop a temperature-driven stage dynamics model to analyse development during winter in this species. 2. The model suggests that overwintering has three phases: two in which no morphological development occurs, followed by a third phase or metamorphosis of the pupae to the adult stage (i.e. post-dormancy) culminating in the emergence of the adult. It is proposed that each phase has a different response to temperature and different optima. 3. The biology of the model is in accord with the empirical knowledge about overwintering in this species, and predicted well the patterns of emergence of adults from six cohorts of dormant pupae reared under different temperature regimes.

Lehmhus, J., M. Hommes and S. Vidal (1997). Effects of living mulches and straw mulch on insect herbivores and their natural enemies in white cabbage. Mitteilungen Der Deutschen Gesellschaft Fur Allgemeine Und Agewandte Entomologie, Band 11, Heft 1-6, Dezember 1997: Entomologists Conference. K. H. Hoffmann and W. Volkl. 11: 289-292.

We tested the effects of different living mulches in white cabbage on the population dynamics of insect pests. Undersowing was done in rows and in full ground cover with two different species of clover (ground clover Trifolium subterraneum cv.Geraldton and strawberry clover Trifolium fragiferum cv.Palaestine). Dead mulching was done with barley straw. Fertilizer treatments were applied when necessary. The abundances of most herbivores were significantly reduced in the fields with full cover of clover. Within row undersowing of clover resulted in a less pronounced reduction of insect pests. The populations of the cabbage aphid Brevicoryne brassicae L. (Homoptera, Aphidae) were the only ones which were efficiently reduced by row undersowing. These reductions were in part due to a reduced colonisation by winged aphids. The contributions of plant quality and predators remain unclear in this respect, but the density of syrphid larvae tended to be higher in intercropped plots despite lower aphid densities on the cabbage plants. The infestation of the cabbage heads by Delia radicum L. (Diptera, Anthomyiidae) and the numbers of Thrips tabaci LINDEMANN (Thysanoptera, Thripidae) and Phyllotreta sp. (Coleoptera, Chrysomelidae) were reduced in treatments with clover sown in full cover only. The results obtained with straw mulching were rather diverse. Cabbage aphid populations were reduced, while egg-laying by Delia radicum and populations of Thrips tabaci were increased. The Lepidoptera did not respond to any of the intercropping methods tested.

Neveu, N., X. Langlet, E. Brunel, M. Lahmer, G. Boivin, M. R. Allo and J. P. Nenon (1997). "The fine structure of the egg shells of the cabbage maggot, Delia radicum L (Diptera: Anthomyiidae), and its relation with developmental conditions and oviposition site." Canadian Journal of Zoology-Revue Canadienne De Zoologie 75(4): 535-541.

The fine structure and evolution of the egg shells of the cabbage maggot, Delia radicum, were studied in a French strain. The chorion did not undergo any modification at oviposition and consisted of three layers, except for the longitudinal strip, where the outer layer was lacking. The vitelline membrane of the oocyte was transformed by densification after oviposition. Differences in the longitudinal strip of the chorion were found between three strains of D. radicum. The strip was 650 mu m long in the French strain and a Canadian strain, but only 250 mu m long in a Moroccan strain. We also studied the effect of relative humidity on the hatching rate of eggs of the French strain and found that low relative humidity decreased the hatching rate. Finally, the function of the longitudinal strip was discussed in relation to climatic conditions.

Roessingh, P., E. Stadler, R. Baur, J. Hurter and T. Ramp (1997). "Tarsal chemoreceptors and oviposition behaviour of the cabbage root fly (Delia radicum) sensitive to fractions and new compounds of host-leaf surface extracts." Physiological Entomology 22(2): 140-148.

Contact chemoreception plays a decisive role in host selection and oviposition behaviour of the cabbage root fly, Delia radicum L. (Diptera, Anthomyiidae). Glucosinolates (mustard oil glucosides) are known to be perceived by the flies, and

when sprayed on paper leaf-models Induce oviposition. Recently it has become clear that other non-volatile types of compounds must also be involved in host selection. A pair of ventro-medial C sensilla on the fifth tarsomere respond strongly to a novel compound called tentatively 'cabbage identification factor' (CIF), but not to sucrose, glucose, fructose and proline, CIF is a new non-glucosinolate oviposition stimulant. A single neurone in each sensillum is activated by this compound and the same is true for glucosinolates. In some flirts a mixture of both types of stimuli evoked an apparent mononeural spike train, whereas in others spikes of two separate cells were activated. The significance of this variability is not yet clear. The new stimulant, CIF, does not evoke responses in glucosinolate receptors in the D sensilla. The involvement of the C-5 sensilla in the detection of host-specific compounds constitutes the first known function for C sensilla in D.radicum. CIF appears to be present in leaf surface extracts from the host-plant Brassica oleracea in quantities as low as 1 ng per gram leaf. In spite of this low level, it stimulates oviposition significantly better than glucobrassicin at higher concentrations, which up till now was known as the mot powerful stimulant for D.radicum.

Spencer, J. L., M. P. Candolfi, J. E. Keller and J. R. Miller (1997). "Specificity of accessory gland extracts in three Delia fly species (Diptera: Anthomyiidae)." Physiological Entomology 22(2): 175-182.

Extracts of testes and male accessory (paragonial) glands made from three species of Delia (onion fly (D.antiqua), seedcorn fly (D.platura), and cabbage fly (D.radicum)) were injected into conspecific virgin females. Extracts of paragonial glands, but not testes, from onion, seedcorn and cabbage fly males stimulated oviposition and suppressed mating when injected into conspecific virgin females. When extracts of paragonial glands from males of these species were injected into heterospecific virgin females, the extracts of D.antiqua and D.platura were fully cross-reactive with respect to oviposition; interspecific injection stimulated oviposition at the level of the conspecific mated controls. Injection of D.radicum extract fully activated the D.antiqua and D.platura ovipositional response. D.antiqua extract caused mating inhibition and partial oviposition in D.radicum; that of D.platura had no effect on either oviposition or mating inhibition in D.radicum. These results suggest that D.antiqua and D.platura are more closely related to one another than either is to D.radicum, and agree with published anatomically-based phylogenies and a genetic distance calculation based on eight enzyme loci. The occurrence of sex peptide cross-reactivity, though asymmetrical, between D.radicum versus D.antiqua and D.platura indicates that, functionally, sex peptides have changed little during the evolution of this genus. An emerging pattern of broad cross-reactivity within genera suggests that sex peptides are not an initiator of reproductive isolation.

Turnock, W. J. and G. Boivin (1997). "Inter- and intra-population differences in the effects of temperature on postdiapause development of Delia radicum." Entomologia Experimentalis Et Applicata 84(3): 255-265.

Canadian populations of D. radicum differ in their response to temperature during postdiapause development. Populations that are primarily of the early-emerging type (less than or equal to 256 D D-04) (St-Jean, Quebec; London, Ontario) have high values for the parameters describing this response: R-m = 12.7-13.3; T-m = 28.0-31.8 degrees C; T-sigma = 10.3-14.2 (R-m, the maximum developmental rate at the temperature, T-m [degrees C] where the developmental rate is highest, and T-m the parameter which gives the shape of the truncated normal curve fitted to the data), a low degree-day requirement for emergence (160-332 D D-04), and may lack a developmental delay at temperatures above ca. 21 degrees C. Populations of the late-emerging type (Kildare, Prince Edward Island) have low parameter values (R-m = 2.5, T-sigma = 19.3 degrees C; T-sigma = 6.4), high degree-day requirements (530 D D-04), and a developmental delay at high temperatures. The parameters for the early-emergers in the population from Winnipeg, Manitoba (74% early) were intermediate (R-m = 9.1, T-m = 27.1 degrees C, T-sigma = 10.7, D D-04 = 246), but resembled the early rather than the late type. This population varied from 31 to 90% early type over a 10-year period and the rate of postdiapause development at 20 degrees C was directly related to the percentage early. In the year with the most rapid development (90% early), development was significantly slower than in the populations from other locations with predominantly early populations, and the year with the slowest development (31% early) showed significantly faster development than that from Kildare, Prince Edward Island (100% late). Therefore the parameters for early and late types of development will not be accurate for use in mixed populations, and the parameters in mixed populations will change among years. Populations of D. radicum in North America and Europe (67 locations by years) varied from 0-100% early. At Winnipeg, the percentage early was directly related to the annual temperature accumulation (DD05) during the growing season. The calculation of developmental parameters for the early-emergers

of mixed populations provides a more accurate basis for estimating the times of first emergence and the first peak of emergence than parameters based on the whole population. Since postdiapause developmental rates vary both among and annually within locations, developmental models should be designed to include such variations.

Baur, R., A. N. E. Birch, R. J. Hopkins, D. W. Griffiths, M. S. J. Simmonds and E. Stadler (1996). "Oviposition and chemosensory stimulation of the root flies Delia radicumand D-floralis in response to plants and leaf surface extracts from resistant and susceptible Brassica genotypes." Entomologia Experimentalis Et Applicata 78(1): 61-75.

In Brassica crops differences in susceptibility to root fly attack can be largely attributed to antixenotic resistance. Plants of four genotypes (two swedes and two kales) with widely differing resistance in field trials, were compared in laboratory choice assays for their susceptibility to oviposition by the root flies Delia radicum (L.) and D. floralis (Fallen) (Diptera, Anthomyiidae). For both species the preference among the genotypes corresponded to the susceptibility of the genotypes in the field. The preference ranking in response to surrogate leaves treated with methanolic surface extracts of the four genotypes was identical to the preference among potted plants, demonstrating that chemical factors on the leaf surface mediate host preference for oviposition in these species. For both species of fly, glucosinolates are major oviposition stimulants and for D. radicnm an additional, nonglucosinolate oviposition stimulant, presently called CIF, is known. We describe a procedure for chromatographic separation of glucosinolates from CIF in leaf surface extracts. In oviposition-choice assays with D. radicum, the CIF-fractions of the two swede genotypes applied to surrogate leaves received a 1.8 and 4.6 times higher proportion of eggs than the respective glucosinolate-fractions, confirming the major importance of CIF as an oviposition stimulant. The genotype of swede that was preferred by both fly species in tests with plants and methanolic leaf surface extracts, also stimulated oviposition more in tests with the glucosinolate-fractions or the CIF-fractions derived from the surface extracts, respectively. Thus, glucosinolates and CIF together account for the observed preference among the genotypes and may also be responsible for their susceptibility under field conditions. In the two kale genotypes the preference for plants or surface extracts differed from the preference among the corresponding glucosinolate- and CIF-fractions, indicating that additional, as yet unknown chemical factors may also be involved. For both groups of stimulants tarsal chemoreceptors allow electrophysiological monitoring of glucosinolate- and CIF-activity in fractionated surface extracts. For D. radicum the chemosensory activity of both glucosinolate- and CIF-fractions corresponded to the respective behavioural activity in the oviposition preference tests, suggesting that preference for oviposition among genotypes can be predicted from the electrophysiological activity of their fractions. The chemosensory response of D. floralis, in particular to the CIF-fractions, was less pronounced than the response of D. radicum, indicating interspecific differences in the perception of the major oviposition stimulants. We discuss the potential application of electrophysiological techniques in support of other screening methods used in breeding for root fly resistance in Brassica crops.

Baur, R., V. Kostal, B. Patrian and E. Stadler (1996). "Preference for plants damaged by conspecific larvae in ovipositing cabbage root flies: Influence of stimuli from leaf surface and roots." Entomologia Experimentalis Et Applicata 81(3): 353-364.

In laboratory dual-choice assays females of the cabbage root fly, Delia radicum, prefer for oviposition plants with roots damaged by conspecific larvae to undamaged controls. Cauliflower and kale plants were inoculated with root fly eggs (25 per plant) and the hatching larvae were allowed to feed on the roots for various periods of time (1-17 days). After 3 (cauliflower) or 5 (kale) days of larval feeding the oviposition preference was most pronounced and flies laid between 64% and 68% of their eggs near plants with damaged roots. Later, with increasing damage but fewer surviving, and thus actively feeding, larvae, the magnitude of the preference declined. The preference for plants already damaged by conspecific larvae may contribute to the previously observed aggregated distribution of D. radicum eggs in Brassica crop fields. Further experiments revealed that the sensory cues inducing this oviposition preference originate from the complex consisting of the damaged roots, the surrounding substrate (soil) and associated microbes, rather than from the aerial plant Darts. In choice assays using the root-substrate complex of damaged and control plants (aerial parts removed), the observed preference for damaged roots was similar to that found for the entire plant but was more pronounced. The damaged roots alone, compared to control roots, received up to 72% (cauliflower) and 75% (kale) of the eggs. By contrast, surrogate leaves sprayed with methanolic leaf surface extracts from the most preferred plants which had been damaged were not discriminated from surrogate leaves sprayed with extracts of the respective control plants. Analysis of glucosinolate levels in methanolic leaf surface extracts revealed that root damage resulted in enhanced concentrations of indole-glucosinolates on the leaf surface in kale but not in cauliflower. Although indole-

glucosinolates are oviposition stimulants for the cabbage root By, the induced changes were apparently too small to influence oviposition behaviour.

Baur, R., V. Kostal and E. Stadler (1996). "Root damage by conspecific larvae induces preference for oviposition in cabbage root flies." Entomologia Experimentalis Et Applicata 80(1): 224-227.

Biron, D., C. Vincent, M. Giroux and A. Maire (1996). "Lethal effects of microwave exposures on eggs and pupae of the cabbage maggot and cabbage plants." Journal of Microwave Power and Electromagnetic Energy 31(4): 228-237.

To control the cabbage maggot (Delia radicum) [Diptera: Anthomyiidae], treatments in an industrial microwave over; (f = 2450 MHz; P = 0 to 6 kW) were carried out in the laboratory to test two developmental stages of the insect. First, treatments were directed at Delia radicum eggs after the transplanting of cabbage plants. Treatments with 10 s at 2100 W, 20 s at 1600 W, 20 s at 2100 W, 25 a at 1100 W, 25 s at 1600 W and 25 s at 2100 W inhibited egg hatching. However exposures caused lethal effects in cabbage plants (Brassica oleracea var. Stonehead). Second, treatments were directed at the maggot pupae after harvest. Treatments with 10 s at 3000 Wand 10 s at 4000 W were more promising, inhibiting the emergence of adults while having no impact on the cabbage plant. Post-harvest treatment would be preferable to spring treatment. High energy levels required to penetrate the soil ata depth of 10 cm to attain all pupae preclude commercial development at the present time.

Braven, J., N. P. Chilcott and C. Hawkes (1996). "Structure-activity relationships in glucosinolates and other compounds stimulating oviposition in the cabbage root fly (Delia radicum)." Journal of Chemical Ecology 22(8): 1567-1578.

The ability of a range of glucosinolates and other compounds in stimulating oviposition of the cabbage root fly (Delia radicum) was determined using a bioassay based on the use of surrogate leaves coated with test compounds. The results show that chemically dissimilar compounds are effective stimulants providing they contain the S=O group. No other part of the glucosinolate molecule was shown to be necessary. It has been shown that compounds other than glucosinolates may be important in the oviposition behavior of D. radicum.

Brown, P. E. and M. Anderson (1996). "Spectral sensitivity of the compound eye of the cabbage root fly, Delia radicum (Diptera: Anthomyiidae)." Bulletin of Entomological Research 86(4): 337-342.

The spectral sensitivity of the compound eye of the cabbage root fly, Delia radicum (Linnaeus), was measured using the electroretinogram (ERG) technique, at fifteen selected wavelengths between 340 nm and 670 nm. The form of the ERG was found to be diphasic in nature. A primary peak of spectral sensitivity in the UV (340-350nm), and a smaller secondary peak in the blue-green region (460-546 nm) were found, together with a shoulder of sensitivity, representing a 'pseudo-peak' as reported for other Diptera, in the red region (630 nm). No significant differences were found between the dorsal and ventral regions of the eye. The peak response in the green region (546 nm) agrees well with existing behavioural data on colour attraction and visual discrimination of host plants by the cabbage root fly.

denOuden, H., A. Bulsink and J. Theunissen (1996). "Compounds repellent to Delia radicum (L) (Dipt, Anthomyiidae)." Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie 120(7): 427-432.

By means of two non-preference test methods a number of pre-selected repellents of Delia radicum has been examined. Dosage increase efficiency of repulsion to larvae and adults has been determined for five and three compounds, respectively. Salicylaldehyde and toluquinone appeared to be promising new repellents. Data from literature about repellents involved are mentioned.

Dosdall, L. M., M. J. Herbut, N. T. Cowle and T. M. Micklich (1996). "The effect of tillage regime on emergence of root maggots (Delia spp) (Diptera: Anthomyiidae) from Canola." Canadian Entomologist 128(6): 1157-1165.

The effect of four tillage regimes on the emergence of root maggots (Delia spp.) (Diptera: Anthomyiidae) was determined on experimental plots seeded the previous year to either Brassica rapa L. or Brassica napus L. The tillage regimes evaluated comprised no tillage, tillage in the spring only, tillage in the fall only, and tillage in both the fall and the spring. Emergence trap collections of Delia radicum (L.) and Delia floralis (Fallen) were made from;he experimental plots from early May to mid-July of 1991 and 1992. In both years, emergence from untilled plots significantly exceeded that from plots subjected to any other tillage treatment. Tillage resulted in a decrease in emergence of 55-64% for D.

radicum, and a reduction of 53-72% for D. floralis. For D. floralis, greatest reductions in emergence following a tillage treatment occurred in plots tilled only in the fall or in plots tilled in both the fall and the spring; however for D. radicum, tillage in the fall, the spring, and in both the fall and the spring reduced emergence to approximately the same extent. Results of our study indicated that canola growers in regions of high population densities of root maggot should cultivate infested fields, preferably in fall, to reduce the emergence success of Delia spp.

Dosdall, L. M., M. J. Herbut, N. T. Cowle and T. M. Micklich (1996). "The effect of seeding date and plant density on infestations of root maggots, Delia spp, (Diptera: Anthomyiidae), in canola." Canadian Journal of Plant Science 76(1): 169-177.

Five seeding dates and four plant densities were evaluated in 1991 and 1992 for reducing infestations of root maggots, Delta radicum (L.) and Delta floralis (Fallen) (Diptera: Anthomyiidae), in both species of canola (Brassica rapa L. and Brassica napus L.), under field conditions in central Alberta, Canada. Infestations were assessed by numbers of eggs laid throughout the season and by degree of damage to taproots at the end of the season. Root maggot infestations were reduced by seeding in late May rather than in early or mid-May, but because seed yield also declined with late-May plantings, delaying canola seeding is not an appropriate cultural control strategy. Increasing plant density, however, resulted in reduced infestations and increased seed yield and so is considered an acceptable control practice. Increases in plant density caused corresponding and statistically significant decreases in basal stem diameter of canola. Moreover, increases in basal stem diameter resulted in corresponding and significant increases in Delia spp. egg populations and damage to taproots from larval feeding. These data suggest that ovipositing females of Delia spp. select larger canola plants, i.e., those seeded earlier or at lower densities, and these are consequently damaged to a greater degree than smaller plants.

Finch, S. (1996). "Effect of beetle size on predation of cabbage root fly eggs by ground beetles." Entomologia Experimentalis Et Applicata 81(2): 199-206.

Laboratory studies were done to determine the numbers of cabbage root fly (Delia radicum L.) (Diptera: Anthomyiidae) eggs eaten by sixty species of ground beetles (Coleoptera: Carabidae) collected from a range of habitats. For 35 species that were between 2.7 mm and 10 mm long, there was a linear relationship between the numbers of eggs eaten and beetle length. For each 1 mm increase in length above 2.7 mm, an additional 18 eggs were eaten/beetle/day. Eight further species within the above size range did not eat any Ay eggs, as these species are known to be either phytophagous or to feed on moving prey. Large numbers of eggs were eaten by beetles in 13 of the 25 genera tested. Based on size, maximum numbers of eggs were eaten by 7 species of Agonum Bonelli, 5 species of Amara Bonelli and seven species of Bembidion Latreille. Only one of the 6 species of Pterostichus Bonelli tested, P. strenuus (Pant.), ate the expected numbers of eggs, the other species being too large to feed from such small prey items as cabbage root By eggs. The numbers of beetles larger than 10 mm that ate eggs was highly variable and so 10 mm was considered the upper size limit of carabid predators of cabbage root fly eggs.

Finch, S. (1996). A review of the progress made to control the cabbage root fly (Delia radicum) using parasitoids. Arthropod Natural Enemies in Arable Land Ii: Survival, Reproduction and Enhancement. K. Booij and L. denNijs. 71: 227-239.

Some of the classical work on the effects of predatory ground beetles as pest control agents, was done at Wellesbourne in the late 1950s and early 1960s. Much of this work used the cabbage root fly (Delia radiculum) as the pest insect and the ground beetles species present in most cultivated fields in northern Europe as the controlling agents, Recent work, however, has shown that these ground beetles are not as effective as predators of the cabbage root fly as previously thought. In this paper, I will act as the Devil's advocate by questioning: (1) how many of these ground beetles can be considered to be truly ''beneficial''?, (2) how many can be relied upon to give predictable levels of control?, and (3) whether the methods now being proposed for enhancing the effects of such beetles are based on sound biological data? As the regulation of cabbage root fly populations by ground beetles now seems limited, I have now started to work on the two major parasitoids of this pest, one wasp (Trybliographa rapae) and one beetle (Aleochara bilineata) both of which can infest a relatively high proportion of the overwintering fly pupae. As this subject is new to me, I will use published data to describe my proposed approach. I hope the other participants can highlight the errors of my ways and indicate the lines of research they consider likely to prove most productive.

Finch, S., R. H. Collier and K. Phelps (1996). "A review of work done to forecast pest insect attacks in UK horticultural crops." Crop Protection 15(4): 353-357.

The timing of attack by pest insects can vary greatly both from region to region and from year to year because the rates at which insects complete their life cycles depends mainly on temperature. A simulation method has been produced for forecasting the timing of attacks by the cabbage root fly (Delia radicum), the carrot fly (Psila rosae), the bronzed-blossom beetle (Meligethes aeneus) and the large narcissus fly (Merodon equestris) from standard weather data collected daily at regional meteorological stations. In collaboration with the Horticultural Development Council(HDC), Horticulture Research International sends a total of 437 updated forecasts each week to growers who pay a levy to the HDC. Forecasts are now being developed for timing attacks by the cabbage aphid, lettuce aphids and by cabbage caterpillars. Copyright (C) 1996 Elsevier Science Ltd.

Hellqvist, S. (1996). "Mulching with grass-clippings in cauliflower: Effects on yield and brassica root flies (Delia spp)." International Journal of Pest Management 42(1): 39-46.

The effects of mulching with organic materials on yield and damage by brassica root maggots (Delia floralis and D. radicum) in cauliflower, were studied in field experiments for 3 years. Mulching with grass-clippings consistently resulted in increased yield and reduced damage by root maggots, as measured by wilting symptoms and root damage. During one of these years, the effects of mulching with grass-clippings on root fly population dynamics was also studied. Mulching did not reduce egg-laying but resulted in increased egg-predation. The number of D. floralis pupae per plant was not reduced by mulching, probably because of higher larval mortality owing to competition in unmulched plots. Mulching decreased the rate of parasitization by Aleochara bilineata (Staphylinidae), resulting in a higher number of healthy pupae per plant in grass-mulched plots, and these healthy pupae were heavier. All these effects were most pronounced when the mulch material completely covered the ground, even close to the stems of the plants.

Kostal, V. and S. Finch (1996). "Preference of the cabbage root fly, Delia radicum (L), for coloured traps: Influence of sex and physiological status of the flies, trap background and experimental design." Physiological Entomology 21(2): 123-130.

Catches of Delia radicum (L.) (Diptera: Anthomyiidae) were compared in water traps that reflected predominantly wavelengths shorter (violet and blue traps) and longer (green and yellow traps) than 500 nm. Traps were positioned in choice and no-choice situations against backgrounds of bare soil and weeds in the field and against backgrounds of brown and green paper in the laboratory. The physiological status of the flies was modified in the laboratory by denying them access to food sources and oviposition sites. Males discriminated significantly more clearly than females between yellow and blue traps. The discrimination between yellow and blue traps was significantly more pronounced when the traps were presented in the choice than in the no-choice situation in both sexes. Green background (weeds and green paper) was highly preferred for landing and thus competed with the traps to such an extent that few flies were caught when nonpreferred violet and blue traps were sited on green backgrounds. Flies seldom landed on the brown background (soil and brown paper) which resulted in the relative increase of catches in the non-preferred violet and blue traps. The preference for yellow traps was innate even in young flies with immature egg-follicles. Females that were ready to lay eggs, even those deprived of an oviposition site till the age of 8 days, also preferred yellow traps. In the no-choice situation, flies deprived of food landed with the same frequency in yellow and blue traps. Food deprivation, however, did not affect preference for yellow traps over the blue traps presented in a choice situation.

Langer, V. (1996). "Insect-crop interactions in a diversified cropping system: Parasitism by Aleochara bilineata and Trybliographa rapae of the cabbage root fly, Delia radicum, on cabbage in the presence of white clover." Entomologia Experimentalis Et Applicata 80(2): 365-374.

Parasitism of the cabbage root fly, Delia radicum (L.) by the staphylinid Aleochara bilineata Gyllenhal and the cynipid Trybliographa rapae Westwood was examined in a cabbage monoculture and a mixed stand of cabbage undersown with white clover. Number of overwintering cabbage root fly pupae per plant was consistently reduced in the mixed stand, and the incidence of plants attacked by cabbage root fly was either reduced or not different in the mixed stand compared to cabbage monoculture. For both parasitoids, the probability of D. radicum attacked plants having at least one parasitized pupa increased with density of cabbage root fly pupae around the plant. For A. bilineata, this positive relation between presence of parasitism and host density was consistently stronger in cabbage monoculture than in

cabbage undersown with clover. Location of a host plant by T. rapae was not consistently affected by the presence of clover. D. radicum attacked plants situated in the cabbage and clover mixture were found by T rapae as easily as in cabbage monoculture. Overall, the 'total risk of parasitism' for a cabbage root fly pupa by A. bilineata was reduced in the mixed stand compared to the cabbage monoculture, whereas the risk of parasitism by T. rapae was not consistently affected by clover. For both parasitoids, intensity of parasitism showed a variable relationship with host density on individual plants attacked by the cabbage root fly. Overall, in spite of consistently lower total density of pupae in the mixed cabbage - clover than in cabbage monoculture, the density of unparasitized pupae was reduced by the presence of non-host plants only in two of the four experiments. The results emphasize the need to include not only herbivore and crop, but also other plant species as well as natural enemies when evaluating management methods.

Ntiamoah, Y. A. and J. H. Borden (1996). "Monoterpene oviposition deterrents for cabbage maggots, Delia radicum (L) (Diptera: Anthomyiidae)." Canadian Entomologist 128(2): 351-352.

Pussemier, L., D. Suett, P. Debongnie, A. Jukes, F. Serneels and G. Univ (1996). "Effect of a single soil pre-treatment with aldicarb and carbofuran on their subsequent behaviour and field performance." 48th International Symposium on Crop Protection, Pts I-Iv 61(2A&B,3): 621-626.

In the spring of 1995, a field experiment was carried out in Ath in order to study the practical consequences of accelerated degradation of soil-applied insecticides under Belgian conditions. A held site was selected and samples taken in the spring of 1994 in order to check their potential for carbofuran and aldicarb degradation. The site was divided into three sub-plots, which in 1994 were cropped and treated with, respectively, (a) carrots and carbofuran (1.5 kg a.i./ha), (b) sugar beets and aldicarb (1.0 kg a.i./ha) and (c) potatoes and no soil insecticide. At the end of the growing season new soil samples were taken in order to assess, under laboratory conditions, the biodegradation potential of these sub-plots after the different soil treatments. The 1995 field experiment was carried out using radish as an indicator crop, and the soil-insecticides were applied according to a logarithmic gradient, using an experimental device brought from Horticulture Research international in England. At harvest, the crop was assessed for damage by the cabbage root fly (Delia radicum). The laboratory results showed that, with carbofuran but not with aldicarb, a single previous treatment increased the degradation rate significantly. There was no evidence of cross-adaptation between the two insecticides. In the field experiment, a significant reduction in biological efficacy of carbofuran was observed when it was applied to the previously carbofuran-treated soil but its performance in the other soils was unchanged.

Royer, L., G. Belair, G. Boivin and Y. Fournier (1996). "Attractiveness of cabbage maggot (Diptera: Anthomyiidae) to entomopathogenic steinernematid nematodes." Journal of Economic Entomology 89(3): 614-620.

The cabbage maggot, Delia radicum (L.), an important pest of crucifer crops, is a good candidate for control by nematodes, because different parts of its life-cycle occur in the soil. To understand the interaction between nematodes and both eggs and larvae of the cabbage maggot, we examined their attractiveness to the Steinernema carpocapsae All strain in muck soil. We also quantified the ability of some steinernematids to intercept migrant Ist instars before root penetration and to follow larvae into root tunnels in a seminatural environment (soil, plant, host). S. carpocapsae All strain was not attracted by cabbage maggot eggs, whereas they oriented toward newly hatched cabbage maggot larvae. S. carpocapsae All and UK (Biosys 252) strains killed a significant proportion of migrant cabbage maggot larvae before they could penetrate into radish roots. Although most steinernematids tested followed larvae into the radish roots, only S. feltiae (=bibionis) induced significant infection. Our results indicate that steinernematids have the ability to intercept cabbage maggot 1st instars and to follow and infect developing cabbage maggot larvae in roots. However, studies must be undertaken to select the best interceptor and tunnel follower nematode species to control the cabbage maggot, as well as to determine the best timing of nematode application.

Schroeder, P. C., C. S. Ferguson, A. M. Shelton, W. T. Wilsey, M. P. Hoffmann and C. Petzoldt (1996). "Greenhouse and field evaluations of entomopathogenic nematodes (Nematoda: Heterorhabditidae and Steinernematidae) for control of cabbage maggot (Diptera: Anthomyiidae) on cabbage." Journal of Economic Entomology 89(5): 1109-1115.

Entomopathogenic nematodes-Heterorhabditis bacteriophora Poinar (Oswego strain), Steinernema carpocapsae (Weiser) (NY001 strain), Steinernema carpocapsae (25 strain), Steinernema feltiae Filipjev (=Neoaplectana carpocapsae Weiser) (369 strain), Steinernema feltiae (27 strain), and Steinernema riobravus Cabanillas and Poinar (355 strain)--were

examined for pathogenicity against cabbage maggot, Delia radicum (L.), larvae in the greenhouse and field. Applications (per plant) of 3,000 and 4,000 infective juveniles of S. feltiae (369 strain), 30,000 infective juveniles of H. bacteriophora (Oswego strain), and 300 and 30,000 infective juveniles of S. feltiae (27 strain) reduced the number of D. radicum that developed to pupae on potted cabbage plants. H. bacteriophora (Oswego) at applications of 3,000 and 30,000 infective juveniles per plant and S. feltiae (27 strain) at applications of 30,000 (but not 3,000) infective juveniles per plant significantly reduced root damage caused by larvae of D. radicum. Logarithmically increased dosages between 100 and 100,000 infective juveniles per plant of S. feltiae (27 strain) linearly reduced the number of D. radicum pupae that developed on potted cabbage plants and the damage caused to the roots by D. radicum larvae. Root and stem dry weights of cabbage plants infested with D. radicum were significantly greater for plants inoculated with 100,000 infective juveniles of S. feltiae (27 strain) than for plants not inoculated with nematodes. Nematode inoculation did not prevent significant losses in root or stem dry weights at dosages less than 100,000 infective juveniles per plant. Soil surface applications of 100,000 and 200,000 infective juveniles per plant of S. feltiae (27 strain) were more effective than subsurface applications in preventing damage by natural or augmented populations of D. radicum larvae on cabbage in the field. However, mortality rates of wax moth larvae exposed to soil samples treated with S. feltiae (27 strain) suggested that this nematode showed greater persistence when applied beneath rather than on the soil surface.

Skilbeck, C. A. and M. Anderson (1996). "The ultrastructure, morphology and distribution of sensilla on the antennae of the adult parasitoids Aleochara bilineata Gyll, and Aleochara bipustulata L (Coleoptera: Staphylinidae)." International Journal of Insect Morphology & Embryology 25(3): 261-280.

The morphology and distribution of the antennal sensilla, of adult Aleochara bilineata and A. bipustulata (Coleoptera: Staphylinidae), important rove beetle predator-parasitoids of root flies, have been examined. The antennae of both sexes and both species are identical. A detailed ultrastructural study was conducted on the adult antenna of A. bilineata, on this basis, there are 3 main classes of olfactory receptors: basiconic sensilla in rimmed-pits, small basiconic pegs, containing 1-4 sensory dendrites, divided into 3 subclasses, and large basiconic pegs, containing a single dendrite. There are also 5 classes of mechanoreceptors; a single class of gustatory receptor, double-walled spoked hairs, non-porous sensilla, and coeloconic receptors of unknown function. Copyright (C) 1996 Elsevier Science Ltd.

Sondgerath, D. and W. MullerPietralla (1996). "A model for the development of the cabbage root fly (Delia radicum L) based on the extended Leslie model." Ecological Modelling 91(1-3): 67-76.

An application of the extended Leslie model to predict the population dynamics of the cabbage root fly is given. This model couples several Leslie processes, one for each stage of the life cycle. The coupling is done via time-dependent transition probabilities reflecting the development status of the individuals which is described by the biological age. The model parameters were identified by experiments carried out. Comparing the simulation results with (i) laboratory experiments (controlled conditions) and (ii) field experiments (variable conditions) a good correspondence is observed. This simulation model can be used to analyze the effect of an insecticide application on the population dynamics of Delia radicum.

Suett, D. L., A. A. Jukes and N. R. Parekh (1996). "Non-specific influence of pH on microbial adaptation and insecticide efficacy in previously-treated field soils." Soil Biology & Biochemistry 28(12): 1783-1790.

The influence of soil pH on the development, stability and expression of accelerated biodegradation of soil-applied insecticides was studied at a single site in four areas, with mean pH values of 5.4, 6.1, 6.3 and 7.5. A brassica crop was treated at sowing with the commercially-recommended dose of carbofuran or chlorfenvinphos. After harvesting this crop the efficacy of a second application of each insecticide was assessed 5 and 14 months after the initial application. Microbiological studies were done to determine the numbers of microorganisms able to degrade carbofuran, carbofuran phenol or chlorfenvinphos as the sole source of carbon. With both insecticides there were significant differences in behaviour, as well as in their biological performance against larvae of the cabbage root fly (Delia radicum) in the different plots. In previously-untreated soils, chlorfenvinphos was similarly and highly effective at all pH values, whereas the performance of carbofuran declined steadily with increasing pH. In the previously-treated soils, the efficacy of chlorfenvinphos was reduced only in the pH 7.5 soil, whereas that of carbofuran was much reduced at all pH values except pH 5.4. Microbiological studies showed that carbofuran and carbofuran phenol-degrading organisms were

present in all the previously-treated soils, but that carbofuran phenol-degrading organisms were predominant in the soils with highest pH. (C) 1997 Elsevier Science Ltd.

Vernon, R. S. and J. S. Broatch (1996). "Responsiveness of Delia spp (Diptera: Anthomyiidae) to colored sticky traps in flowering and rosette stage canola." Canadian Entomologist 128(6): 1077-1085.

The responses of adult cabbage maggot [Delia radicum (L.)], turnip maggot [D. floralis (Fallen)], radish maggot [D. planipalpis (Stein)], and seedcorn maggot [D. platura (Meigen)] to sticky traps painted blue, yellow, green, non-UV-reflecting white, or UV-reflecting white, were determined in a field of canola (Brassica rapa cv. Tobin) at the rosette and flowering stages. Traps colored white, blue, or yellow generally caught higher numbers of D. radicum, D. floralis, and D. planipalpis than did traps colored green or UV-reflecting white. Depending on the crop developmental stage and its background color, response to color sometimes differed both within and between the sexes. This was most pronounced for D. floralis, for which blue and white traps were preferred by males at the rosette stage but not the flowering stage, and for which white, but not blue, traps were preferred by females at the rosette stage. White and blue, but not yellow, were the colors preferred by male and female D. platura in our study, with UV-reflecting white also being preferred by males during the flowering stage. It was observed that catches on white and yellow traps were often significantly different, and that white versus yellow preferences could be reversed within or between males and females of certain species during the rosette or flowering stages. The data suggest that the concurrent use of white and yellow sticky traps should be considered when conducting relative abundance surveys of Delia spp. in canola fields.

Wiech, K. and C. Brit Crop Protect (1996). Intercropping as possible method of cabbage pest control in Poland.

Early white cabbage (cv. Pierwszy zbior) and late white cabbage (cv. Kamienna glowa) were treated with pesticides, left untreated, undersown with white clover (cv. Podkowa). The undersown did not effect damage caused by cabbage root fly (Hylemyia brassicae) to early cabbage but significantly decreased the number of nea beetles (Phyllotreta sp.) In the case of late cabbage, when clover completely covered the soil it reduced the number of cabbage aphid (Brevicoryne brassicae) (both alate and wingless forms) and cabbage moth (Mamestra brassicae). No effect was observed in case of diamondback moth (Plutella maculipennis) and small cabbage white (Pieris rapae). Undersowing reduced the weight of early cabbage heads by 25% and late cabbage by 46%. Less competitive white clover cultivar is required for further experiments.

Ellis, S. A., M. L. Hallam, C. J. Ottway and D. Winters (1995). An evaluation of a chitin based fertiliser against potato cyst nematode, cabbage root fly and Rhizoctonia solani.

Finch, S. (1995). "EFFECT OF TRAP BACKGROUND ON CABBAGE ROOT FLY LANDING AND CAPTURE." Entomologia Experimentalis Et Applicata 74(3): 201-208.

Pieces (600 mm x 800 mm) of coloured board, plastic sheeting and woven materials, placed beneath water traps prevented the traps from becoming soiled during rainy weather. Such backgrounds are not recommended for use with traps for monitoring populations of the cabbage root fly (Delia radicum L. - Diptera:Anthomyiidae), however, as, instead of increasing trap catch they reduced the numbers of female flies caught by 70%-90%. The main effect was that the visually attractive stimuli from the introduced backgrounds competed with those from the trap. A white background competed with a white trap on a direct fly/unit area basis. Green backgrounds stimulated males to land and the vertical stems of both real and artificial grass induced trivial flights that resulted in greater numbers of males entering traps resting on short grass. Most females were caught over bare soil. To minimize the variation in catch between traps used for monitoring cabbage root fly populations, the background beneath each trap should be similar. For maximum capture, the background should be of grass for male flies and of bare soil for female flies. Care is required if data from traps within mulched crops are used to make pest control decisions, as they will underestimate considerably the numbers of flies in such crops.

Finch, S. (1995). The potential for controlling the cabbage root fly Delia radicum by releasing laboratory-reared parasitoids.

Hartman, T. P. V. and D. I. Southern (1995). "GENOME REORGANIZATION FROM POLYTENY TO POLYPLOIDY IN THE NURSE CELLS FOUND IN ONION FLY (DELIA-ANTIQUA) AND CABBAGE ROOT FLY (DELIA-RADICUM) OVARIES (DIPTERA, ANTHOMYIIDAE)." Chromosome Research 3(5): 271-280.

The material required to ensure successful embryogenesis in the onion fly (Delia antiqua) and the cabbage root fly (Delia radicum) (Diptera, Anthomyiidae) is supplied by 15 nurse cells, while the oocyte chromosomes enter a quiescent stage during prophase I of meiosis. This level of transcription is achieved by the polyploidization of the nurse cell DNA. Elongate polytene chromosomes form in both species, but lack the banding and conspicuous puffing commonly seen in other dipteran tissues. The polytene chromosomes contract until they finally appear as small, densely staining spheres. These fragment into large numbers of endochromosomes that are much smaller than their mitotic counterparts, which then despiralize, resulting in the flocculate appearance of the nurse cell nucleus. Photodensitometry revealed a gradient of DNA values between nurse cells near the oocytes and those further away. Final DNA values 1000 times the haploid level were recorded in the nurse cell nearest to the oocyte compared with 336 times the C-value in the most distal cell. At lower temperatures (<10 degrees C), the polytene chromosomes become banded and longer. None of the onion flies kept in these conditions produced viable eggs, though there was some reproductive success among the cabbage root flies.

Jonasson, T., M. AhlstromOlsson and T. J. Johansen (1995). "Aleochara suffusa and A-bilineata Col: Staphylinidae as parasitoids of Brassica root flies in northern Norway." Entomophaga 40(2): 163-167.

A sample of Delia puparia collected in late autumn from a brassica field at Tromso, northern Norway, was investigated to study the level of parasitism by Aleochara. Both A. suffusa and A. bilineata were reared from puparia of the cabbage root fly, Delia radicum, and the bean seed flies, D. florilega and/or D. platura. Only two specimens of A. bilineata emerged from puparia of the turnip root fly, D. floralis. Both Aleochara species hibernated in the larval stage and both pupated inside the host puparium. Most specimens of A. suffusa emerged from small hosts (D. florilega/D. platura), whereas the majority of A. bilineata emerged from host species of larger size (D. radicum/D. floralis). The time to develop from first instar larva to adult was similar for both A. suffusa and A. bilineata. Parasitoids developing in large hosts emerged later than those in small hosts, the delay being the same for both species of Aleochara.

Kostal, V. and P. Simek (1995). "DYNAMICS OF COLD-HARDINESS, SUPERCOOLING AND CRYOPROTECTANTS IN DIAPAUSING AND NONDIAPAUSING PUPAE OF THE CABBAGE ROOT FLY, DELIA-RADICUM L." Journal of Insect Physiology 41(7): 627-634.

The cabbage root fly, Delia radicum L., overwinters as a phanerocephalic pupa (PCP) in a diapause state and its development may be temporarily stopped at the PCP stage even by high summer temperatures. Cold acclimation (5 days at 5 degrees C) of non-diapausing PCP resulted in an increased cold hardiness (survival of exposure to -15 degrees C for 1 or 20 days) and was associated with an increase of trehalose content (from 6.6 to 10.0 mu g/mg wet weight). Non-diapausing pupae in a high-temperature quiescence had a higher osmotic pressure of haemolymph (623 mOsm) and a higher glucose content (3.4 mu g/mg) in comparison to normal non-diapausing pupae (550 mOsm, 1.4 mu g/mg). Diapausing PCP at the start of diapause showed cold hardiness levels equal to non-diapausing PCP, Their cold hardiness rapidly increased during the first 10-30 days of diapause development attaining a maximum between days 30 and 50 followed by an obvious decrease. Osmotic pressure increased from about 550 mOsm at the start of diapause to 860 mOsm by day 80 and then dropped slowly. Trehalose increased from 4.7 to 11.2 mu g/mg during the first 80 days and then declined too. Glucose showed transitional increase of concentration during the first 20 days of diapause development followed by an abrupt drop until about day 50 and repeated the increase toward the diapause termination. Myo-inositol level increased slowly during diapause development showing a plateau after 80 days. Supercooling capacity of the PCP stage was similar irrespective of the physiological state or age of the pupa.

Langer, V. (1995). "PESTS AND DISEASES IN ORGANICALLY GROWN VEGETABLES IN DENMARK - A SURVEY OF PROBLEMS AND USE OF CONTROL METHODS." Biological Agriculture & Horticulture 12(2): 151-171.

Based on grower crop loss data from 1985-1987 and field and storage assessments from 1987, important pests and diseases of organic vegetables in Denmark are identified. The most important pests are cabbage root fly (Delia radicum), onion neck rot (Botrytis allii) and carrot rust fly (Psila rosae). The organic growers employ cultural plant protection methods such as placement and timing of crops, crop rotation, crop selection and field sanitation

extensively, while direct control methods are rarely applied. Growers' perceptions of pest problems and crop loss due to pest and disease damage in organically grown vegetables change with marketing patterns and quality demands.

Larsson, J. I. R., J. Eilenberg and J. Bresciani (1995). "ULTRASTRUCTURAL-STUDY AND DESCRIPTION OF CYSTOSPOROGENES-DELIARADICAE N-SP (MICROSPORA, GLUGEIDAE), A MICROSPORIDIAN PARASITE OF THE CABBAGE ROOT FLY DELIA-RADICUM (LINNAEUS, 1758) (DIPTERA, ANTHOMYIDAE)." European Journal of Protistology 31(3): 275-285.

The microsporidium Cystosporogenes deliaradicae sp. nov., a parasite of the adipose tissue of adult cabbage root flies, Delia radicum in Denmark, is described based on light microscopic and ultrastructural characteristics. All life cycle stages have isolated nuclei. The sporogony is polysporoblastic, yielding 4-16 (most commonly 6 or 8) ovocylindrical spores, measuring 1.2-1.5 x 4.6-5.5 mu m when fixed and stained. The spore wall has an approximately 43 nm thick, layered exospore with a median layer resembling a double membrane. The polaraplast is uniformly lamellar. The isofilar, 114-123 nm thick, polar filament is arranged in 11-15 (most commonly 12-13) coils in a single layer close to the spore wall. The angle of tilt is approximately 35 degrees. The last coil touches the posterior pole of the spore. A sporophorous vesicle is produced by the sporont. The envelope is generated as a duplication of the plasma membrane. Typically the vesicle primordia grow from one pole of the sporont to the other. The episporontal space initially has granular inclusions. Later septate, persistent tubules of exospore material appear. Simultaneously with the release of sporoblasts, wide tubulus-like, non-persistent structures are formed. They are covered by regularly spaced electron-dense material. anomalous sporogony was frequently observed, probably caused by a simultaneous parasitism by the fungus Strongwellsea castrans. The systematic position of the microsporidium is discussed, including the reasons for incorporating the genus into the family Glugeidae.

Mangan, F., R. Degregorio, M. Schonbeck, S. Herbert, K. Guillard, R. Hazzard, E. Sideman and G. Litchfield (1995). "COVER CROPPING SYSTEMS FOR BRASSICAS IN THE NORTHEASTERN UNITED-STATES .2. WEED, INSECT AND SLUG INCIDENCE." Journal of Sustainable Agriculture 5(3): 15-36.

Winter rye (Secale cereale L.) is the dominant cover crop used in the northeastern United States. At three different locations, rye was compared with systems using the winter-annual legume hairy vetch (Vicia villosa Roth) seeded alone and in combination with rye, These cover crops were seeded in the fall and managed the following spring. Management consisted of either incorporation or mow-killing the cover crops for, enhanced weed suppression. Hairy vetch in combination with rye produced more biomass and gave as good or better weed suppression when left on the soil surface than either cover crop species alone. Leaving these cover crops on the soil surface as a dead mulch gave better weed suppression than incorporation of the cover crops. At one site, mowed ''vetch + rye'' suppressed weeds at least as effectively as plots that received conventional herbicides. The dead mulch led to decreased cabbage maggot egg (Delia radicum L.) and diamondback moth larvae (Plutella xylostella L.) infestation at one site and increased slug incidence at another site.

Slovak, M., L. Kucerova and V. Vallo (1995). "FLIGHT ACTIVITY OF 2 SPECIES OF THE DELIA GENUS (DIPTERA, ANTHOMYIIDAE) IN SOUTHWESTERN SLOVAKIA." Biologia 50(2): 177-184.

Flight activity of local populations of the cabbage root fly (Delia radicum) and the seedcorn maggot D. platura has been monitored at Borska nizina lowland in the course of 1990 and 1998. Investigated species of root maggots have been completing two generations per year and the onset of a third one seemed to be in preparation. Activity peaks of first generation adults have been divided into early- and late-emerging flies. One part of the second-generation flies has emerged without aestivation the other ones' development continued after aestivation. Thermal requirements for the development of individual generations have been established.

Theunissen, J., C. J. H. Booij and L. A. P. Lotz (1995). "EFFECTS OF INTERCROPPING WHITE CABBAGE WITH CLOVERS ON PEST INFESTATION AND YIELD." Entomologia Experimentalis Et Applicata 74(1): 7-16.

During two consecutive years the effects of intercropping fresh market white cabbage with two species of clover on pest populations and yield were studied. White cabbage cv. Minicole was intercropped with Trifolium repens (white clover) and Trifolium subterraneum (subterranean clover) as compared to the monocrop. During the season observations were made on pest population developments, especially of Mamestra brassicae L. (cabbage moth), Brevicoryne brassicae L. (cabbage aphid), Delia brassicae L. (cabbage root fly), and evaluation of caterpillar feeding

injury. At harvest the yield in quantity and quality was determined to be able to assess the gross financial result. Intercropping effects in terms of suppression of oviposition and larval populations of various pests were found. Although no pesticides were used and competition reduced the weight, the quality of the intercropped cabbages lead to a better financial result compared to the monocropped cabbage crop. The results are discussed in the perspective of the practical implications in the context of IPM.

Turnock, W. J., G. Boivin and J. W. Whistlecraft (1995). "PARASITISM OF OVERWINTERING PUPARIA OF THE CABBAGE MAGGOT, DELIA-RADICUM (L) (DIPTERA, ANTHOMYIIDAE), IN RELATION TO HOST DENSITY AND WEATHER FACTORS." Canadian Entomologist 127(4): 535-542.

Puparia of Delia radicum collected in late autumn at Winnipeg and Portage la Prairie (Manitoba), St-Jean-sur-Richelieu (Quebec), London (Ontario), and St. John's (Newfoundland) were parasitized mainly by Aleochara bilineata (Gyllenhal) (Coleoptera: Staphylinidae) and Trybliographa rapae (Westwood) (Hymenoptera: Cynipidae). At Winnipeg, St-Jean, and St. John's parasitism by A. bilineata was high (<94%) and by T. rapae was low (<3%). At London, both parasitoids attacked less than 14% of the host puparia. At Winnipeg, host population density was related to parasitism by A. bilineata and to the temperature and rainfall during June and July. Parasitism by A. bilineata may be related to cumulative degree-days over 5 degrees C during June and July at Winnipeg and during June and September at London. In Canada, the parasitoid complex is not effectively stabilizing host population density. The introduction of additional parasitoid species should be considered.

Ester, A., S. B. Hofstede, P. S. R. Kosters and C. P. Demoel (1994). "FILMCOATING OF CAULIFLOWER SEED (BRASSICA-OLERACEA L VAR BOTRYTIS L) WITH INSECTICIDES TO CONTROL THE CABBAGE ROOT FLY (DELIA-RADICUM)." Crop Protection 13(1): 14-19.

To assess the protection against cabbage root fly larvae achieved in cauliflower crops by filmcoating the seed with insecticide, six field experiments were carried out between 1990 and 1991. Various dosages of insecticides were tested at four widely separated locations in The Netherlands with high and moderate population densities of the cabbage root fly. The plants were raised in 'loose-filled cells' and peat 'blocks', or as peg plants. The efficacy of formulations of isofenphos, chlorpyrifos and fonofos, at two and three dosages of seed filmcoating, were compared with a conventional post-planting treatment. Filmcoating with fonofos was less effective in controlling cabbage root fly larvae than the post-planting treatment. Chlorpyrifos at 28.8 g a.i. kg(-1) seed and isofenphos at 30 g a.i. kg(-1) seed consistently gave as good control as a post-planting treatment of each plant.

Hartman, T. P. V. and D. I. Southern (1994). "FEMALE MEIOSIS IN THE ONION FLY AND CABBAGE ROOT FLY (DIPTERA, ANTHOMYIIDAE)." Genome 37(5): 848-857.

The sequence of female meiosis was investigated in two populations of the cabbage root fly (Delia radicum) and three populations of the onion fly (D. antiqua). In contrast with the completely achiasmate males, both species showed high levels of recombination in females. However, significant differences in chiasma frequency occurred between individuals within populations and between the populations. It was not uncommon to find aneuploidy of the X chromosomes. The autosomes occasionally showed asynapsis or desynapsis, but normal disjunction of univalents was facilitated by distance pairing.

Humphreys, I. C. and D. J. Mowat (1994). "EFFECTS OF SOME ORGANIC TREATMENTS ON PREDATORS (COLEOPTERA, CARABIDAE) OF CABBAGE ROOT FLY, DELIA-RADICUM (L) (DIPTERA, ANTHOMYIIDAE), AND ON ALTERNATIVE PREY SPECIES." Pedobiologia 38(6): 513-518.

The egg predator, Bembidion lampros, and carabids in total, were more numerous in brassica plots to which organic materials had been applied. The difference persisted into the year following the last application and was at least partly due to increased breeding in organically-treated plots. The difference was immediately detectable in plots treated with manure but was delayed in plots to which straw had been applied. Predation on eggs of Cabbage Root Fly was not significantly increased, probably because egg numbers were low and formed a relatively small part of the predator diet. Alternative prey for carabids was also more abundant in organically-treated plots. The presence of straw on the soil surface reduced Cabbage Root Fly oviposition. The level of parasitism was reduced by straw and slurry treatments.

Isidoro, N., M. Solinas, R. Baur, P. Roessingh and E. Stadler (1994). "ULTRASTRUCTURE OF A TARSAL SENSILLUM OF DELIA-RADICUM L (DIPTERA, ANTHOMYIIDAE) SENSITIVE TO IMPORTANT HOST-PLANT COMPOUNDS." International Journal of Insect Morphology & Embryology 23(2): 115-125.

The ultrastructure of a pair of tarsal ''C'' sensilla located on the ventromedial side near the distal margin of the 5th tarsomere of the female cabbage root fly, Delia radicum (L.) (Diptera : Anthomyiidae) was investigated by electron microscopy and electrophysiological recordings. This ''C'' sensillum is a typical gustatory sensillum, consisting of a uniporous hair-shaft inserted in a specialized socket and innervated by 5 sensory neurons (i.e. one mechanosensitive and 4 chemosensitive). One of the chemoreceptor cells is sensitive to host-plant compounds, stimulating oviposition. Non-host-plant (carrot) leaf extracts and sucrose did not stimulate any of the receptor cells. Direct contacts between sensory cell somata were observed, and the possibility of peripheral neural interaction at the sensillum level is discussed.

Kostal, V. and S. Finch (1994). "INFLUENCE OF BACKGROUND ON HOST-PLANT SELECTION AND SUBSEQUENT OVIPOSITION BY THE CABBAGE ROOT FLY (DELIA-RADICUM)." Entomologia Experimentalis Et Applicata 70(2): 153-163.

The behaviour of female cabbage root flies during host plant selection was studied in the laboratory using brassica plants growing in backgrounds of bare soil, clover, grass, peas and four non-living materials. Gravid females landed about twice as often on brassica plants growing in bare soil than on comparable plants growing amongst non-host plants. Once a receptive female landed on a brassica plant, the female made, on average, four 'spiral flights' and two jumps on and off the plant before laying alongside the plant. Surrounding a brassica plant with a diverse background altered the behaviour of the flies, so that the spiral flights around the host plant were replaced by short hops between nearby vertical objects. The loss of contact and recontact with the host plant then prevented the females from accumulating sufficient contacts with the host plant to be stimulated to lay. Spiral flights around host plants appear to determine whether or not flies will lay alongside host plants. Flies in mixed plantings have a reduced rate of settling on the host plant, and a higher rate of locomotion, because they land frequently on non-host plants. Hence, visual stimuli appeared to have greater effects than chemical or mechanical barriers in deterring flies from laying alongside brassica plants in diverse backgrounds. In 'choice' situations, backgrounds of real plants reduced oviposition alongside brassica plants by at least 50%. In 'no-choice' situations, flies laid similar numbers of eggs alongside all brassica plants irrespective of plant background or plant size. If numbers of fly eggs are to be reduced on commercial brassica crops by undersowing the crops with clover, plants growing in bare soil may also have to be included to provide the flies with sites preferred for oviposition.

Kosters, P. S. R. and S. B. Hofstede (1994). EFFECT OF THE PERIOD BETWEEN SOWING AND TRANSPLANTING ON CABBAGE ROOT FLY (DELIA-RADICUM) CONTROL IN BRASSICAS WITH CHLORPYRIFOS FILM-COATED SEEDS. Seed Treatment: Progress and Prospects. T. Martin: 211-216.

Tamer, A. (1994). REARING STUDIES OF TRYBLIOGRAPHA-RAPAE (WESTW) WHICH IS THE MOST IMPORTANT PARASITOID OF THE CABBAGE ROOT FLY DELIA-RADICUM (L).

Denouden, H., J. H. Visser, D. P. W. Alkema, J. J. Devlieger and P. S. M. Derks (1993). "EXPERIMENTS WITH VOLATILE SUBSTANCES IN SLOW-RELEASE FORMULATIONS CAUSING REPELLENCY FOR OVIPOSITION BY THE CABBAGE ROOT FLY, PHORBIA-BRASSICAE BCHE (DIPT, ANTHOMYIIDAE)." Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie 115(3): 307-312.

For the purpose of causing repellency against oviposition of Phorbia brassicae 6 repellents in slow release formulations were tested. The best formulation showed an acceptable repellency for at least 5 weeks. Such a protection probable can be sufficient (e.g. for cauliflower) for building up a resistance against the larvae of P. brassicae. Further field experiments are needed for improving the carrier substances.

Finch, S. (1993). "INTEGRATED PEST-MANAGEMENT OF THE CABBAGE ROOT FLY AND THE CARROT FLY." Crop Protection 12(6): 423-430.

Improved insecticide application and pest forecasting have reduced drastically the amounts of insecticides applied to vegetable crops to control the cabbage root fly (Delia radicum) and the carrot fly (Psila rosae). By growing plants that are partially resistant to the carrot fly, it is possible to apply less insecticide than the dose recommended for the crop.

The application of smaller amounts of even the more selective chemicals is now being demanded on crops grown for certain supermarket chains. Analysts from the UK Ministry of Agriculture, Fisheries and Food and the supermarkets ensure that pesticide residues do not exceed the levels permitted. In crops where only small amounts of insecticides are now applied, natural predators should prevent large increases in pest insect populations and natural parasitoids should reduce the numbers of pest insects entering subsequent generations. The use of physical (crop covers), cultural and microbial (e.g. fungi, bacteria and nematodes) types of control is also discussed. Undersowing brassica crops with clover appears to have potential for producing commercially acceptable vegetable crops without the use of synthetic insecticides.

Jones, T. H., M. P. Hassell and S. W. Pacala (1993). "SPATIAL HETEROGENEITY AND THE POPULATION-DYNAMICS OF A HOST PARASITOID SYSTEM." Journal of Animal Ecology 62(2): 251-262.

1. The cabbage root fly, Delia radicum, at Silwood Park is attacked by both generalist and specialist natural enemies. This paper uses spatial and temporal census data to examine the relative contributions of these natural enemies to the population dynamics of D. radicum. 2. Data on the distributions and mortalities of D. radicum on 40 swede plants in nine consecutive years have been analysed. Using a maximum likelihood technique, the parameters (together with their support limits) have been estimated from these data for a model of an insect host-generalist-specialist interaction. 3. Three particular cases of the model are analysed: (i) only the generalist, Aleochara bilineata, is present; (ii) only the specialist, Trybliographa rapae, is present; and (iii) both species of natural enemy are present. 4. The study points to an interesting interplay between the different natural enemy species. (i) T. rapae can promote stability by virtue of its spatial response to host density, but only within a very narrow range of values of the host's rate of increase. (ii) A. bilineata acts as a simple, between-generation density-dependent factor and thus, in a straightforward way, tends to regulate the host population. (iii) When the two enemies act together a further property appears, provided that the survivorship of T. rapae is sufficiently high; the interplay of the two natural enemies can now lead to alternative, three-species stable states.

Kostal, V. (1993). "COLD-HARDINESS AND SUPERCOOLING CAPACITY IN DIAPAUSING AND NONDIAPAUSING STAGES OF THE CABBAGE ROOT FLY DELIA-RADICUM." Cryobiology 30(5): 524-531.

Kostal, V. (1993). "PHYSICAL AND CHEMICAL FACTORS INFLUENCING LANDING AND OVIPOSITION BY THE CABBAGE ROOT FLY ON HOST-PLANT MODELS." Entomologia Experimentalis Et Applicata 66(2): 109-118.

Various plant models were used in both choice and no-choice tests in the laboratory to assess landing and oviposition preferences of the cabbage root fly, Delia radicum (L.). The main factor governing the site most suitable for landing was the conspicuousness of the object and not its shape. Oviposition was influenced considerably by the pre-conditioning of the females. Deprived females laid eggs even when denied access to both host plant chemicals and host-plant models. The dominant role of contact chemical stimuli in host acceptance was reconfirmed, but only a combination of physical and chemical stimuli appeared capable of eliciting normal oviposition. The combination of contact chemical stimuli and the presence of a stem on the test model had a synergistic effect on the numbers of eggs laid in both choice and no-choice situations. In choice bioassays, female cabbage root flies distinguished between models of different shapes, heights and sizes. The size and shape of the models appeared to be perceived in part after the flies had landed.

Kostal, V. (1993). "OOGENESIS AND OVIPOSITION IN THE CABBAGE ROOT FLY, DELIA-RADICUM (DIPTERA, ANTHOMYIIDAE), INFLUENCED BY FOOD QUALITY, MATING AND HOST-PLANT AVAILABILITY." European Journal of Entomology 90(2): 137-147.

The oogenesis, oviposition and longevity of individually-held cabbage root fly, Delia radicum (L.), females that were deprived of mating opportunities, host plants or adult foods were compared with those of flies that were not deprived. The rate of formation of the first batch of mature eggs was not influenced by this deprivation. The lack of proteins or carbohydrates in the diet reduced total fecundity and also, in the case of carbohydrates, longevity. The absence of a host plant resulted in a blocked oviposition and a retarded development of the second and subsequent follicles. After some period of host deprivation (highly variable among individuals), egg development in the second follicles recommenced, and females oviposited even though host plant cues were lacking. Virgin females also showed a delayed onset of oviposition, had a lower total fecundity and a shorter life span and retained two or even three eggs in each

ovariole at the time of death. Variability within treatment groups was great, ranging in females that were deprived of host plant or mating opportunities from almost complete inhibition of egg development and oviposition to nearly normal oviposition.

Phelps, K., R. H. Collier, R. J. Reader and S. Finch (1993). "MONTE-CARLO SIMULATION METHOD FOR FORECASTING THE TIMING OF PEST INSECT ATTACKS." Crop Protection 12(5): 335-342.

The timing of attack by pest insects can vary greatly both from region to region and from year to year because the rates at which insects complete their life cycles depend mainly on temperature. In addition, variation between individual insects in their rate of development can lead to a spread of activity. A simulation method, based on rates of insect development, has been produced for forecasting the timing of attack by pest insects. Variability is incorporated using the 'same-shape property' which implies that the coefficient of variation of the rate of insect development is independent of temperature. The method is feasible because it uses a fixed number of individuals from one generation to the next and simulates the timing of events rather than the population dynamics of the insects. The method is sufficiently flexible to allow insect resting phases to occur at the appropriate instant for each individual. Its effectiveness in predicting the behaviour of the cabbage root fly (Delia radicum). the carrot fly (Psila rosae), the bronzed blossom beetle (Meligethes aeneus) and the large narcissus fly (Merodon equestris) is demonstrated for one site in one season. To be of practical use, the method has been designed to use standard meteorological data. Estimation of soil temperatures at 6 cm and the derivation of equations for estimating diurnal variation are described in two appendices. The basis of the method is the integration of a temperature-dependent rate function over time. A third appendix describes a quicker and more accurate method of integration than that usually employed in pest forecasting work.

Suett, D. L., A. A. Jukes and K. Phelps (1993). "STABILITY OF ACCELERATED DEGRADATION OF SOIL-APPLIED INSECTICIDES - LABORATORY BEHAVIOR OF ALDICARB AND CARBOFURAN IN RELATION TO THEIR EFFICACY AGAINST CABBAGE ROOT FLY (DELIA-RADICUM) IN PREVIOUSLY TREATED FIELD SOILS." Crop Protection 12(6): 431-442.

The behaviour and biological performance of aldicarb and carbofuran was studied over 2 years in soils from 18 sites within a single 200 ha farm. All the soils had been treated with a single application of the recommended dose of carbofuran at some time during the previous 5 years. In laboratory incubation experiments with freshly applied carbofuran, the time required for the rate of change of insecticide concentration to reach a maximum (initial lag phase) ranged from 1.2-1.6 weeks in soils treated 1 or 2 years previously to >4 weeks in soils treated 4 or 5 years earlier. Differences in the behaviour of freshly applied aldicarb in these soils were comparatively small. A simple model was developed to describe the degradation of carbofuran and to calculate the duration of the initial lag phase. In the field, log-dose evaluations of insecticide performance against cabbage root fly (Delia radicum) in the 18 soils showed a strong correlation between the efficacy of carbofuran and the interval between treatments. The most effective treatments were in the soil treated 5 years previously and in the previously untreated soil. A strong association between efficacy and the duration of the initial lag phase indicated that data from laboratory studies could be used to predict field performance. It was concluded that, after a single application of the recommended dose of carbofuran, at least 3 years should be left before re-applying the insecticide. There was no significant relationship between the performance of aldicarb and the interval following carbofuran application.

Walgenbach, J. F., C. J. Eckenrode and R. W. Straub (1993). "EMERGENCE PATTERNS OF DELIA-RADICUM (DIPTERA, ANTHOMYIIDAE) POPULATIONS FROM NORTH-CAROLINA AND NEW-YORK." Environmental Entomology 22(3): 559-566.

Cabbage maggot, Delia radicum (L.), populations from North Carolina (Fletcher and Scaly Mountain) and New York (Geneva and Highland) were surveyed to detect differences in the emergence pattern of flies from overwintered pupae. Populations from all locations consisted of different proportions of early- and later-emerging individuals. However, populations from New York consisted predominately of early-emerging individuals (greater-than-or-equal-to 90%), whereas populations from North Carolina were composed of a higher percentage of later-emerging individuals. Emergence patterns of F, progeny from crosses between early- and later-emerging flies from Scaly Mountain demonstrated that emergence traits were genetically controlled. D. radicum phenology studies in North Carolina suggested that temporal isolation of the two types was halted by an extended period of aestivation during the summer months, which subsequently allowed the two populations to interbreed during the autumn months. The relative proportion of early:late emergers appears to be unstable over time, which may be due to differential mortality factors

operating when populations are temporally isolated or due to dominance or recessive factors governing earliness or lateness, or both.

Eilenberg, J., N. Wilding and J. Bresciani (1992). "ISOLATION INVITRO OF STRONGWELLSEA-CASTRANS FUNGI, ENTOMOPHTHORALES A PATHOGEN OF ADULT CABBAGE ROOT FLIES, DELIA-RADICUM DIPT, ANTHOMYIIDAE." Entomophaga 37(1): 65-77.

The entomogenous fungus Strongwellsea castrans was isolated in vitro for the first time, by incubating conidia projected from infected cabbage root flies (Delia radicum) in a simple, semi-defined liquid medium comprising dextrose, yeast extract and lactalbumin hydrolysate buffered to pH 7. The fungus grew as long unitunicate hyphae. After transfer to a solid nutrient medium, multinucleate hyphal bodies were formed which developed a thick, laminated wall. Neither conidia nor resting spores developed in liquid or on solid media and the fungus survived successive sub-culturing only in liquid media. Using the API-ZYM system, tests on extracts on hyphae of S. castrans were positive for 11 enzymes but there were no consistent differences in enzyme profiles between S. castrans and fungi of the related genus Erynia.

Ester, A. and C. P. Demoel (1992). CONTROLLING CABBAGE ROOT FLY IN BRUSSELS-SPROUTS BY FILMCOATING SEEDS WITH INSECTICIDES.

Finch, S. (1992). "IMPROVING THE SELECTIVITY OF WATER TRAPS FOR MONITORING POPULATIONS OF THE CABBAGE ROOT FLY." Annals of Applied Biology 120(1): 1-7.

Traps placed within brassica crops to monitor changes in cabbage root fly activity could be made more selective by painting black the inner wall of the standard fluorescent yellow water-traps. Traps could also be made more selective by covering them with cylinders of Netlon(R) mesh, although this procedure reduces the numbers of cabbage root fly caught by about 70%. Of the single-coloured traps tested, those painted "marigold" yellow were the most selective in capturing female cabbage root flies. Although white and certain blue traps were as effective as the best yellow traps at capturing cabbage root flies, such traps should be avoided, as they catch 4-5 times as many of the closely-related bean seed fly. The presence of bean seed flies makes cabbage root fly identification more difficult and adds considerably to the time required to sort trap catches.

Finch, S. and M. S. Elliott (1992). "CARABIDAE AS POTENTIAL BIOLOGICAL AGENTS FOR CONTROLLING INFESTATIONS OF THE CABBAGE ROOT FLY." Phytoparasitica 20: S67-S70.

Laboratory tests with carabid ground beetles found in Wellesbourne fields indicated that intermediate-sized beetles such as Bembidion tetracolum, Amara familiaris and Agonum dorsale were more effective predators of cabbage root fly (Erioischia brassicae) eggs than small beetles, e.g. Bembidion lampros and Trechus quadristriatus, or large beetles, e.g. Harpalus rufipes and Pterostichus melanarius. Further tests indicated that A. dorsale would be an ideal predator, as it can survive up to one month without food, is not killed by P. melanarius, aggregates naturally, and eats large numbers of cabbage root fly eggs/larva. A. dorsale is also relatively easy to retain near the stems of plants by simple barriers and is not cannibalistic. Unfortunately, sufficient A. dorsale were not available for greenhouse trials. Greenhouse trials with B. tetracolum indicated that two beetles per plant were sufficient to control the high levels of cabbage root fly infestation normally encountered in the field at Wellesbourne.

Kostal, V. (1992). "PREDICTION OF FLIGHT ACTIVITY IN 3 SPECIES OF THE GENUS DELIA (DIPTERA, ANTHOMYIIDAE) BY DAY-DEGREE MODEL." Acta Entomologica Bohemoslovaca 89(1): 21-28.

Flight activity in three Delia species were determined by the method of accumulation of day-degrees (dd) above a lower development threshold (LDT = 6-degrees-C). The onset of activity of the spring generation of Delia radicum (L.) required an accumulation (sum of effective temperatures, SET) of 185.5 +/- 31.8 dd, its peak 210.0 +/- 32.5 dd and the SET accumulated from the onset of spring to the onset of activity of summer generation was 644.5 +/- 26.2 dd. The SET obtained for Delia platura Meig. were 156.3 +/- 10.0 dd, 223.7 +/- 36.0 dd, 428.7 +/- 35.5 dd, and for D. florilega L. 118.3 +/- 41.5 dd, 207.0 +/- 51.2 dd, 352.7 +/- 40.8 dd. Accumulation of air temperatures was started on February 1.

Kostal, V. (1992). "ORIENTATION BEHAVIOR OF NEWLY HATCHED LARVAE OF THE CABBAGE MAGGOT, DELIA-RADICUM (L) (DIPTERA, ANTHOMYIIDAE), TO VOLATILE PLANT METABOLITES." Journal of Insect Behavior 5(1): 61-70.

Newly hatched larvae of the cabbage maggot, Delia radicum (L.), responded to various olfactory stimuli from their host plants and oriented themselves by the concentration gradients of these stimuli. allyl and ethyl isothiocyanate (NCS), characteristic metabolites of host Brassicaceae, elicited positive taxis, but at a higher concentrations were repellent. Benzyl NCS was neutral; only at the highest concentration was it slightly repellent. Phenyl, cyclohexyl, and butyl NCS were repellent in the highest amounts used. Volatile compounds emanating prevailingly from surface parts of plants were both attractive (hexanol, hexanal, cis-3-hexen-1-ol, linalool) and repellent (hexylacetate, cis-3-hexenyl-acetate, benzaldehyde, myrcene, terpinene, alpha-pinene, limonene). While the attractiveness was associated with NCS group and with unsaturated and saturated alcohols and aldehydes with an optimal six-carbon chain length, the repellency was probably caused by a cyclized carbon chain and an acetate group. The activity of a compound was strongly influenced by its concentration.

Lei, Z., T. A. Rutherford and J. M. Webster (1992). "HETERORHABDITID BEHAVIOR IN THE PRESENCE OF THE CABBAGE MAGGOT, DELIA-RADICUM, AND ITS HOST PLANTS." Journal of Nematology 24(1): 9-15.

The behavior of Heterorhabditis zealandica Poinar strain T327 was investigated in the presence of the cabbage maggot, Delia radicum L., and plants that are susceptible to D. radicum infestation. Newly formed puparia and freeze-killed third instar larvae were attractive to infective nematodes. Newly harvested infective nematodes did not respond to the puparia, whereas 1-month-old and 2-month-old nematodes reached the insect targets within 15 minutes. There were no significant differences in the ability of similar-sized, third instar larval D. radicum and Galleria mellonella L., the greater wax moth, to attract nematodes. There was a tendency for a greater number of insects to attract more nematodes. The roots of ball cabbage and radish were equally attractive to nematodes, but rutabaga roots neither attracted nor repelled the nematodes. Germinated seeds of radish attracted nematodes, and there was a tendency for more numerous germinated seeds to attract more nematodes.

McDonald, R. S. and M. K. Sears (1992). "ASSESSMENT OF LARVAL FEEDING DAMAGE OF THE CABBAGE MAGGOT (DIPTERA, ANTHOMYIIDAE) IN RELATION TO OVIPOSITION PREFERENCE ON CANOLA." Journal of Economic Entomology 85(3): 957-962.

A choice bioassay was used in the laboratory to investigate oviposition preference of the cabbage957g962, Delia radicum (L.), for canola, Brassica campestris L. cv. Tobin, in different developmental stages. Given a choice of two different ages of canola plants, females invariably preferred to oviposit in sand around the oldest plants. Greatest preference was shown for 5-wk-old plants in the stem elongation stage. The effect of oviposition on plants in the five-leaf (3-wk-old), stem elongation (5-wk-old), and initial flowering (7-wk-old) stages was also examined by artificial infestation with 10 eggs per plant and assessment of root damage and numbers of puparia recovered. Root damage or survival from eggs to pupation did not differ significantly with stage of plant development. In a separate experiment, root damage was related (r2 = 0.76) to introduction of 10, 25, or 50 eggs per plant in the stem elongation stage. However, percentage survival from eggs to pupation and pupal weight did not differ significantly among treatments. Microscopic examination of root damage revealed that larvae consumed a narrow band of tissue bordered on the outside of the taproot by a thin layer of periderm and phloem tissue and on the inside by the parenchyma cells of secondary xylem. Independent of larval density, wounds never penetrated to the center of the root. Consequently, no plants in any of the development stages examined were killed by larval feeding. Plants appeared to compensate for damage by a significant increase in root weight with increasing level of infestation.

Noronha (1992). Effect of density and host plant type on fecundity and survival of Delia radicum (Bouché), Delia antique (Meigen) and Delia platura (Meigen). Montreal, McGill University. Ph.D. Thesis.

Roessingh, P., E. Stadler, G. R. Fenwick, J. A. Lewis, J. K. Nielsen, J. Hurter and T. Ramp (1992). "OVIPOSITION AND TARSAL CHEMORECEPTORS OF THE CABBAGE ROOT FLY ARE STIMULATED BY GLUCOSINOLATES AND HOST PLANT-EXTRACTS." Entomologia Experimentalis Et Applicata 65(3): 267-282.

The role of glucosinolates in the oviposition behaviour of the cabbage root fly, Delia radicum (L.) (Diptera, Anthomyiidae) was investigated using egg counts and electrophysiological recordings from tarsal contact chemoreceptors. The glucosinolates present both inside and on the surface of cauliflower leaves were determined. The

total amounts obtained with the two methods differed by a factor of 100. The extract of the leaf surface contained about 60 mug per g leaf extracted (gle), the total leaf extract 7.5 mg per gle. The glucosinolate patterns of the two extracts were qualitatively similar, but the ratios of the content of individual glucosinolates showed considerable differences. The D sensilla on segment 3 and 4 of the tarsus of D. radicum females were shown to contain a sensitive receptor cell for glucosinolates. In contrast, the receptor cells of the D sensilla of the other segments did not respond in a dose dependent way to these compounds. The glucosinolate receptors were found to be especially sensitive to glucobrassicin, gluconasturtiin and glucobrassicanapin with thresholds of about 10(-8) M to 10(-9) M. Large differences (up to two orders of magnitude) were observed among the different glucosinolates. A significant correlation was found between the behavioural discrimination index and the electrophysiological results. But no obvious correlation existed between the chemical nature of the glucosinolate side chain (e.g. indole, aromatic and aliphatic groups), and their stimulatory activity. However, a significant correlation was found between the overall length of the side chain and the biological activity. Although the flies discriminated clearly between model leaves with and without glucosinolates, a clear dose response curve was only obtained for the indole glucosinolate glucobrassicin. Since the most stimulatory fraction of the surface extract contained no glucosinolates, it was concluded that other compounds, in addition to glucosinolates, do play an important role for the stimulation of oviposition.

Ross, K. T. A. (1992). "COMPARATIVE-STUDY OF THE ANTENNAL SENSILLA OF 5 SPECIES OF ROOT MAGGOTS - DELIA-RADICUM L, D-FLORALIS F, D-ANTIQUA MG, D-PLATURA MG (DIPTERA, ANTHOMYIIDAE) AND PSILA-ROSAE F (DIPTERA, PSILIDAE)." International Journal of Insect Morphology & Embryology 21(2): 175-197.

A comparative study of the antennal sensilla of Delia radicum L., D. floralis F., D. antiqua Mg., D. platura Mg. (Diptera : Anthomyiidae) and Psila rosae F. Diptera : Psilidae) is undertaken. For both sexes of each species, the type, distribution, and density of sensilla are determined. All 5 species have trichoid (olfactory) and grooved (olfactory) sensilla. Basiconica I (blunt) sensilla (olfactory) are found on each of the species examined, except D. platura. Basiconica II (tapered) (olfactory) and clavate (olfactory) sensilla are found only on Delia species. Also, only Delia species have single-chambered, dorsal pits, and these contain basiconic II pit sensilla (olfactory). Common to all 5 species is a multi-chambered ventral pit (olfactory). In the ventral pit, all 5 species have grooved pit sensilla (olfactory). In addition to this type of sensillum the Delia species have smooth-walled conical pit sensilla (hygro-/thermosensitive) and P. rosae has granular pit sensilla (hygro-/thermosensitive). Smooth-walled tapered pit sensilla (hygro-/thermosensitive) are found in D. radicum. Similarities and differences in the density of surface sensilla between dorsal and ventral funicular surfaces, male and female flies, and oligophagous (D. antiqua, D. radicum, D. floralis and P. rosae) and polyphagous (D. platura) species are compared. Several differences in sensillum density between the dorsal and ventral funicular surfaces are observed, but these do not fit into a consistent trend. Except for D. radicum, there are differences in sensillum density between male and female flies. For the oligophagous species, females have a greater sensillum density, whilst for the polyphagous D. platura males have a greater sensillum density. Comparisons between species show the greatest differences between the Delia species and P. rosae, and within the 4 Delia species, differences in sensillum density do not correlate with host range or body size.

Ross, K. T. A. and M. Anderson (1992). "LARVAL RESPONSES OF 3 VEGETABLE ROOT FLY PESTS OF THE GENUS DELIA (DIPTERA, ANTHOMYIIDAE) TO PLANT VOLATILES." Bulletin of Entomological Research 82(3): 393-398.

Larval responses of Delia radicum (Linnaeus), D. floralis (Fallen) and D. antiqua (Meigen) to plant volatiles were measured using a behavioural assay. Larvae were attracted to their host-plant, but non host-plants either had no effect or were repellent. Testing of individual secondary plant volatiles indicated that larvae were attracted to secondary plant volatiles from their host-plant, but were neither attracted nor repelled by secondary plant volatiles from non host-plants. A general plant volatile did not have this effect.

Senior, D., D. N. Antill and B. J. Emmett (1992). "EVALUATION OF INSECTICIDES AGAINST CABBAGE ROOT FLY IN CELL-RAISED CULINARY SWEDES." Annals of Applied Biology 120: 2-3.

Simser, D. (1992). "FIELD APPLICATION OF ENTOMOPATHOGENIC NEMATODES FOR CONTROL OF DELIA-RADICUM IN COLLARDS." Journal of Nematology 24(3): 374-378.

Control of Delia radicum (cabbage maggot) in field collards (Brassica oleracea) was compared after one or two applications of entomopathogenic nematodes, Steinernema carpocapsae (All strain) and Heterorhabditis bacteriophora (HP88 strain), a single application of granular chlorpyrifos, and a water-only treatment. Nematodes were applied with a sprayer during the egg stage of first-generation D. radicum, and chlorpyrifos was hand placed around collard stems during the same period. A second nematode application was made 10 days later. Chlorpyrifos treatment resulted in fewer puparia per plant, less root damage and higher yield than all other treatments, including the control. Collard yield from nematode-treated beds did not differ from controls. These data indicate that, under these field conditions, the species or strains of entomopathogenic nematodes tested did not reduce the number of active cabbage maggots, nor did they prevent collard root damage.

Theunissen, J. and G. Schelling (1992). CABBAGE-CLOVER INTERCROPPING - OVIPOSITION OF DELIA-RADICUM.
Turnock, W. J., B. Timlick, B. E. Galka and P. Palaniswamy (1992). "ROOT MAGGOT DAMAGE TO CANOLA AND THE DISTRIBUTION OF DELIA SPP (DIPTERA, ANTHOMYIIDAE) IN MANITOBA." Canadian Entomologist 124(1): 49-58.

The cabbage root maggot, Delia radicum (L.), was the only Delia species capable of attacking undamaged roots of canola [oilseed rape, Brassica napus (L.)] that was found in commercial fields in Manitoba. Adults of the overwintering generation infest canola. Their progeny, adults of the first generation, left the maturing plants after completing a single generation. Root maggot damage occurred in fields in all agricultural regions of the province. The mean percentage of the roots with damage was higher in the more northerly agricultural regions (15.8%) than in the south (8.0%). Most of the damage was light and the damage did not visibly affect the growth or vigour of the plants. Foot rot fungi were not associated with the feeding damage. In cage experiments, the seed yield of canola did not decrease with increasing proportions of plants damaged by D. radicum. The percentage of plants with root maggot damage (DAM) was best described in a polynomial by the mean daily air temperature (TEMP) and the total precipitation (RAIN) for June and July: log (DAM + 1) = -12.3 + 0.66 TEMP + 0.09 RAIN - 0.004 (TEMP x RAIN). The level of damage caused by the larvae of D. radicum to canola in commercial fields during the years 1985 through 1988 did not appear to have caused yield losses. However, the level of damage increased with increasing precipitation and temperature during June and July so a series of favourable years could lead to increased damage and possibly to significant yield losses.

Brunel, E., R. Carballo and Y. Blot (1991). "EFFECT OF CYROMAZINE (AN INSECT GROWTH-REGULATOR) ON THE CABBAGE ROOT FLY DELIA-RADICUM (DIPTERA ANTHOMYIIDAE)." Bulletin De La Societe Zoologique De France-Evolution Et Zoologie 116(3-4): 267-273.

Cabbage root maggots invade cruciferae roots and cause some damage, as well to vegetable crops such as rape in Europe and America. Difficulties were met with chemical control, particularly since organophosphorous and carbamates are destroyed by soil microbial degradation, and so other research trials were undertaken. Cyromazine, a triamine insect growth regulator (IGR), was very active against developing D. radicum. Laboratory tests were made with Trigard (PW 75) at different doses. Slices of turnip were drenched in the solution for the larvae; for adults it was added in the drinking water. Results showed that larvae and adults were susceptible to IGR: at higher concentrations, the most common effect was modification of shape and colour of larvae and pupae. Mortality increased with larger doses. The LC50 was 1,7-mu-g/l for larvae as well as for adults. Longevity and fecundity of adults were reduced to one quarter compared with the controls. Eggs produced were not viable. Some experiments are planned to test the effect of cyromazine on plant protection in field conditions.

Collier, R. H., S. Finch, K. Phelps and A. R. Thompson (1991). "POSSIBLE IMPACT OF GLOBAL WARMING ON CABBAGE ROOT FLY (DELIA-RADICUM) ACTIVITY IN THE UK." Annals of Applied Biology 118(2): 261-271.

A program for simulating the patterns of egg-laying by populations of the cabbage root fly was used to model the effects of global warming on future cabbage root fly attacks. An increase of 3-degrees-C in mean daily temperature would cause the cabbage root fly to become active about a month earlier in the year than at present. Under such conditions, the emergence of flies from the overwintering population would be less synchronised, as the completion of diapause and post-diapause development would occur at the same time in different individuals within the population. However, there would continue to be only three generations of fly each year, even in the south of England. With temperature increases of 5-degrees-C or 10-degrees-C, the fly would complete four generations each year and

aestivation would seriously disrupt egglaying. These rises in temperature would have a major impact on cabbage root fly activity and would require new strategties for controlling this pest.

Finch, S. (1991). "INFLUENCE OF TRAP SURFACE ON THE NUMBERS OF INSECTS CAUGHT IN WATER TRAPS IN BRASSICA CROPS." Entomologia Experimentalis Et Applicata 59(2): 169-173.

The contribution of the various surfaces of a water trap to the trap's overall effectiveness was studied in brassica crops by painting black different parts of fluorescent-yellow water-traps. Three pest species, Delia radicum (L.), D. platura (Meig.), and Meligethes aeneus (Fab.)/Meligethes viridescens (Fab.), together with blowflies and syrphids, were caught in large numbers. Each insect responded differently to the yellow/black traps. The numbers of insect caught indicated that the area of trap involved in capturing D. radicum was effectively twice the surface area of the water. Yellow traps for monitoring D. radicum populations could be made more selective by painting the inner wall black, as such traps caught similar numbers of D. radicum to all-yellow traps but 50% fewer D. platura, Meligethes sp. and blowflies, and 95% fewer syrphids.

Finch, S. (1991). ARE ATTRACTANT CHEMICALS ISOLATED FROM HOST-PLANTS OF PRACTICAL VALUE IN PEST-CONTROL SYSTEMS - A HYPOTHESIS BASED ON EXPERIMENTS WITH THE CABBAGE ROOT FLY.

Georgis, R., H. K. Kaya and R. Gaugler (1991). "EFFECT OF STEINERNEMATID AND HETERORHABDITID NEMATODES (RHABDITIDA, STEINERNEMATIDAE AND HETERORHABDITIDAE) ON NONTARGET ARTHROPODS." Environmental Entomology 20(3): 815-822.

The effect of entomopathogenic nematodes on nontarget arthropods in the laboratory, field soils, and a stream were assessed. In the laboratory, adult predators were less susceptible to the nematodes Steinernema carpocapsae (Weiser) (Rhabditida: Steinernematidae) and Heterorhabditis bacteriophora Poinar (Rhabditida: Heterorhabditidae) than the immature stages. In field tests, entomopathogenic nematodes that had significantly suppressed pest populations (Popillia japonica Newman, Japanese beetle, Scapteriscus vicinus Scudder, tawny mole cricket, Otiorhynchus sulcatus (F.), black vine weevil, Delia radicum (L.), cabbage maggot, and Diabrotica virgifera virgifera LeConte, western corn rootworm) did not adversely affect the numbers of nontarget soil arthropods in comparison with the untreated control. In contrast, broad-spectrum chemical insecticides (isofenphos, ethoprop, or chlorpyrifos used as chemical checks) significantly reduced or showed a tendency to reduce nontarget arthropod populations. In a stream trial, S. carpocapsae significantly reduced black fly larval populations, but the nontarget insects often increased in the treatment sites. Decreases in nontarget populations were matched by approximately equal or greater reductions in the upstream controls. We conclude that entomopathogenic nematodes do not adversely affect nontarget arthropods when used for short-term control of insect pests.

Kostal, V. (1991). "THE EFFECT OF COLOR OF THE SUBSTRATE ON THE LANDING AND OVIPOSITION BEHAVIOR OF THE CABBAGE ROOT FLY." Entomologia Experimentalis Et Applicata 59(2): 189-196.

Field and laboratory experiments were made in order to understand the relation between the spectral characteristic of a substrate and its attractiveness for Delia radicum (L.) (Diptera: Anthomyiidae) flies to land or oviposit. Landing females preferred substrates with high reflectance of green and particularly of yellow wavelengths, but substrates with a high proportion of the blue and green reflectance simultaneously (light blue and white) were also very attractive. Unattractive substrates had either low reflectance across the whole insect-visible spectrum (dark blue) or increased reflectance only in orange or red region of the spectrum (red) or a large proportion of UV reflectance (aluminium). Landing males were most attracted to the substrates with the highest total reflection. Oviposition attractiveness of a substrate grew with an increase in the proportion of reflectance in the blue and a decrease in the green regions of the spectrum. In addition, the oviposition attractiveness increased with increasing total reflection and contrast with the background, and decreased with a high proportion of UV reflectance.

Kostal, V. (1991). "BEHAVIORALLY TESTED SPECTRAL SENSITIVITY OF THE CABBAGE ROOT FLY (DELIA-RADICUM) (DIPTERA, ANTHOMYIIDAE)." Acta Entomologica Bohemoslovaca 88(3-4): 173-179.

The relative attractiveness of narrow-band wavelengths of light, in the spectral region of 340-620 nm, to the cabbage root fly (Delia radicum) was determined using behavioral technique. Phototactic responses to monochromatic light of

different wavelengths were tested in the test chamber. The intensities of light were equivalent only in the visible region of the spectrum (400-620 nm. 0.15 mW.cm-2), in the UV region (340 and 366 nm) the intensity was lower (0.09 mW.cm-2). UV light (366 nm) was the most attractive despite its lower intensity, the attractiveness then drops at 400 nm, there is a secondary peak in the blue (430 nm) followed by a sharp drop in attractiveness toward the blue green (500 nm) and shallow tertiary peak in the green (540 nm), followed by a decline to a minimum at 620 nm. Males and females responded similarly, the males were less active. Females were able to distinguish the UV, blue, green and red regions of the spectrum. Attraction to the green light (540 nm) was probably not influenced by the reproductive state of the females.

McDonald, R. S. and M. K. Sears (1991). "EFFECTS OF ROOT DAMAGE BY CABBAGE MAGGOT, DELIA-RADICUM (L) (DIPTERA, ANTHOMYIIDAE), ON YIELD OF CANOLA, BRASSICA-CAMPESTRIS L UNDER LABORATORY CONDITIONS." Canadian Entomologist 123(4): 861-867.

The effects of root damage by larval cabbage maggots, Delia radicum (L.), on yield of canola, Brassica campestris L., were examined in laboratory experiments. Inoculations of eggs or first-instar larvae resulted in significant root damage. Damage that exceeded 50% of taproot surface area resulted in fewer racemes, fewer productive seed pods on axillary racemes, lower total biomass, and reduced yield of seed. Despite the latter effect, damage that restricts the number of flowering racemes and induces abortion of seed on axillary racemes may increase the efficiency of yield in canola, which flowers indeterminately over a short growing season.

Ross, K. T. A. and M. Anderson (1991). "SENSILLA OF THE LARVAE OF DELIA-RADICUM L, D-FLORALIS F AND D-ANTIQUA MG (DIPTERA, ANTHOMYIIDAE)." International Journal of Insect Morphology & Embryology 20(6): 275-282.

A comparative SEM study of the sensilla of larval Delia radicum, D. floralis and D. antiqua (Diptera : Anthomyiidae) was undertaken. All had a dorsal organ and an anterior organ. These may contain olfactory receptors, contact chemo- and mechanoreceptors. Delia radicum and D. floralis also possessed a ventral organ, which is a possible chemo- and mechanoreceptor. Campaniform (mechanoreceptor) and hair sensilla, which may be humidity receptors, were present on the body segments.

Ross, K. T. A. and M. Anderson (1991). "ULTRASTRUCTURE OF THE FUNICULAR SENSILLA OF THE CABBAGE ROOT FLY, DELIA-RADICUM L (DIPTERA, ANTHOMYIIDAE)." International Journal of Insect Morphology & Embryology 20(3): 83-101.

A transmission electron microscope study of the funicular sensilla of the cabbage root fly, Delia radicum, (Diptera:Anthomyiidae), showed 4 types of surface sensilla and 5 types of pit sensilla. The ultrastructure of the surface sensilla indicated all had a primary olfactory function. These include thick-walled multiporous trichoid sensilla, thin-walled multiporous basiconic sensilla (with 2 subtypes), thin-walled multiporous clavate sensilla, and grooved sensilla with channels at the base of each of the grooves. Clavate sensilla had 2 types of dendrites, one tubular, the other "scrolled". This 2nd type may indicate an additional thermosensitive function. The dorsal pits contained thin-walled multiporous basiconic sensilla with a tapered tip. The ventral pits contain 3 types of sensilla, which have no wall pores and an inflexible socket. These may contain thermo- and/or hygroreceptors and include smooth-walled conical-, smooth-walled tapered- and striated pit sensilla. The 4th type is a grooved pit sensillum similar to the surface type.

Vandesteene, F. and L. Vanparys (1991). "GRANULE INSECTICIDES APPLICATIONS FOR CONTROLLING THE CABBAGE ROOT FLY DELIA BRASSICAE-B IN BRUSSELS-SPROUTS." Landbouwtijdschrift-Revue De L Agriculture 44(1): 21-30.

The effectiveness of the insecticides chlorfenvinphos, carbofuran, carbosulfan, chlorpyrifos, fonofos, furathiocarb, tefluthrin and chlorpyrifos + dimethoate in controlling larvae of the cabbage root fly was investigated during 1986, '87, '88 and '89. These experiments were carried out at Staden on Brussels sprouts planted at the end of May. Granule insecticides were applied around the base of the plant with a graduated glass a few days after planting or at planting in the row with a strewer. Damage to the roots of the Brussels sprouts by cabbage root fly larvae was assessed both 5-6 and 11-12 weeks after planting. In each experiment the damage to the cortex of the roots of 20 to 40 plants of each treatment was assessed on a five category scoring scale. In that way, a mean root damage index was calculated for each treatment. The numbers of larvae and pupae were also recorded on the plants assessed for root damage and the mean numbers of larvae and pupae per plant were calculated. In 1986, the roots of the Brussels sprouts were heavy infested by larvae of the cabbage root fly, at the first counting 12 larvae were found at the untreated plants. Treatments with

granules around the base of the plants were very efficient, but the activeness of treatments in the row was poor: 3 to 5 larvae were found. On the other hand, there was little damage caused by the larvae of the cabbage root fly during 1987 and '88 and every treatment was efficient. Just like in 1986, the roots of the Brussels sprouts were heavily damaged in 1989: at the second counting 17 larvae and pupae were found at the untreated plants. Once more, the treatments in the row were little effective.

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Cole, R. A., T. H. Jones and S. Finch (1989). "DETERRENT EFFECT OF CARBOXYLIC-ACIDS ON CABBAGE ROOT FLY OVIPOSITION." Annals of Applied Biology 115(1): 39-44.

Collier, R. H., S. Finch and M. Anderson (1989). "LABORATORY STUDIES ON LATE EMERGENCE IN THE CABBAGE ROOT FLY (DELIA-RADICUM)." Entomologia Experimentalis Et Applicata 50(3): 233-240.

Collier, R. H., S. Finch and M. Anderson (1989). "OXYGEN-UPTAKE BY PUPAE OF EARLY-EMERGING AND LATE-EMERGING BIOTYPES OF THE CABBAGE ROOT FLY DELIA-RADICUM L." Functional Ecology 3(5): 613-616.

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Kowalski, R., S. E. Davies and C. Hawkes (1989). "METAL COMPOSITION AS A NATURAL MARKER IN ANTHOMYIID FLY DELIA-RADICUM (L)." Journal of Chemical Ecology 15(4): 1231-1239.

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To determine the importance of beetle predators on the natural control of cabbage root fly, experiments were carried out in 1958 and 1959 using various types of barriers to obtain different levels of beetle populations on cauliflower plots. A barrier of DDT-treated straw, placed in the soil around some plots, decreased the numbers of beetles within them and allowed a greater number of eggs and larvae of cabbage root fly to survive than on the untreated plots,

resulting in a greater crop damage. Another type of barrier allowed the beetles to enter plots but made it difficult for them to leave. On these, fewer cabbage root-fly eggs and larvae survived and the crop damage was much less than on the plots surrounded by straw barriers. Where plants were treated with insecticide the root-fly population was reduced to a minimum and crop yields were considerably increased. The insecticide, however, caused a reduction in the numbers of predatory beetles.

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