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Prospects for the insect parasitic nematode *Thripinema nicklewoodi* (Siddiqi) against Western flower thrips, *Frankliniella occidentalis* (Pergande) in ornamentals

Steven Arthurs & Kevin M. Heinz..... 1

Abstract: There is an urgent need for effective biological control agents for western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) infesting greenhouse ornamentals. We are evaluating potential introduction strategies for the thrips parasitic nematode, *Thripinema nicklewoodi* Siddiqi, which although not lethal causes sterility of female WFT. Laboratory studies show that the nematode can infect and reproduce in WFT over the range of temperatures recorded in a Texas (U.S.A.) commercial greenhouse during thrips outbreak periods. Moreover, greenhouse studies using potted chrysanthemums demonstrate that it may establish within WFT populations following low level inoculation. However, relatively poor transmission and slow speed of kill prevented it from being effective over a single crop cycle. *T. nicklewoodi* may have value in a longer term thrips management strategy and/or in combination with other biological control agents.

Key words: *Thripinema nicklewoodi*, Western flower thrips, nematodes, biological control

The costs of biological pest control in protected tomato crops

Andrzej Bednarek & Wojciech Goszczyński..... 5

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Key words: tomato crops in greenhouses, biological pest control, natural enemies, cost of plant protection, whiteflies, mites, leaf miners

Choice of predatory mites for biological control of ground-dwelling stages of western flower thrips within a 'push-pull' strategy on pot chrysanthemum

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Key words: western flower thrips, *Frankliniella occidentalis*, *Orius laevigatus*, *Stratiolaelaps (Hypoaspis) miles*, *Gaeolaelaps (Hypoaspis) aculeifer*, pot chrysanthemum, biological control

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Abstract: Western Flower Thrips (WFT) *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), is worldwide one of the most important pests on vegetables and ornamental crops under greenhouse and field conditions. Conventional chemical and biological control tactics, targeting only at the foliar-feeding stages, usually provide no satisfactory control levels. Thus we investigated the potential of entomopathogenic nematodes (EPNs) and soil inhabiting predacious mites (*Hypoaspis* spp.) against soil-dwelling life stages of WFT. Our results indicate that all soil-dwelling life stages of WFT are susceptible to the tested EPN strains/species. Virulent strains, applied at a dose rate of 400 infective juveniles cm⁻² resulted in 80 and 40–60% WFT mortality under laboratory and microcosm conditions, respectively. Releases of *H. aculeifer* (Canestrini) at 2,800 mites m⁻² reduced WFT population by 78%. Combined applications of EPNs and *H. aculeifer* significantly lowered the number of emerging WFT adults compared to the untreated control as well as to individual releases of EPNs and predacious mites. These findings may open up a new venue for biological control of WFT.

Key words: Western Flower Thrips, *Frankliniella occidentalis*, entomopathogenic nematodes, *Hypoaspis* spp., biological control

Higher-order predators in greenhouse systems

Jacques Brodeur, Conrad Cloutier & Dave Gillespie.....33

Abstract: A growing number of biological control programs tend to combine two or more species of natural enemies to reduce populations of arthropod pest species. Recent evidence from field situations indicates that higher-order predators may disrupt biological control by interfering with other beneficial organisms, mainly through intraguild predation. In greenhouse crops, higher-order predators are usually released as a second line of defense, when pest populations have reached high densities. We argue that interference by higher-order predators is less likely to be important in greenhouses than in other agroecosystems. The negative effects of intraguild predation would be reduced by the low probability of establishment of higher-order predators and the periodic releases of high numbers of more specialized biocontrol agents.

Key words: greenhouse crops, biological control, intraguild predation, generalist predators

The potential of *Atheta coriaria* Kraatz (Coleoptera: Staphylinidae), as a biological control agent for use in greenhouse crops

V.A. Carney, J.C. Diamond, G.D. Murphy & D. Marshall.....37

Abstract: An efficient, cost-effective protocol for rearing the staphylinid *Atheta coriaria* Kraatz on an artificial diet was developed. Laboratory trials showed *A. coriaria* to be highly predatory against fungus gnats, shoreflies and western flower thrips. A naturally occurring population of *A. coriaria* in a commercial greenhouse demonstrated its potential for long-term establishment and survival.

Key words: biological control, *Atheta coriaria*, rearing, predation, monitoring, greenhouses

Distribution, thresholds, and biological control of the twospotted spider mite (Acari: Tetranychidae) on bent cane cut roses in California

Christine Casey & Michael Parrella.....41

Abstract: The goal of this project was to develop an IPM program for the twospotted spider mite on greenhouse grown bent cane cut roses. This work was part of a larger project to develop a model IPM program for floriculture crops that incorporated the use of fixed precision sampling, action thresholds, and biological control. Specifically, we used Taylor's power law to quantify twospotted spider mite spatial distribution in order to develop a sampling plan. We also examined the relationship between spider mite density and photosynthesis in the rose plant to develop an action threshold for this pest. Finally, we

looked at a technique to enhance movement of the mite predator, *Phytoseiulus persimilis*, in this crop.

Twospotted spider mite spatial distribution was shown to be highly aggregated on bent cane roses under both chemical and biological control. Using the Taylor's power law coefficients we determined that a sample of 38 plants per 929 m² could predict mite density with a precision of 0.25. The relationship between spider mite density and rose plant photosynthesis suggested that our nominal action threshold of 5 mobile stages/leaf/week was too low. We also demonstrated that the use of interplant bridges facilitated predatory mite movement between rose plants in the bent cane system. Implementation of the IPM program developed from this study resulted in key pest densities and control costs that were comparable to or less than those obtained under a conventional control program.

Key words: sampling, thresholds, photosynthesis, biological control, roses, *Tetranychus urticae*, *Phytoseiulus persimilis*

Demonstration and implementation of a reduced risk pest management strategy in fresh cut roses

Christine Casey & Michael Parrella45

Abstract: Our goal was to develop and implement a pest management program using reduced risk pesticides and biological control agents to manage the key pests of cut roses. This program represents the largest effort to implement an IPM program on floriculture crops in the United States. Eight growers spanning the major rose production areas of California participated. Data were collected at each location from an IPM and a conventional practice greenhouse. We used a comprehensive sampling plan that provided information on the density of insects, mites, and diseases. Based on thresholds developed for each of the pests, we took no action; applied a reduced risk pesticide; or released biological control agents.

Twospotted spider mite and western flower thrips densities were the same or significantly lower in the IPM compared to the conventional practice greenhouses. Biological control of mites was successful at all locations. Pesticide use was generally lower in the IPM greenhouses. Efforts to reduce prophylactic applications of fungicides using a model to predict powdery mildew incidence need further study. Control costs were comparable under the two programs.

Key words: sampling, thresholds, biological control, roses

Status of biological and integrated control in greenhouse vegetables in Spain: Successes and challenges

Cristina Castañé49

Abstract: Spain is one of the main vegetable producers in Europe. Due to the mild weather greenhouses are unheated semi-open structures in which pest populations reach high levels. Pest origin is mainly from outdoors but there is also a rich fauna of natural enemies that colonize the greenhouses. This is an important consideration for developing effective biological control programs in this region. Nowadays, peppers are the main success in biological control, in spite of the Tomato Spotted Wilt Virus problem transmitted by the western flower thrips. For tomatoes, biological control is only applied in regions free of inoculums of the Tomato Yellow Leaf Curl Virus, transmitted by *Bemisia tabaci*.

Key words: tomato, peppers, thrips, whiteflies, natural enemies

Preliminary study on the effect of nitrogen fertilization on cotton aphid, *Aphis gossypii*

Amanda Chau, Kevin M. Heinz & Fred T. Davies, Jr.53

Abstract: The effect of nitrogen fertilization on the abundance of cotton aphid, *Aphis gossypii* Glover, was studied on chrysanthemum, *Dendranthema grandiflora* Tzvelev var. "Charm". We tested five fertilization treatments that consisted of 20%, 50%, 75%, 100% and 130% of the recommended nitrogen level. We transferred five apterous aphids to each pot at the beginning of the experiment and counted aphids weekly for 3 weeks. There were

no significant effects of nitrogen on aphid abundance possibly due to delay reaction of the host plants to changes in nitrogen levels.

Key words: cotton aphid, *Aphis gossypii*, nitrogen fertilization, chrysanthemum, *Dendranthema grandiflora*, aphid abundance

Intraspecific interactions among the predators *Orius majusculus* and *Aphidoletes aphidimyza*

Rikke Kirkeløkke Christensen, Annie Enkegaard & Henrik F. Brødsgaard.....57

Abstract: Predation by the generalist predator *Orius majusculus* on the widely used aphid predator, *Aphidoletes aphidimyza* was studied in laboratory experiments. In 24-hour tests in small arenas, mortality of *A. aphidimyza* eggs and larvae were measured when exposed to *O. majusculus*. In addition it was examined if the introduction of aphids, *Aphis gossypii*, as alternative prey would affect the degree of predation. *O. majusculus* consumed gallmidge eggs in large numbers, independent of the presence of aphid prey. Larvae of *A. aphidimyza* was killed in substantial amounts when presented to *O. majusculus* as the only prey species, but the predation was significantly reduced in the presence of *A. gossypii*.

Key words: *Aphidoletes aphidimyza*, *Orius majusculus*, intraguild predation, biological control, glasshouse crops

The interplay between biological characteristics and interactions among predatory mites in biocontrol on protected crops

Michael de Courcy Williams & Lidija Kravar-Garde61

Abstract: The survival of the immature stages of four species of phytoseiid mites (*Phytoseiulus persimilis*, *Iphiseius degenerans*, *Neoseiulus californicus* and *N. cucumeris*) was high and the adult life span (after the first egg was laid) varied between 19-58 days between species. Survival of food deprivation differed substantially between species and was doubled when water was available. There was little indication of negative intra- or inter-specific interactions between the immatures of the four species when food was available. Under food deprivation the survival of immatures of the specialist predator *P. persimilis* was reduced by the generalist predators *N. californicus* and *I. degenerans*.

Key words: phytoseiid mites, life span, survival, interactions, intraguild predation

“Resistance” towards biological control

Annie Enkegaard & Henrik F. Brødsgaard.....65

Abstract: Failure in biological control of the shallot aphid, *Myzus ascalonicus*, a close relative of *M. persicae*, with the parasitoids *Aphidius colemani* and *A. ervi* in a Danish commercial Bellflower culture led to investigations into the interactions between the aphids and the parasitoids. Laboratory experiments revealed that *A. colemani*, *A. ervi* and *Aphelinus abdominalis* either did not parasitise or had an extremely low degree of parasitisation of *M. ascalonicus*. This resulted from behavioural defence mechanisms that caused *M. ascalonicus* to quickly drop from the plants or walk away from the parasitoid in response to the first examining touch combined with apparent emission of alarm pheromones to alert the aphid colony. The parasitoids lost interest in the aphids when they began walking. This, combined with the fact that a large proportion of dropping aphids probably survived by merely landing on lower plant parts of the very compact Bellflower plants, meant that *A. colemani* and *A. ervi* neither directly nor indirectly exerted any effect on the *M. ascalonicus* population – creating, in effect, a situation of resistance to parasitoid biocontrol.

Key words: *Myzus ascalonicus*, *Myzus persicae*, *Aphidius colemani*, *Aphidius ervi*, *Aphelinus abdominalis*, parasitisation, biological control, glasshouse pests

New pests in Ontario greenhouse vegetables

G. Ferguson & Les Shipp69

Abstract: The increasing occurrence of new pests in Ontario is an emerging issue with the industry. The constant need to develop new control programs that are compatible with

existing IPM programs has been increasingly difficult. Between 1991 and 2001, eight new pests have been observed in greenhouse vegetable crops in Ontario. Such a situation calls for increased vigilance over the movement of goods and people into, and out of Ontario. It also requires that we give thought to potential new pests and the measures necessary for combating such pests.

Key words: new pests, Ontario, greenhouse vegetables

Biological and integrated control in vegetables in British Columbia: The challenge of success
David R. Gillespie73

Abstract: The production of greenhouse vegetable crops in British Columbia has grown in the past two decades, and relies heavily on natural enemies for control of pest insects and mites. This growth, increased sophistication of the industry, and increased complexity of the IPM system, constrains the application of natural enemies for biological control of pests and predisposes the IPM system to failure. These constraints must be addressed if biocontrol-based IPM in greenhouses is to continue.

Key words: pests, natural enemies, integrated control

Mass rearing of *Aphidoletes aphidimyza* Rondani for control of aphids
Hyun Gwan Goh.....77

Abstract: Mass rearing of predatory gall midge *Aphidoletes aphidimyza* Rondani was studied. All of the three foods must be grown or reared: plant-aphid-gallmidge. The mass rearing was studied in three steps: 1) growing pea and cucumber plants, 2) rearing of aphids, and 3) rearing of *A. aphidimyza*. The pea and *Megoura crassicauda* were used for *A. aphidimyza* larva. The cucumber and *Aphis gossypii* served as a stimulus of oviposition of the *A. aphidimyza* adult.

Key words: mass rearing, *Aphidoletes aphidimyza*, *Megoura crassicauda*, *Aphis gossypii*

Developments in IPM for protected cropping in Australia
Stephen Goodwin & Marilyn Steiner81

Abstract: The Australian protected cropping industry is receiving support for improvements to pest and disease management through a number of initiatives. These include the provision of two new Centres for R&D dedicated to the industry, the development of publications to assist producers to adopt IPM strategies and as a resource for a new training course designed specifically for them, and a program of research to continue the development of native natural enemies as biocontrol agents. The last mentioned started with the commercial release of the indigenous phytoseiid mite, *Typhlodromips montdorensis* (Schicha) for use against western flower thrips, *Frankliniella occidentalis* (Pergande) and other key thrips species such as onion thrips, *Thrips tabaci* Lindeman and plague thrips, *Thrips imaginis* Bagnall. The research program also includes the evaluation of new biorational products involving azadirachtin (AzaMax™) and the beneficial fungi, *Beauveria bassiana*, *Metarrhizium anisopliae* and *Verticillium lecanii*, and a range of chemistry new to the Australian horticultural industry.

Key words: IPM, protected cropping, Australia

Physical methods for the control of *Bemisia tabaci* and its impact on TYLCV infection in greenhouse tomato in Morocco
A. Hanafi, B. Murphy, I. Alaoui & R. Bouharroud.....85

Abstract: The development of IPM tactics in greenhouse crops in Morocco has evolved quickly over the last ten years showing impressive reductions in pesticide use while improving crop quality and yield. Unfortunately, the introduction of Tomato Yellow Leaf Curl Virus (TYLCV) and its vector, *Bemisia tabaci* has significantly increased the need for pesticide applications and impacted the ability of many growers to grow disease free crops. In response growers have been adapting IPM tactics focused primarily on prevention of

disease transmission. A number of tactics have been implemented with some degree of success such as resistant cultivars, rouging diseased plants, and alternate planting dates. For managing the vector, *B. tabaci*, farmers have adopted improved pest monitoring and control guidelines, mass trapping, exclusion nets, and pesticide rotation to preserve effective pesticides. However, the two tactics most relied on by farmers are chemical controls and exclusion nets to reduce disease transmission by *B. tabaci*. Nowadays, over 98% of greenhouses use insect nets of various mesh gauge sizes to exclude *B. tabaci* from greenhouses. Considering the time and expense devoted to exclusion nets, evaluations were begun to determine the benefits of using insect nets within the overall IPM program. Factors such as the effect of mesh size on disease incidence and *B. tabaci*, impact on biological control, disease management and crop yields are included. The first objective of the program compared the efficacy of two mesh gauge sizes most commonly used by farmers, the 10x14 and the 10x20 gauge mesh. Preliminary field comparisons suggest there may be significant differences in efficacy between the most common mesh gauges and their value to pest management.

Key words: Tomato Yellow Leaf Curl Virus, exclusion nets, physical control, *Bemisia tabaci*

Evaluating a new non-toxic pesticide for integrated control of *Bemisia tabaci* in protected agriculture in Morocco

A. Hanafi, R. Bouharroud & B. Murphy89

Abstract: The introduction of TYLCV and its insect vector *Bemisia tabaci* have exacerbated crop losses, disrupted IPM programs and have seen the loss of pesticides to insect resistance from overuse. In the Mediterranean and North African regions this pest complex has single-handedly challenged the ability of the region to produce high quality and quantity of horticultural products for the export market. To address this problem, investigations were begun to modify current IPP practices to include more effective management tactics for TYLCV and *B. tabaci*. One focus of this research was the evaluation of alternative pesticides for control of *B. tabaci* populations that would not disrupt current IPM programs. Here we present preliminary results evaluating the efficacy, field performance and user recommendations for one alternative pesticide, AGRI-50 (CAL AGRI PRODUCTS, Los Angeles, California, USA). Evaluations were conducted in the laboratory to ascertain efficacy at all life stages of *B. tabaci*. Further studies were conducted in commercial tomato greenhouses in Morocco to determine optimum application rate, spray volume and compatibility with commercial cultural practices. Laboratory trials have shown AGRI-50 to be effective against the adult and all nymph stages of *B. tabaci*, particularly, the tenacious pupa stage at concentrations from 2500 to 5000 ppm. A single application was found capable of nearly complete control of late *B. tabaci* pupae and prevented emergence of the newly developed adults. In commercial tomato greenhouse trials AGRI-50 was found to achieve economic control equal to or greater than many conventional pesticides. Furthermore, it was found that this level of control could be achieved using standard application equipment and spray volumes. Research examining compatibility of AGRI-50 with current IPM practices have shown that bumble bee pollinators are unaffected by Agri-50 applications and evidence has been accumulated showing relatively low impact on important natural enemies such as *Eretmocerus* sp. and *Diglyphus* sp. parasitoids.

Key words: IPM, *Bemisia tabaci*, AGRI-50, low risk insecticides, greenhouse

Biological control of cabbage root fly using entomopathogenic nematodes in glasshouse experiments

Andrew J. Hart & Deena M. Willmott93

Abstract: A number of different species and isolates of entomopathogenic nematodes were used against cabbage root fly, *Delia radicum*, infesting potted cauliflower under glasshouse conditions. *Steinernema affine* was found to be the most effective isolate tested. This isolate was then compared with a commercial product (*S. feltiae*, marketed as 'Nemasys®) at a range of doses. *Steinernema affine* gave a significantly higher level of control compared to the commercial strain.

Key words: entomopathogenic nematodes, *Steinernema* spp., biological control, *Delia radicum*

Development of an integrated control strategy for leafminers in leafy salads with potential for extrapolation to other cropping systems
Justine Head, Lisa F. Palmer & Keith F.A. Walters.....97

Abstract: Leafminers are serious pests of many cropping systems throughout the world. With increased resistance to pesticides new approaches are required to obtain high levels of control. The efficacy and compatibility of chemical insecticides and foliar applications of the entomopathogenic nematode, *Steinernema feltiae*, were evaluated for the control of *Liriomyza huidobrensis*. In the laboratory, pesticides routinely used against leafminers resulted in less than 30% larval mortality, whereas 65% mortality followed treatment with abamectin. In contrast, up to 97% larval mortality was obtained by one application of *S. feltiae* made to an infested Chinese brassica crop as part of an integrated program. Information obtained in this study has potential for use in other cropping systems.

Key words: *Liriomyza huidobrensis*, entomopathogenic nematodes, insecticides, integrated pest control

Abamectin plus pymetrozine; an extremely useful addition to the IPM armoury
Neil Helyer101

Abstract: Abamectin is active against spider mites and, at a higher rate, leaf miners and thrips, whereas the selective pesticide pymetrozine has activity against many sap sucking insects such as aphids, mealybug and whitefly but minimal side effects on most beneficials. The two products can be safely mixed together for spray application against a wide range of pest organisms including as above plus leaf hopper, psyllids and scale insects. Trials indicate good crop safety when applied to poinsettia for control of autumn migrating whitefly and thrips, whilst enabling growers to maintain a background biological control programme.

Key words: abamectin, pymetrozine, integrated control, sucking pests, phytotoxicity, poinsettia, whitefly

Development and life-span of *Macrolophus pygmaeus* Rambur at different temperatures and influence of host plants and prey
Martin Hommes & Stephanie ter Horst.....103

Abstract: In Germany, releases of *Macrolophus* bugs to control whiteflies in protected tomato crops have developed into a standard procedure. Currently two different species, the Mediterranean *M. caliginosus* Wagner and the endemic *M. pygmaeus* Rambur are offered on the market. To find out which species should be preferred for biological pest control some investigations on the biology of the endemic species were conducted. The life-span of *M. pygmaeus* adults was very long, on average from 24 days at 25°C to 140 days at 15°C for females and from 41 to 192 days for males, respectively. The mean development time for all larvae stages together took 15.5 days at 25°C to 37.5 days at 15°C. The investigations on host plants and prey showed that if enough prey food was offered, the influence of the host plant was negligible. Whereas without sufficient food supply the host plant has a great effect on the development and mortality of larvae stages.

Key words: biology, life-span, development time, predatory bug, *Macrolophus pygmaeus*

Predation and oviposition rate of the predatory bug *Orius laevigatus* in the presence of alternative food
Jan Hulshof & Marika Linnamäki107

Abstract: The effect of the presence of alternative food (*Ephestia kuehniella* eggs and pine pollen) on the predation and fecundity rate of *Orius laevigatus* was studied. The presence of pine pollen enhanced the predation rate of 3rd instar nymphs and adult bugs on thrips larvae (*Frankliniella occidentalis*), whereas the predation rate of the 4th instar nymphs on thrips larvae and that of adult female bugs on adult thrips was not affected. Both nymphal stages killed, irrespective of the presence of alternative food, only thrips larvae,

but not adults, when both stages were offered simultaneously. Even in the absence of thrips as prey, both pine pollen and *E. kuehniella* eggs supported the bugs' fecundity. In preliminary greenhouse tests, the alternative food did not enhance the bugs' persistence in the cucumber crop, probably due to cannibalism. Further experiments should therefore consider not only the alternative food, but also the assumed cannibalistic behavior of the bugs.

Key words: *Orius laevigatus*, *Frankliniella occidentalis*, alternative food, pollen, *Ephestia kuehniella*

Lygus rugulipennis Poppius (Het. Miridae): Options for integrated control in glasshouse-grown cucumbers
R.J. Jacobson.....111

Abstract: Damaging infestations of *Lygus rugulipennis* Poppius are becoming more common in glasshouse-grown cucumbers in the U.K. and IPM compatible control measures are urgently required. The entomopathogenic fungus, *Beauveria bassiana* [Balsumo] Vuillemin, and the antifeedant chemical, pymetrozine, have been shown to reduce *L. rugulipennis* numbers and damage respectively when applied as high volume sprays or low volume mists. A combination of both control measures may provide the ultimate solution to this problem.

Key words: *Lygus rugulipennis*, cucumbers, *Beauveria bassiana*, pymetrozine, IPM

Interactions between the two polyphageous predators *Orius majusculus* and *Macrolophus caliginosus*
Lene Jakobsen, Annie Enkegaard & Henrik F. Brødsgaard115

Abstract: The mutual predation between the two polyphagous predators *Orius majusculus* and *Macrolophus caliginosus* was examined in laboratory experiments in the presence and absence of *Frankliniella occidentalis*. Predation occurred but was unidirectional since neither nymphs nor adults of *M. caliginosus* preyed upon *O. majusculus*. Adults of *O. majusculus* preyed upon *M. caliginosus* in absence and in some circumstances also in presence of *F. occidentalis*. *O. majusculus* nymphs did not prey upon *M. caliginosus* either adults or nymphs. The predation rate of *O. majusculus* on *F. occidentalis* was unaffected by the presence of *M. caliginosus*. This suggests that the presence of *M. caliginosus* in a culture will not hamper the biological control of *F. occidentalis*.

Key words: biological control, interactions, *Macrolophus caliginosus*, *Orius majusculus*, *Frankliniella occidentalis*

Spinosad: An effective biocide for inclusion in integrated pest management programs for *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) on greenhouse cucumbers
Terri Jones, Cynthia Scott-Dupree, Ron Harris, Les Shipp & Brenda Harris.....119

Abstract: Currently there are no efficacious insecticides available for use against western flower thrips *Frankliniella occidentalis* Pergande, that have minimal impact on biological control agents that are used in integrated pest management programs for greenhouse cucumbers. Our research indicates that the biocide spinosad is effective against thrips and has minimal impact on *Orius insidiosus* (Say).

Key words: spinosad, western flower thrips, integrated pest management, greenhouse, biological control agents

The potential of Sterile Insect Technique (SIT) as one of the strategies for control of *Liriomyza trifolii* (Diptera: Agromyzidae) infesting greenhouse crops
Roy Kaspi & Michael Parrella123

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Key words: *Diglyphus isaea*, *Liriomyza trifolii*, SIT

Influence of extracts from sage (*Salvia officinalis* L.) on some biological parameters of *Tetranychus urticae* Koch. feeding on Algerian Ivy (*Hedera helix variegata* L.)

Beata Kawka & Anna Tomczyk127

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Key words: sage extracts, *Tetranychus urticae*, biology parameters, *Hedera helix variegata*

The impact of the exotic predatory mite *Neoseiulus californicus* (McGregor) on native phytoseiid species

Danuta Kropczyńska131

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Key words: *Neoseiulus californicus*, releases, local fauna of phytoseiid mites

An overview of biological control in ornamental greenhouses in Québec, Canada

Liette Lambert, Alain Cécyre, Thierry Chouffot, Susan Johnson & Andrée Roy135

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Key words: ornamental, biological control, Canada (Quebec), greenhouses, interior plantscapes

When native non-target species go indoors: a new challenge to biocontrol of whiteflies in European greenhouses <i>A.J.M. Loomans, I. Staneva, Y. Huang, G. Bukovinskiné-Kiss & J.C. van Lenteren</i>	139
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Key words: *Aleyrodes proletella*, *Aleyrodes lonicerae*, *Encarsia*, *Eretmocerus*, biocontrol, non-target

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Key words: intraguild predation, hyperparasitism, *Encarsia*, biocontrol, non-target effects

Evaluating environmental risks of biological control introductions: how to select safe natural enemies? <i>A.J.M. Loomans, J.C. van Lenteren, F. Bigler, G. Burgio, H.M.T. Hokkanen & M.B. Thomas</i>	147
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Key words: biological control, introductions, exotics, environmental risks, non-target effects

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different species of beneficial were introduced on more than twenty-five different crop, thus showing that it is possible to develop this technique on a large scale. The efficiency of introduced beneficials is increased by using banker-plants on approximately 95 ha; it will certainly be possible to decrease the unit cost in this way.

Key words: biological control, France, areas, pests, beneficials, vegetables, ornamentals

Biological control French greenhouse ornamentals
Jean-Charles Maisonneuve155

Introduction: From 1988, biological control (BC) has been developed in France in greenhouse ornamentals, reaching 52 hectares of these crops in 2001. Ten years ago, it was difficult to imagine this kind of crop protection. However, a constant increase of this area in that period has been observed.

Many crops can be protected by this alternative way of plant protection: - cut flowers, - potted plants, - bedding plants, - cities greenhouses

So, these examples of application of BC on very different crops show that it is possible to protect many crops and not only tomato or cucumber, like in the past, with an acceptable cost. The main idea about this development can be thus summarised: in 2002 the beneficials sold are able to protect a large scale of ornamental crops.

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Christine Marrec, Franck Lolivier, Géraldine Le Corre & Jean-Charles Maisonneuve161

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Key words: *Chrysoperla carnea*, *C. kolthoffi*, biological control, strawberry, aphid

Regulations are necessary for biological control agents
Peter G. Mason & Ulrich Kuhlmann165

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Key words: regulations, biological control, invasive species, biodiversity

Mating disruption of cabbage loopers (*Trichoplusia ni*, Lepidoptera: Noctuidae) and the response of *Trichogramma brassicae* (Hymenoptera: Trichogrammatidae) to host pheromone in pepper greenhouses
R.R. McGregor, D.R. Gillespie, D.M.J. Quiring & M.R.J. Foisy173

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Key words: spider mites, biological control, integrated control

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Key words: *Chrysodeixis chalcites*, *Spodoptera exigua*, *Cotesia marginiventris*, *Cotesia vanessae*, greenhouse vegetables

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Key words: *Anthocoris* spp., aphids, voracity, prey preference, biological control, glasshouse pests

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Key words: *Anthocoris* spp., aphids, intraguild predation, prey preference, biological control

The use of biological control in Canadian greenhouse crops

G.D. Murphy, G. Ferguson, Ken Fry, Liette Lambert, Margaret Mann & Jim Matteoni.....193

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Key words: biological control, Canada, greenhouses, survey

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Bożena Nawrocka201

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Key words: *Frankliniella occidentalis*, cucumber, tomato, control, Spinosad

Macrolophus caliginosus affected by a fungal pathogen

Barbro Nedstam205

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Key words: *Macrolophus caliginosus*, *Entomophthora* sp., tomato, biological control

Biotechnology and its potential effect on the development and implementation of biological control/IPM strategies in greenhouses

Michael Parrella209

Abstract: Biotechnology can be defined as the application of our knowledge and understanding of biology to meet practical needs. By this definition, biotechnology is as old as the growing of crops and the making of wines and cheeses. Today's biotechnology is largely identified with molecular biology and its applications in medicine and agriculture based on our understanding of the genetic code of life. While controversy swirls around this technology in both scientific and lay circles, one cannot doubt that we are in the midst of a biological revolution. Various aspects of this technology including the advent of transgenic crops and utilizing the tools of biotechnology for studies of arthropods and pathogens will be reviewed and discussed with respect potential impact on development and implementation of biological control and IPM in glasshouses.

Key words: biotechnology, transgenic crops, biological control, IPM

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Key words: biological control, greenhouse pests, two-spotted spider mite, *Tetranychus urticae*, greenhouse whitefly, *Trialeurodes vaporariorum*, entomopathogenic fungi, entomopathogenic bacteria, *Paecilomyces fumoso-roseus*, *Bacillus thuringiensis*

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P.M.J. Ramakers & R.H.M. Maaswinkel.....221

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Key words: organic, chrysanthemum, pest, aphid, thrips

Current status of biological control of diseases in greenhouse crops – a commercial perspective

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The future prospects for microbial fungicides are discussed from the industry point of view.

Key words: biological control, biopesticides, commercialisation, disease, market, registration

Fecundity and survival of mass reared *Phytoseiulus persimilis* (Acari:

Phytoseiidae)

David A. Raworth & Susan Bjørnson233

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Key words: *Phytoseiulus persimilis*, fecundity, survival, model, efficacy

Influence of greenhouse microclimate on the efficacy of *Beauveria bassiana* (Balsamo) Vuillemin for control of greenhouse pests
Les Shipp, Yun Zhang, David Hunt & Gillian Ferguson237

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Key words: *Beauveria bassiana*, greenhouse pests, humidity, greenhouse vegetables

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Key words: biological control, natural enemy, movement, dispersal, virtual plants

Development of a new thrips predator, *Typhlodromips montdorensis* (Schicha) (Acari: Phytoseiidae) indigenous to Australia
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Key words: phytoseiid mite, thrips, integrated control

Management of thrips on cucumber with *Typhlodromips montdorensis* (Schicha) (Acari: Phytoseiidae)
Marilyn Steiner & Stephen Goodwin249

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Key words: cucumber, thrips, phytoseiid mites, integrated control

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Key words: *Macrolophus caliginosus*, *Tetranychus urticae*, *Trialeurodes vaporariorum*, functional response, prey preference

State of integrated crop protection in Dutch nursery stock and future prospects

Anton van der Linden269

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Key words: pests, diseases, integrated control, natural enemies

Greenhouse trials in Massachusetts and New York with *Amblyseius cucumeris*: effects of formulation and mechanical application

Roy Van Driesche, Suzanne Lyon, John Sanderson, Tina Smith, Paul Lopes, Susan MacAvery, T. Rusinek & Gary Couch273

Abstract: Trials in spring bedding plant crops in 2000 and 2001 in Massachusetts and New York commercial greenhouses measured the ability of *Neoseiulus (Amblyseius) cucumeris* to control western flower thrips, *Frankliniella occidentalis*. In 2000, the effect of formulation (mites in bran vs. sachets) was examined at three businesses. At all three sites, we found that sticky card catches of adult thrips were lower in greenhouses receiving mites formulated in bran vs. sachets. In 2001, we compared western flower thrips densities in greenhouses in which *N. cucumeris* releases were made either via hand application (sprinkle) of mites formulated in bran or mechanical application of the same material with a battery powered air blower ("mite gun"). Results suggested that the two application methods did not differ in their ability to suppress thrips populations.

Key words: western flower thrips, predacious mites, formulation method, application method, *Neoseiulus (Amblyseius) cucumeris*, *Frankliniella occidentalis*, biological control, bedding plants

Invasive species as pests in greenhouses: forecasting, preventing and remediating future invasions

Roy Van Driesche277

Abstract: Greenhouses are susceptible to invasions from local species pools. Some such invaders have characteristics permitting them to be moved readily by the shipment of plant materials between businesses within the greenhouse industry, allowing species to become internationally distributed pests, sometimes in relatively brief periods. Such new pests disrupt pest control systems and require new responses. Greenhouse operators need to predict, prevent and remediate such invasions by deliberate collective action. Prediction should flow from crop-specific, country-specific inventories of current greenhouse pests to identify pests of greenhouse crops still confined to local areas, but which have features conducive to further spread. Prevention should be fostered by

development of sophisticated, web-based identification systems focused on the high risk potential invaders identified in the prediction phase. Remediation requires application of classical biological control, an approach not familiar to greenhouse operators. This approach requires search for new natural enemies in the native ranges of new pests, study of host ranges of new agents, obtaining legal permissions for release of new agents in multiple countries, and finally development of systems for production of new species. Production of some species will be uneconomical for insectaries, but might be achieved through mutual aid networks of entomologists at conservatories and other facilities. These activities require the development of a new body, an international consortium of greenhouse operators, which can pool contributions of member businesses and hire staff with appropriate technical expertise to conduct the activities mentioned above. Such a coordinated effort to confront invasive species in greenhouses is likely to be more effective than the current fragmented system of local response.

Key words: greenhouses, invasive species, prevention, forecasting, classical biological control

Risks of importation and release of exotic biological control agents: how to determine host specificity?

J.C. van Lenteren, F. Bigler, G. Burgio, H.M.T. Hokkanen & M.B. Thomas.....281

Abstract: In the past 30 years many exotic natural enemies have been imported, mass reared and released as biocontrol agents for greenhouse pests. Negative effects of these releases for greenhouse biological control have not been reported yet. The current popularity of biological control may, however, result in problems, as an increasing number of projects will be executed by persons not trained in identification, evaluation and release of biocontrol agents. Therefore, a working group of OECD is developing a guidance document for registration requirements of exotic natural enemies. This guidance document is based on protocols for risk assessment that are being developed within the EU project "Evaluating Environmental Risks of Biological Control Introductions into Europe" [ERBIC]. In this paper, the state of affairs concerning these developments is summarized.

Biological control and survival of *Echinothrips americanus* in pepper

Jeroen van Schelt, Hans Hoogerbrugge, Yvonne van Houten & Karel

Bolckmans285

Abstract: Ten different predators: *Franklinothrips vespiformis*, *Franklinothrips orizabensis*, *Amblyseius limonicus*, *Macrolophus caliginosus*, *Orius laevigatus*, *Orius majusculus*, *Aeolothrips tenuicornis*, *Dicyphus hesperus*, *Geocoris punctipes* and *Chrysoperla carnea* were tested as potential biological control agents against *Echinothrips americanus*. All predators had their impact on the thrips population, however *M. caliginosus* had the strongest and most long lasting effect. This corroborates with field observations that growers who use *M. caliginosus* never have problems with *E. americanus*. The 50% survival of *E. americanus* at 5 and 10 degrees was one and three weeks, respectively. This indicates that a good sanitation between crop change is very important.

Key words: *Echinothrips americanus*, *Franklinothrips vespiformis*, *Franklinothrips orizabensis*, *Amblyseius limonicus*, *Macrolophus caliginosus*, *Orius majusculus*, *Aeolothrips tenuicornis*, *Dicyphus hesperus*, *Geocoris punctipes*, *Orius laevigatus*, *Chrysoperla carnea*, sweet pepper, survival

Performance of *Neoseiulus cucumeris* as a biocontrol agent of the Western Flower Thrips in cut roses

Irene Vänninen & Marika Linnamäki289

Abstract: *Neoseiulus cucumeris* is the most commonly used thrips predator in greenhouses, despite that it may not be the best option on all crops. We tested the performance of this mite against the Western Flower Thrips (WFT) on cut roses in spring/summer conditions of Finland. Biweekly application rates of 1000-2000 predators per m² (from controlled release sachets, or CRS) in four 38 m² greenhouse compartments in May-September resulted in a cumulative flower crop (Escimo) that was 72-89% free of thrips damage in three compartments of four. In a commercial greenhouse, predators applied

preventatively every six weeks between January and June did not disperse from the CRS to leaves or flowers of roses before the middle or end of April. Our results have three implications: (1) the CRS-method may not be the best option to release *N. cucumeris* against WFT in cut roses; (2) *N. cucumeris* may not be the best predatory mite species for use in cut roses; and (3) light conditions during the winter months in northern Europe appear to slow down the dispersal of *N. cucumeris* to roses from CRS, a phenomenon that may interfere with the desired effect of preventative WFT control in this crop.

Key words: predatory mites, thrips, *Frankliniella occidentalis*, roses, biological control

Influence of a biofungicide Trichodermin-BL on growth and development of plants

Dmitry V. Voitka.....293

Abstract: The stimulating action of a biological preparation Trichodermin-BL on seed qualities of vegetable crop seeds: tomato, fodder beet and carrot was determined. Trichodermin-BL use in the technology of cucumber, tomato, spring wheat makes more active growth and development of plants, promotes their productivity increase. The application of a biopreparation in purple *Echinacea* plants increases the output of medicinal raw material.

Key words: biocontrol, diseases, antagonists, *Trichoderma* spp., sowing qualities, stimulating effect, tomato, beet, carrot, cucumber, spring wheat, medicinal crops

Intraguild predation (IGP) between the phytoseiid mites *Phytoseiulus persimilis* and *Neoseiulus californicus* and the effects on their population dynamics

Andreas Walzer & Peter Schausberger297

Abstract: Predation, mortality, development and oviposition of *Phytoseiulus persimilis* and *Neoseiulus californicus* was examined when provided with con- or heterospecific prey. Irrespective of the type of prey, both species completed juvenile development. *P. persimilis* was more cannibalistic than *N. californicus*, whereas *N. californicus* exhibited stronger intraguild predation than *P. persimilis*. Oviposition was only possible for *N. californicus* preying on heterospecifics. *N. californicus* preferred to prey on heterospecifics when given the choice between con- and heterospecifics. When confined to detached bean leaves, *P. persimilis* was outcompeted by *N. californicus* within 30 days, which was attributed to asymmetric intraguild predation. The effects of IGP and competition for food between *P. persimilis* and *N. californicus* and the consequences on the combined release of the two species are discussed.

Key words: *Phytoseiulus persimilis*, *Neoseiulus californicus*, *Tetranychus urticae*, intraguild predation, competition for food

Effect of various release schedules of *Eretmocerus mundus* on the control of *Bemisia tabaci* in organic greenhouse peppers, in Israel – preliminary results

Phyllis Weintraub, Nurit Sapira, Elad Chiel & Shimon Steinberg301

Abstract: Trials were carried out in two varieties of sweet pepper grown in walk-in tunnels covered with insect-proof screening in the Arava Valley, Israel. Adult *Bemisia tabaci* (Grenadius) were released in all tunnels and allowed to establish for 2 weeks before release of *Eretmocerus mundus* Mercet. The total number of *E. mundus* released was the same for all tunnels, however, the release schedules were varied: 2/m² once a week for 4 weeks; 4/m² once every 2 weeks, twice; and 8/m² one time. Results were monitored by counting parasitized *B. tabaci* on leaves and by monitoring adult whiteflies with yellow sticky traps. The most efficacious release schedule appeared, from these preliminary results, to be 2 *E. mundus*/m² per week for 4 weeks. *Encarsia* spp. invaded the tunnels.

Key words: *Eretmocerus mundus*, *Bemisia tabaci*, *Encarsia* spp., pepper, organic greenhouse

Biological parameters of <i>Orius</i> spp. for control of thrips in Japan <i>Eizi Yano, Kazuya Nagai, Kazuhiro Watanabe & Kaori Yara</i>	305
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Abstract: Recent studies about life history and predation of Japanese indigenous *Orius* spp. are reviewed in relation to their mass rearing and evaluation of their potential for biological control of thrips. *O. sauteri* has been studied in detail. The minimum amount of *Ephestia kuehniella* eggs to rear one individual of *O. sauteri* from egg to adult emergence and for oviposition and adult survival was estimated as fundamental information for economic rearing. Life history studies of *O. sauteri* suggest that it cannot control thrips effectively under low temperature or short photoperiod. Another species, *O. strigicollis*, which shows low diapause incidence, is preferred for commercial use.

Key words: *Orius* spp., life history, predation, mass rearing, thrips, biological control