SESSION III

BIOLOGY OF NATURAL ENEMIES AT GREENHOUSE SCALE

Use of the predators *Orius laevigatus* and *Aeolothrips* spp. to control *Frankliniella occidentalis* populations in greenhouse peppers in the region of Monastir, Tunisia

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The use of *Orius laevigatus* and *Aeolothrips* spp. to control *Frankliniella occidentalis* in greenhouse peppers in Tunisia produced different results according to predator species and different doses and release frequencies. In the case of the predator bug *O. laevigatus*, the most effective dose was 1 individual per m² repeated three times with an interval of one week. Although *O. laevigatus* releases caused *F. occidentalis* populations to decrease for only one week, the predator was able to become installed in the crop and to proliferate. In the case of the predatory thrips *Aeolothrips* spp., no individuals were recorded in the pepper greenhouse even after the third release. However, the *F. occidentalis* population decreased to low average values of 0.42 and 0.06 thrips per flower as a result of the spontaneous colonization of individuals of *O. laevigatus* from other greenhouses.

Evaluation of four lacewing species for aphid control in sweet pepper

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Four species of lacewings were evaluated for control of the peach aphid *Myzus persicae* in sweet pepper. *Crysopa perla* was very effective in controlling aphids, probably because the adults also consume aphids. All other lacewings did not reduce aphid numbers sufficiently. *Chrysoperla lucasina* was establishing better than *Crysoperla affinis.* The hemerobiid *Micromus variegatus* seems to prefer the lower plant parts. Since this species is relatively small, more individuals are needed to control aphids. Preliminary releases in large greenhouses suggest that none of the lacewing species establish well when released as adults. Further research is needed to trigger them to stay and oviposit into a sweet pepper crop.

Improved biological control of 'problem' aphids on protected herbs

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Hawthorn-parsley aphid, *Dysaphis apiifolia* and mint aphid, *Ovatus crataegarius* are 'problem' aphid species on protected parsley and mint respectively. Grower experience has indicated that these aphids are not parasitised by the three aphid parasitoid species available until recently, i.e. *Aphidius colemani*, *Aphidius ervi* and *Aphelinus abdominalis*. A new mix of six parasitoid species is now available, including the above three species and in addition, *Aphidius matricariae*, *Ephedrus cerasicola* and *Praon volucre*. In laboratory bioassays, all six species except for *A. ervi* parasitised hawthorn-parsley aphid, and *A. matricariae*, *E. cerasicola* and *P. volucre* parasitised mint aphid. In semi-field glasshouse cage experiments, *A. colemani* and *A. matricariae* parasitised and reduced numbers of hawthorn-parsley and mint aphids respectively on parsley and mint.

Experimental studies of the biological control of aphids in protected strawberry crops in France

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Integrated pest management is increasingly used by growers in France in protected strawberry crops due to difficulties with chemical control, especially on soilless crops. Various different pests can attack strawberries, including: aphids, mites, thrips, tarsonemids, mirid bugs and, more recently, *Drosophila suzukii.* A survey was carried out from 2010 to 2012 in the South-East of France that confirmed the presence of up to six aphid species. Since 2008, promising trial results from aphid control have been obtained in experimental tunnels, based on the efficiency of lacewings that were released onto aphid-infested plants and parasitism by certain parasitoids adapted to aphid species.

Possibilities for integrated control of citrus mealybug in commercial ornamental greenhouses

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Since the 2000's, the citrus mealybug *Planococcus citri* has become a key pest in integrated ornamental greenhouse crops in The Netherlands. While adopting a more integrated approach toward controlling other pests, growers have abandoned regular applications of broad spectrum pesticides, thereby allowing mealybugs to become more widespread. The benefits of both inundative and inoculative releases of (commercially available) natural enemies of this pest have been studied. Three encyrtid parasitoid species: *Coccidoxenoides perminutus*, *Leptomastix dactylopii* and *Anagyrus pseudococci* were tested on potted plants of *Epipremnum aureum* infested with citrus mealybug *P. citri*. Parasitoid performance was evaluated under confined conditions in large cages. Weekly release of *L. dactylopii* and *A. pseudococci* supressed the development of small hot spots and prevented the spread of mealybug from infested plants to healthy plants, but did not result in pest eradication. Most *Epipremnum* plants treated by these two parasitoids were marketable. *C. perminutus* gave insufficient control. The relevance of introducing natural enemies for controlling mealybugs in greenhouse ornamentals is discussed.

Selection of *Trichogramma* spp. (Hym.: Trichogrammatidae) for the biological control of *Tuta absoluta* (Lep.: Gelechiidae) in greenhouses by an entomo-ecological simulation model

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A greenhouse trial was carried out, between October 2011 and April 2012, on tomato crops with the aim of evaluating the biotic potential of two species of *Trichogramma* (*T. achaeae* and *T. urquijoi*) for the control of the South American tomato moth, *Tuta absoluta*. The trial also studied the relationship of the latter with the predator *Nesidiocoris tenuis*, which is also used in biological control programmes in greenhouses. With this objective, we developed a mathematical model which makes it possible to evaluate and compare the effects of different biological control agents. As a result we established that *T. achaeae* was better at controlling pest populations than any other species. We also noted a significant intra-guild competition effect of the predator on both species of *Trichogramma*.

Biological control of *Tuta absoluta* (Lepidoptera: Gelechiidae) in protected tomato crops in Argentina

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We present the results of a ten-year research project on life history traits and field interaction of two main *Tuta absoluta* indigenous larval parasitoids, *Pseudapantales dignus* and *Dineulophus phtorimaeae.* These natural enemies naturally coexist in cropping conditions, and show positive characteristics as biological control agents against *T. absoluta* by means of augmentative releases in Argentinian protected tomato crops.

Effects of selected factors on the reproductive fitness of the predatory mirids *Macrolophus pygmaeus* and *Nesidiocoris tenuis* (Heteroptera: Miridae)

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The use of the predatory mirids *Macrolophus pygmaeus* and *Nesidiocoris tenuis* for the control of arthropod pests on greenhouse tomatoes is at present limited in some Mediterranean regions by factors of an economic and technical nature. To assess the influence of the production and distribution process, the availability of a supplementary food source and seasonal climatic trends in the reproductive fitness of the two mirid species, some laboratory and semi-field experiments were conducted during the last year. The adverse effects of the stress experienced by commercially supplied insects have clearly emerged through the investigation, but at different levels of intensity for the sources tested. The supply of *Ephestia kuehniella* eggs has shown pronounced effects on the reproductive fitness of the predatory mirids, in some cases allowing a partial recovery of fertility in stressed individuals and confirming the suitability of supplementary food sources in improving mirid performances. Furthermore, the results of the tests carried out appear to indicate that *M. pygmaeus* is more suitable for winter releases in Sardinian tomato greenhouses, whereas *N. tenuis* is to be preferred for autumn releases.

Effect of *Orius laevigatus* and *Amblyseius swirskii* releases on *Frankliniella occidentalis* populations in pepper crop greenhouses in the Bekalta region of Tunisia

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Knowledge of local beneficial insects is needed in Integrated Pest Management (IPM) to control the pests present in greenhouses without reducing predator populations through the use of pesticides. The natural introduction of the local predatory bug *Orius laevigatus* into pepper greenhouses had a significant impact on the population of *Frankliniella occidentalis,* reducing its numbers to very low values of about 0.73 and 0.65 individuals per flower. However, the installation of insect-proof nets prevented the migration of *O. laevigatus*. Similarly, from the first pesticide treatments on April 13 and 18, 2010 against aphids and downy mildew, the *O. laevigatus* population decreased considerably until it disappeared completely. This proves that this predator is very sensitive to pesticides. During this time, *F. occidentalis* proliferated and its population increased to values of 13.76 thrips per flower on May 19, 2010 in greenhouse G1 and 7.23 thrips per flower on June 2, 2010 in greenhouse G2. In consequence, the infestation rate also increased to values between 90 and 100% in both greenhouses. It should be noted that when the lateral ventilation entrances to both greenhouses were opened on April 21, 2010, a second introduction of the predator from the outside was noted. The *O. laevigatus* population then increased again until the end of the study period. Moreover, the third pesticide treatment, which was against whiteflies and used the product Calypso (thiachloprid), did not completely eliminate *O. laevigatus* as the others did. On the other hand, it was found that combining the natural introduction of *O. laevigatus* and the release of the predatory mite *Amblyseius swirskii*, which is less sensitive to pesticides, was most effective at reducing the *F. occidentalis* population and keeping it at very low levels of about 0.43 and 0.55 individuals per flower.

Releasing syrphid larvae (Diptera: Syrphidae) as an effective aphid biocontrol strategy in Mediterranean sweet-pepper greenhouses

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Syrphid larvae are an important group of natural enemies reducing the population density of aphids in agricultural crops. Nevertheless, there is only one species commercially available, *Episyrphus balteatus*, which despite occurring naturally in the Mediterranean basin, is not the best adapted to the conditions found in its agricultural areas. Furthermore, syrphid flies are commercialised and released in the field as pupae, which implies several difficulties: maintaining adults at a sufficiently high number in a given area, providing flowering plants to allow their maturation and mating, and retaining them during enough time to guarantee that females lay their eggs on the aphid-infested spots. Concerning these issues, it has already been proposed to introduce immature stages in the field, thus reducing the time needed until actual pest reduction can be observed. In this work we assess the effectiveness as an aphid control agent of the syrphid *Sphaerophoria rueppellii*, the main predator of aphids in Mediterranean greenhouse crops and one of the most promising biocontrol agents in such agricultural systems. Syrphids were released as larvae, since they are able to directly act *in situ* and with no time lapses between the release and the predatory activity.
The study was conducted from March to June 2012 in commercial greenhouses of sweet pepper owned by the Demonstration and Technology transference center 'El Mirador', located on San Javier (Murcia). This is a semi-arid climatic zone of southeastern Spain, near the Mediterranean coast. Three different aphid species occurred in the greenhouse in a sequential order: *Myzus persicae*, *Aphis craccivora* and *Macroshipum euphorbiae*. While *M. persicae* and *M. euphorbiae* are known as important pests in horticultural crops, the Cowpea aphid, *A. craccivora*, has been cited very few times on such crops. This species constitutes a very damaging pest due to the fact that it produces large amounts of honeydew on leaves, fruits and preferably on flowers, leading to the abort of most of them.
The objectives of this study were: 1) to assess the effect of larval releases of *S. rueppellii* on the reduction of the population of the three aphid species that occurred throughout the crop cycle; 2) to evaluate the effect of the reduction of the aphid infestation on the fruit production. Fresh weight per plant was quantified throughout the harvesting period, and the fruits were also given a commercial quality classification to measure the reduction on the fruit quality that might lead to commercial damage due to aphid infestation. The suitability of *S. rueppellii* and releasing syrphid larvae as effective aphid control strategies are discussed.

Multi-stage dynamic model for a prey-predator interaction: Application to *Spodoptera exigua* (Lep.: Noctuidae) and *Nabis pseudoferus* (Hem.: Nabidae) in greenhouse conditions

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The beet armyworm, *Spodoptera exigua*, is a highly polyphagous insect pest of various agricultural crops, including vegetables and ornamentals. It is a serious pest in several crops in greenhouses (e.g.: pepper and watermelon). In turn, the predator *Nabis pseudoferus*, belonging to the Nabidae family, is a strict zoophagous species commercially available in Spain. Several trials have been carried out on the biology and ecology of the pest and predator species in pepper crops, under both laboratory and greenhouse conditions in southern Spain. In this work, through trials, the efficacy of the predator species to control different levels of the pest infestation has been evaluated in commercial pepper greenhouses. With the data from these trials, a degree-day dependent and stage-structured dynamic mathematical model for predator-prey systems has been developed and validated using the data from these trials. From the results it can be seen that the 'degree of depression' found in the prey population, between the first and second generation, was 7.3 which is equivalent to an 86.3% mortality rate between generations. This value is close to the percentage of efficiency found in other publications, which is a good validation of the model. The current situation of biological control in greenhouse crops is quite complex: use of entomophagous species (parasitoids or predators) isolated or together with other natural enemies, different nutritional characteristics of entomophagous insects (ranging from omnivorous to strict zoophagous species), different release techniques (bio-propagation or pre-transplant, inoculative or inundative releases, reservoir plants, etc.). This complexity can make necessary the application of mathematical models. Their implementation can be considered an excellent tool in biological control practice.