Biological control

Session IV

Biological control of *Bemisia tabaci* s.l. using parasitoids

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Although *Bemisia tabaci* is the host of many parasitoid species, it seems to defy the conventional successes that are known for using parasitoids to control whiteflies. The reasons are probably due to a combination of the extensive host range and mobility of the pest, its quick life cycle and high reproductive rate. These preclude overall permanent control of the pest and the reduction of its levels to non-economic levels by natural enemies. The alternative is the utilization of parasitoids mainly under augmentative-inundative programs to control the pest. Due to the high cost of parasitoid production, the use is only on specific crops exhibiting damage/price combinations that facilitate such activities. At present, a few species have been studied found suitable for active biological control programs and are used mainly in protected agriculture such as greenhouses and screen houses. Use is made principally of *Encarsia* species like *E. formosa* which is principally used against the greenhouse whitefly and of *Eretmocerus* species, of which *E. eremicus* and *E. mundus* are utilized most. Some of the parasitoid species are being imported and shipped internationally for these purposes whereas others are local species of variants that are collected and mass reared. Recent studies both, of population dynamics in relation to the host insects and the life history traits of the parasitoids, have contributed greatly to the efficacy of their mass rearing and utilization. This enables those that are interested in biological control of *B. tabaci* to choose the more suitable parasitoid species of a given species combination. Further work is needed on other species of parasitoids that might serve as efficient controlling agents.

Biological control of *Bemisia tabaci* using predators

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A long list of predatory species are reported to consume *Bemisia tabaci*, although most of them are generalist predators that have broaden their prey range after *B. tabaci* outbreaks. No specific predators of *B. tabaci* are currently used in biological control programs. The impact that local generalist predators have in reducing *B. tabaci* populations has often been undervalued and only their role has been recognized after pest outbreaks. Because of the mild climate in the Mediterranean region, *B. tabaci* in greenhouses may come from outdoor harvested host crops in addition to their introduction with seedlings. Therefore, control of whitefly populations in outdoor crops is essential for successful biological control of indoor crops. The role that native predators have in maintaining low populations of *Trialeurodes vaporariorum* in field crops is very important for the management of greenhouse populations of this pest. Some of these predatory species are presently used for *T. vaporariorum* control in certain greenhouse crops. Populations of both whitefly species are concurrently present in many areas of the Mediterranean region and the role of this predatory complex on the control of *B. tabaci* in vegetable crops will be discussed.

The influence of temperature on the development, behaviour and control efficiency of *Eretmocerus eremicus* parasitizing *Bemisia tabaci* B-biotype on Poinsettia

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The development, behaviour and control efficiency of *Eretmocerus eremicus* n.sp. Rose & Zolnerowich (Hymenoptera: Aphelinidae) attacking *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) B-biotype on Poinsettia (*Euphorbia pulcherrima* Willd.) was investigated in climatic chambers at temperatures and light regimes used in commercial Poinsettia production. The egg-adult developmental time for *E. eremicus* was 15.6, 28.5 and 46.2 days at 24ºC, 21ºC and 18ºC, respectively. At a host density of 1.8 second instar nymphs per cm^2 leaf area, time spent walking decreased by 16% , time spent drumming probing and oviposition decreased with 40%, time spent preening increased by 45%, and time spent resting increased by 52% when temperature decreased from 24ºC to 18ºC. The rate of encounter was 16.5 and 8.9 hosts/hour, and oviposition rate was 3.9 and 1.8 eggs/hour, at 24ºC and 18ºC, respectively. Oviposition occurred in 24% of the encountered hosts at 24ºC and in 21% of encountered hosts at 18ºC. Mean handling time (drumming, probing and oviposition) was 101 seconds at 24ºC and 121 seconds at 18ºC. Host feeding was observed at both temperatures. Efficacy experiments showed that the emergence of adult *E. eremicus* was delayed with 3-4 weeks and that flight was markedly reduced at 18ºC compared to 24ºC and 21ºC. Almost no flight occurred at 15ºC. Mean proportion of parasitized *B. tabaci* pupae during the a period of 4-14 weeks after potting was about 80% at 21ºC and 24ºC, but was more than halved at 18ºC. Mean mortality of *B. tabaci* nymphs caused by other factors than parasitism decreased from 75% at 24ºC to 62% at 2ºC and 16% at 18ºC. This additional mortality was more than 90% higher than the control mortality at 21ºC and 24ºC, and was reduced by about 24% at 18ºC. A high proportion of the dead nymphs had puncture marks, indicating that a significant degree of the host nymphs were killed by host feeding. The light regime did not affect adult emergence, parasitism and host nymph mortality, but the population increase of *B. tabaci* was strongly reduced at 10:14 hours ligh:dark compared to 20:4 hours light:dark. *E. eremicus* gave good control of *B. tabaci* during a period of 14 weeks after potting at 21ºC and 24ºC at both light regimes (98-96 efficiency), but gave no control at all at 18ºC.

The ability of *Eretmocerus eremicus* to manage *Bemisia* populations in the southwest US

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Bemisia tabaci has been shown to disperse between patches for distances of up to 7 km in a single morning. This allows the whitefly to readily move between crops in the desert southwestern United States. Recent studies have demonstrated that *Eretmocerus eremicus* has a limited ability to disperse (< 100 m in the same time period). This is likely explained by foraging strategies and ovarian dynamics. Regardless of the underlying reasons, it seems that *E. eremicus* can not keep pace with *B. tabaci* in the dynamic situation found under our conditions.

Comparison of biology and behavior of *Eretmocerus* spp. on tomato

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A video recording system was used to monitor and compare foraging behaviors of three species of *Eretmocerus* (Aphelinidae) attacking *Bemisia tabaci* (Gennadius), Biotype B (also known as *B. argentifolii* Bellows & Perring) (Homoptera: Aleyrodidae) on tomato leaves (*Lycopersicon esculentum* Mill. cv 'Carnival'). The parasitoids studied were: *Eretmocerus* sp. nr. *furuhashii* Rose & Zolnerowich (originally collected from tomato in Taiwan), *E. melanoscutus* Zolnerowich & Rose (originally collected from tomato in Taiwan), *E. mundus* Mercet (originally collected from cotton in Spain), and *E. tejanus* Rose & Zolnerowich (collected from cabbage in Texas). Development rates were studied for *E. melanoscutus*, *E.* nr. *furuhashii*, and *E. tejanus* at 27ºC on tomato. Development times differed significantly: E. nr. *furuhashii* developed in 14.7 d, *E. melanoscutus* in 15.3, and *E. tejanus* in 17.2. The behavioral studies showed that *E. tejanus* was not an effective parasitoid on tomato. *E. tejanus* spent significantly less time on the leaves, attacked fewer hosts (oviposition + host feeding), and spent less time ovipositing, host feeding, and preening compared to *E. mundus* or *E*. sp. nr. *furuhashii. E*. sp. nr. *furuhashii* and *E. mundus* spent a mean of about 50 min on the leaves; *E. tejanus* averaged about 11 min. Of 32 female *E. tejanus* tested, 10 spent zero minutes on the leaves. *E*. nr. *furuhashii* spent 23.2% of its time on leaves ovipositing, 23.8% host feeding, and 7% preening. The remaining time (46%) was spent either walking, resting or other behaviors. Proportional behaviors for *E. mundus* were: oviposition, 24.2%; host feeding, 9.2%; preening, 7.8%; and, remaining time, 58.8%. Time for *E. tejanus* was: oviposition, 22.2%; host feeding, 21.1%; preening, 2.1%; and, remaining time 54.6%. This study supports previous findings that *E. mundus* should be expected to be a relatively effective parasitoid against *B. argentifolii* on tomato, whereas *E. tejanus* would probably be ineffective.

Comparison between the functional responses of *Er. mundus* and *En. pergandiella*

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Functional responses and mutual interference were compared between the native (U.S.A.) *Encarsia pergandiella* Howard (Hymenoptera: Aphelinidae) and *Eretmocerus mundus* Mercet (Hymenoptera: Aphelinidae) from Spain using *Bemisia tabaci* (Gennadius), Biotype B (= B. argentifolii Bellows & Perring) (Homoptera: Aleyrodidae) as host. Type II functional response curves were fitted to the data and were used to calculate handling time. *Eretmocerus mundus* attacked more whitefly nymphs than *E. pergandiella*. Handling times estimated from the functional responses were 72 min for *E. pergandiella* and 12 min for *E. mundus,* suggesting that lower attack rates for the former parasitoid may be attributed to longer handling times. The statistically estimated handling time for *E. mundus* was compared with an estimate derived from empirical observations of parasitoid behavior. Actual observations of handling time, defined as oviposition, host feeding and associated preening, yielded a mean handling time of <2 min, suggesting that functional response experiments may not produce reliable estimates of handling time. The mutual interference coefficient *m* of *E. mundus* was numerically higher than that for *E. pergandiella* (0.238 vs 0.184, respectively). Although there were no significant differences in *m*, the comparison raises the interesting question of whether parasitoids with higher attack rates may also have higher levels of mutual interference under conditions of high density.

Status of *Bemisia tabaci* on cotton and population dynamics of its parasitoids on alternate host plants in Pakistan

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Pakistan is the fifth largest cotton producer in the world. Its production dropped from 2.2 million metric tons in 1991-92 to 1.3 million tons in 1993-94 because of the leaf curl virus transmitted by *Bemisia tabaci*. Whitefly has been a pest of cotton in Pakistan for many years but was not a major pest until the 1990s. It appears in the field in the month of July, before effective fruit formation starts, and may continue up to early October under normal conditions and does considerable damage to cotton crop. In Pakistan, 236 plant species belonging to 132 genera and 51 families have been recorded as hosts of this pest. Population dynamics of parasitoids (*Encarsia* spp. & *Eretmocerus* spp) of *B. tabaci* on alternate host plants was investigated. Level of parasitism was 15-56% on *Lantana camara* from January to March, 9-50% on *Solanum melongena*, 13-44% on *Glycine max* and 25% on *Ipomoea batatas* during April to June. Its population was 40-80% on *Gossypium hirsutum* in June to July. During August to September 38-69% on *Convolvulus arvensis*, and October to November ranged between 17-85% on *Achyranthis aspera*. Among other factors, whitefly out breaks have been triggered by the widespread use of insecticides for the control of whitefly and other co-existing pests, which resulted in large-scale reductions of its natural enemies and development of resistance to most of the conventional insecticides. Role of natural enemies in regulating whitefly population on cotton and other host plants and possibility of such hosts to act as reservoir for the multiplication and shifting of promising parasitoids to cotton at appropriate time are discussed.

Potential for biological control of the whitefly, *Bemisia tabaci*, vector of cassava mosaic geminiviruses using parasitoids in Uganda

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Bemisia tabaci is the vector of cassava mosaic geminiviruses (CMGs) that cause cassava mosaic disease (CMD), which in turn causes devastating yield losses to cassava in sub-Saharan Africa. Studies were conducted on the abundance and species composition of *B. tabaci* parasitoids on cassava in four different agro-ecologies in Uganda, and on the population dynamics of cassava whitefly parasitoids on CMD-resistant and CMD-susceptible varieties. The aim was to create a better understanding of the parasitoid fauna and parasitism of *B. tabaci* in cassava fields, and to describe and quantify the population dynamics of cassava whitefly parasitoids. Parasitoid abundance and parasitism varied between locations and between seasons within the locations; highest parasitoid densities were observed at Namulonge in the Lake Victoria crescent while the lowest was at Kalangala (an island in the Lake Victoria crescent). In all the locations, parasitism was mainly due to *Encarsia sophia* (Girault & Dodd) and *Eretmocerus mundus* Mercet. Other, rarely collected and only partially identified parasitoids were *Encarsia* ?*mineoi* only observed at Namulonge, and *Encarsia* 'E1', an undescribed species, observed at Bulisa, Namulonge and Lyantonde. Parasitism was highest at Bulisa (61.5%) and ranged from 41.8% to 44.1% at the other sites. Parasitoids appeared in the fields after second to third instar nymphs of *B. tabaci* became available and *Eretmocerus* sp. was more abundant than *Encarsia* spp. Parasitism was generally slightly higher on the susceptible variety than on the resistant variety; higher *E. sophia* numbers and percent parasitism were recorded on the resistant variety during both trials, while *Eretmocerus mundus* numbers were significantly higher on the resistant variety during trial two only. The patterns in development in parasitoid number were similar on both varieties during the two trials. It was, however, noted that parasitoid abundance increased with nymph numbers, whereas percent parasitism decreased with increase in nymph numbers. Further studies are being planned to investigate possible causes of seasonal and geographical variation in parasitoid abundance and means of manipulating them to enhance whitefly control.

Population dynamics and natural enemies of *Bemisia tabaci* (Gennadius, 1889) on different horticultural crops in the Canary Islands

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Horticultural crops represent about the 46,4% of total agricultural production in the Canary Islands, with an average production of about 368.228Tm. Outbreaks of *Bemisia tabaci* (Gennadius, 1889) (Hemiptera, Aleyrodidae) have been reported in tomato, cucumber, peppers, zucchini, melon and beans; followed by high production losses by direct and indirect damage. In the archipelago, this whitefly transmits economically important viruses such us, the Geminivirus Tomato yellow leaf curl virus, and the Crinivirus Cucurbit yellow stunting disorder virus and Tomato chlorosis virus. Population dynamics of *B. tabaci* and its natural enemies has been studied in a number of commercial greenhouses (tomato (11), cucumber (3), sweet-pepper (3) and zuchini (1)) during two growing seasons, Autumn/Winter and Spring/Summer. Numbers of adult whiteflies were recorded on three leaves from the middle-upper part of 96 randomly selected plants. Samples of 96 leaves from the lower part of the plant were collected and parasitized pupae were counted under stereomicroscope. Incidence of *B. tabaci* transmitted-viruses was also evaluated. The identification of the virus infection was made by hybridisation with (DIG)-labeled probes; evaluation of the disease severity was made by symptom observation in the field. In order to improve our knowledge on *B. tabaci* natural enemy's complex, a survey of secondary hosts of the whitefly species and its natural enemies was also conducted. Samples were collected of the most frequent weeds and ornamentals growing in the vicinity of horticultural crops. Collections of parasitized material of *B. tabaci* were made in various sites from the main horticultural crop areas in the Canary Islands. *Eretmocerus mundus* Mercet and *Encarsia sophia* (Timberlake) (Hymenoptera, Aphelinidae) were the most common parasitoids of *B. tabaci* in tomato, cucumber and sweet-pepper greenhouses, although differences were registered in their dominance throughout seasons. Other parasitoid species have been collected in low numbers or are of localised importance in certain areas. Results of these studies will be presented.

Eretmocerus mundus and *Eretmocerus eremicus* (Hymenoptera: Aphelinidae) for *Bemisia tabaci* (Homoptera: Aleurodidae) control on greenhouse pepper in the southeast of Spain

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Bemisia tabaci is one of the main phytopathological problems of greenhouse peppers since 1988 when it started to spread over more than the 1800 pepper crop hectares. Resistance to pesticides and the application of biological pest control on over fifty percent of greenhouse pepper crop surface make it necessary to assay new natural enemy management strategies to achieve whitefly control. During the last two growing seasons release strategies have been assayed for *Eretmocerus mundus* and *E. eremicus* in experimental biological control greenhouses in the Campo de Cartagena (Murcia). Higher parasitism rates and better whitefly control were observed for *E. mundus* than for *E. eremicus*. In comparative assays *E. eremicus* was much more abundant than *E. mundus*. The best *B. tabaci* control was achieved with early release that targeted *B. tabaci* first generations. *Encarsia lutea* was detected in greenhouses with high *E. mundus* parasitism.

Developmental biology of *Eretmocerus mundus*

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Eretmocerus mundus oviposits under its host, *Bemisia tabaci*. Egg hatch occurs within ca. 3 days of oviposition. The first instar larva penetrates the host and development proceeds within a capsule of epidermal origin. Recent studies have shown that no matter under which host instar *E. mundus* eggs are laid, penetration into the host proceeds only during the host's fourth instar, typically sometime prior to the transition to adult characteristics. Thus, it is understandable that while *E. mundus* will oviposit under any of its host's four instars, the parasitoid prefers to lay an egg under either a second or third instar. Since approximately three days are required for parasitoid egg development, oviposition under a second or third instar whitefly will result in hatch occurring under a third or young fourth instar host; the period of time during which first instar parasitoid will be forced to remain outside its host will be minimal as will be its chances to miss the window during which the whitefly is vulnerable to penetration. The host's epidermis and cuticle react to the hatching parasitoid larva by first forming a curved inlet and then engulfing the developing parasitoid. A host originating, parasitoid induced, capsule is formed and later engulfs the parasitoid larva. The capsule plays a role in host disintegration and transmission of nutrients to the developing *E. mundus* larva. The capsule disintegrates when the parasitoid is in its third larval stage. Numerous problems arise concerning the function of the capsule and its formation.

Activity of predators in relation to population density of *Bemisia tabaci* in cotton plants

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Cotton field were examined for *Bemisia tabaci*-associated predators during two seasons. In each, ca. 150 randomly selected cotton leaves, each on a different plant were marked. Each leaf was visited every 3 hours for 24 hours and the incidence of predators thereupon was noted. Following the observation period the leaves were picked and the whitefly populations on them recorded. The data allowed us to draw correlations between predator occurrence and the density of whitefly on the leaves and to determine the main activity hours of the main predacious species. The proportion of leaves visited by predators correlated positively with the abundance of whitefly upon each leaf. However, no such correlation was observed when analyzing the numbers of predators per visited leaf. Most visits of the 8 taxa registered occurred between 12:00 and 21:00 hrs except for *Orius* spp. that were more abundant during the morning hours. An analysis of the possible impact of the species will be presented.

Foraging behavior of whiteflies and their phytoseiid predators

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Mites of the family Phytoseiidae, co-occurring with whiteflies in the Middle East area were collected and evaluated as biological control agents for *Bemisia tabaci* (Gennadius). In greenhouse experiments, each of the two phytoseiid predators, *Euseius scutalis* (Athias-Henriot) and *Typhlodromips swirskii* (Athias-Henriot), suppressed *B. tabaci* populations on single, cucumber plants. However, at a larger spatial scale, differences in dispersal capacity between prey and predators will affect biological control. Adult phytoseiids have no wings and they are much smaller in body size, than the adult whiteflies. This causes phytoseiids to be much less mobile than their prey. Therefore, we investigated the foraging behaviour of adult whiteflies and their predators in release experiments in a greenhouse. First, we tested whether predatory mites find and aggregate on plants infested with immature whiteflies, and second, whether adult whiteflies discriminate between plants that harbour phytoseiids and predator-free plants. The two predator species were found in higher numbers on plants infested with whiteflies than on uninfested plants but this difference was consistently significant in all experiments only for *T. swirskii.* Whitefly release experiments showed that adult female whiteflies could learn to avoid plants with *T. swirskii*, while they accepted host plants of the same species without predators. Because this predatory mite attacks mainly the juvenile stages of whiteflies, adult whiteflies do not avoid predator-occupied plants to escape predation. It seems more likely that they avoid exposing their offspring to the predatory mites. Thus, by being more mobile than predatory mites and by avoiding plants with predatory mites, whiteflies oviposit on enemy-free plants, thereby creating a temporary refuge in space for their offspring. We expect this game of hide and seek to give rise to spatial pattern formation in the dynamics of predator and prey and we discuss the consequences for biological control.

Efficacy of natural enemies in the biological control of *Bemisia tabaci* biotype "B" (Homoptera: Aleyrodidae) in Egypt

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Bemisia tabaci biotype "B" (Homoptera : Aleyrodidae) is one of the most important pest attacking different economic plants in Egypt. The present work deals with natural enemies of this pest found in Egypt. Eight parasitoids and nine predatory species were recorded attacking *B. tabaci* biotype "B". *Eretmocerus mundus* Mercet, *Encarsia sophia* (Girault) and *Chrysoperla carnea* Steph., were the most effective natural enemies found attacking this economic pest. Parasitism rates were 13 and 30% for the forementioned parasitoids, respectively. *C. carnea* was 280 individuals/30 leaves. Percent parasitism and average numbers of predators indicate the need of importing some specific parasitoids and predators to control this pest in Egypt.

Biological control of *Bemisia tabaci* (Gennadius) with *Eretmocerus mundus* (Mercet) and *Macrolophus caliginosus* (Wagner) in greenhouse tomatoes

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Eretmocerus mundus (Hymenoptera: Aphelinidae) and *Macrolophus caliginosus* (Heteroptera: Miridae) are the most abundant natural enemies of *Bemisia tabaci* (Homoptera: Aleyrodidae) in the Mediterranean area. A semifield experiment was conducted to evaluate efficiency of these two natural enemies to control *B. tabaci* in greenhouse tomatoes from August to December of 2002. In a greenhouse with 12 exclusion cages (48 tomato plants/cage), infested artificially with adults of *B. tabaci*, four treatments were tested: *E. mundus* (2 adults/plant, 6 releases), *M. caliginosus* (0.3 adults/plant, two releases), *E. mundus* (2 adults/plant, 6 releases) plus *M. caliginosus* (0.3 adults/plant, two releases) and a control treatment without natural enemies. The results show that releases of *E. mundus* alone or in combination with *M. caliginosus* provided a great level of whitefly suppression. Very few nymphs and parasitised pupae were observed in these treatments. However release of *M. caliginosus* alone did not control *B. tabaci* populations. These results suggest that *E. mundus* is a good biocontrol agent of *B. tabaci*, and if there were a spontaneous colonization of *M.caliginosus* from around crops would not disturb *E. mundus* action.

Greenhouse trials with a new bioinsecticide under development to control whitefly

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Two similar greenhouse trials were carried out on tomato plants in Tenerife and in Barcelona to assess the efficacy of a new bioinsecticide under development by FuturEco S. L. (Barcelona, Spain) in order to control whiteflies (*Bemisia tabaci* and *Trialeurodes vaporariorum*). Three treatments were compared in both studies: 1) Control treatment; 2) Biological treatment (active ingredient = *Paecilomyces fumosoroseus*); 3) Chemical treatment (active ingredient = pyriproxyfen). The bioinsecticide and the chemical product were applied 3 times during the experiments. Whitefly development was assessed by field and laboratory counting. Temperature and relative humidity were registered daily. The number of adults/leaf was determined during the assays by evaluating their number on the top leaves of the plants. The level of infestation of the nymphs was also determined. Discs of leaves from each plot of the different treatments were kept in a growth chamber (25±1ºC; 16L:8D) and 5 days later the number of the last nymph stages and their state were reported. In both trials, the biological and chemical treatments reduced the number of adults and healthy nymphs compared with the control. The bioinsecticide presented a slower but more persistent effect than the chemical treatment.

Using life tables to measure the contribution of conservation biological control of *Bemisia tabaci*

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Within agricultural systems there are multiple abiotic and biotic mortality forces acting on pest insect populations. These forces may be naturally-occurring, as in the case indigenous natural enemies, or man-made as exemplified by insecticides or cultural manipulations. Estimating the contribution and effect of each mortality factor may be difficult because of interactions between factors resulting in mortalities that may be either replaceable or indispensable. From the perspective of conservation biological control, estimating mortality caused by extant natural enemies within the context of other mortality agents is important to understanding the base contribution of biological control to pest suppression, and to evaluating the benefits of manipulating the habitat and other system inputs. We will summarize research with whiteflies in cotton in which cohort-based life tables were used to structure, quantify, analyze and interpret the effects of indigenous natural enemies relative to the effects of other simultaneous mortality factors, especially insecticides, acting on pest populations. The results provide a mechanistic understanding of how integration of natural enemies with use of selective insecticides result in the development of an efficient pest management strategy.

Effect of UV- absorbing plastic sheets on the attraction and host locating ability of *Eretmocerus mundus* Haldman

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UV-absorbing plastic sheets were compared with conventional plastic sheets for their effect on the host finding ability of *Eretmocerus mundus*, an important parasitoid of the sweet potato whitefly, in sweet pepper greenhouses. In 2000/2001 season, 4 plants infested with *Bemisia tabaci* nymphs were placed at the corners and *E.mundus* adults were released at the center of each greenhouse. Parasitization rates were low both under regular plastic (8%-14%) and under UV absorbing plastic (4%-6%). In 2001/2002 season a plant infested with *B.tabaci* nymphs was located in the center of each greenhouse wereas the *E.mundus* adults were released at the corners. In the greenhouses covered with a UV-absorbing plastic no signs of parasitism were observed, whereas in the greenhouses covered with regular plastic we found a varying level (2% - 27%) of parasitism. In addition, the attraction of *E. mundus* to natural light compared with UV-filtered light was tested under laboratory conditions in a Y shaped pipe system ("Light olfactometer"). More wasps were attracted to the arm covered with regular plastic. These results demonstrate the critical role of UV light in *E. mundus* host location process.

Susceptibility of field populations of adult *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) and *Eretmocerus* sp. (Hymenoptera: Aphelinidae) to cotton insecticides in Burkina Faso (West Africa)

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Whitefly infestations and parasitism were monitored year round in overlapping cotton crops sown at three dates in Burkina Faso to record the relative abundance of *Bemisia tabaci* (Gennadius) and its parasitoids, *Eretmocerus* spp. and *Encarsia* spp. in control and insecticides sprayed plots. Low *B. tabaci* populations developed during rainfall period. Pest populations increased when rainfall ended and, the levels reached were higher in insecticide treated (48 nymphs/leaf) than in control (25 nymphs/leaf) plots. Parasitism reached 88.7% in control plots, and 53.7% in insecticide treated plots. *Eretmocerus* spp. were more abundant than *Encarsia* spp. in both treated and control plots. A logarithmic relationship that later reversed to a linear inverse relationship was observed between rates of *B. tabaci* and percentage of parasitism. In general percentage parasitism followed the abundance of pest populations except in March and April where parasitism increased while *B. tabaci* populations decreased. In a separate experiment, adult *Eretmocerus* spp. were released into caged cotton plants to study the impact of augmentative releases of the parasites on the population dynamics of the pest. Pest densities increased from 1.47 nymphs/leaf to 39.4 nymphs/leaf in the control, but were reduced to 0.8 and 0.6 nymphs/leaf in the cages where respectively 4 and 8 parasitoids have been released per plant. Parasitism is an important factor reducing *B. tabaci* populations during and after growing season and, *Eretmocerus* spp. are promising biological control candidates against the pest in cotton.

The predatory capacity of *Macrolophus caliginosus* Wagner and *Nesidiocoris tenuis* (Reuter) (Heteroptera: Miridae) preying on whiteflies

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To evaluate the predatory capacity of the mirid bugs *Macrolophus caliginosus* Wagner and *Nesidiocoris tenuis* (Reuter) preying on whiteflies, some preliminary investigations were undertaken under greenhouse and laboratory conditions. The field surveys were carried out in the south of Sardinia, in 25 winter tomato crops infested by *Bemisia tabaci* (Gennadius) and *Trialeurodes vaporariorum* (Westwood). After the release of 1 to 8 predatory bugs per m^2, the whitefly and mirid populations were monitored monthly throughout the growing season. The relationships among the predator/prey ratio, the whitefly abundance and the predation rate were studied for three different species compositions of the mirid populations (number of *M. caliginosus*/total mirid number: > 0.80; < 0.20; approximately 0.45). Due to its higher predatory capacity at low prey densities, *N. tenuis* seemed to be more efficient than *M. caliginosus* in controlling the whitefly infestations. In order to evaluate the functional response of the two mirid bugs to *T. vaporariorum* pupae, an experiment was carried out in simplified arenas (Petri dishes). The functional response parameters were estimated by the Holling disk equation. In comparison with *M. caliginosus*, *N. tenuis* increased the number of pupae consumed at a lower prey density and showed a higher attack coefficient. If action thresholds were established to minimize risk of damage associated with plant feeding by *N. tenuis*, this zoophytophagous predator could probably play an important role in IPM programs for protected crops.

Results of integrated pest management with *Bemisia tabaci* and ToCV in tomato greenhouses of Roussillon (southern France)

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Results of monitoring population of *Bemisia* and symptoms of ToCV on tomato in greenhouses of Roussillon (southern France) with integrated pest management combining comprehensive use of predators such as *Macrolophus* and insecticide pyriproxyfen show the importance of plant vigor to overpass critical point and reach a very good control of both pest and vector. The threshold of *Macrolophus* at the end of the crop and the final yield of tomato could be consider as a full sucess of IPM thanks to biological efficiency of pyriproxyfen and its good compatibility with the beneficials involved.

Distribution and abundance of mirids in horticultural crops in the region of Murcia (Spain)

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Horticultural areas of the region of Murcia (Spain) were monitored to determine the species composition and abundance of mirid fauna. Prospecting was done in summer and included both commercial and traditional crops, distributed from north to south of the region. Samples were taken mainly from tomato and other plants such as pumpkin, egg plant, etc. when available. The most abundant species were *Macrolophus* sp., *Nesidiocoris tenuis*, *Dicyphus cerastii* and *D. tamaninii*. Almost no mirids were collected on commercial crops. A gradient on the distribution of *Macrolophus* and *N. tenuis* was observed from north to south: the latter species was more abundant in the south and vice versa. *Dicyphus cerastii* was much more abundant than *D. tamaninii*.

The use of alternative host plants for *Dicyphus hesperus* on greenhouse tomatoes

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The response of the zoophytophagous *Dicyphus hesperus* (Heteroptera: Miridae) against *Trialeurodes vaporariorum* was assayed on tomato crops with and without mullein (*Verbascum thapsus* L.) as an alternative host plant for *D. hesperus*. The aim of the work was to determinate if the use of *V. thapsus* facilitated the establishment of the predator, supported the predator population when whitefly was scarce on tomato plants and improved whitefly control. Tomato and mullein plants were sampled weekly for *D. hesperus* and whitefly through the whole growing season. The use of mullein as an alternative host plants facilitated the establishment of *D. hesperus* on tomato crop: the number of *D. hesperus* in tomato houses with mullein was higher than in houses without for several weeks after the release. In both, houses with and without mullein, a satisfactory whitefly control was achieved and *D. hesperus* density on tomato decreased after that of whitefly. *D. hesperus* population increased on mullein plants as whitefly was reduced on tomato and remained high for several months until the end of the crop.

Effects of prey, *Bemisia tabaci*, and host plant switching on life-history parameters of the predator *Macrolophus caliginosus*

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Insectary plants are increasingly being used in Conservation Biological Control programs to enhance maintenance and establishment of predators in crops. *Macrolophus caliginosus* Wagner (Heteroptera: Miridae) is an omnivorous predator that feeds on plant juices and preys on whitefly (*Bemisia tabaci* and *Trialeurodes vaporariorum*), and several other tomato pests. Previous field work with two insectary plants in tomato greenhouses, showed a poorer establishment of the predator when dispersing from *Dittrichia viscosa* than from *Nicotiana tabacum*. Laboratory experiments were conducted to determine how the presence of *Bemisia tabaci* and host-switching during nymphal development affected selected life-history parameters of *M. caliginosus.*

Evaluation of *Orius majusculus* and *Orius laevigatus* as a predators of *Bemisa tabaci*

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Several species of *Orius* (Heteroptera: Anthocoridae) are present among the predatory fauna that spontaneously colonizes both protected and open field crops in the Mediterranean area. *Orius laevigatus* and *O. majusculus* are abundant in crops such as cucumber, melon, pepper, bean or strawberry. Although they are polyphagous, most species of *Orius* are well known as thrips predators and have been used in IPM programs for the control of *Frankliniella occidentalis* and *Thrips tabaci*. We conducted laboratory experiments to assess the possibility of using these species of anthocorid bugs as biocontrol agents of the whitefly *Bemisia tabaci*. Nymphs and adults of both predatory bugs were able to prey on eggs, pupae and adults of *B. tabaci*. Nymphal development feeding on pupae of *B. tabaci* lasted 13.5 and 12.4 days for *O. laevigatus* and *O. majusculus* respectively. In order to complete their nymphal development prey consumption ranged between 56 and 62 larvae of *B. tabaci*. These results are similar to those obtained previously with *F. occidentalis*, suggesting that *B. tabaci* is a suitable prey for the development of both predatory bugs.