

BIOLOGICAL CONTROL OF THE CITRUS LEAFMINER IN ISRAEL: SUCCESSSES AND FAILURES IN THE ESTABLISHMENT OF THE INTRODUCED PARASITIDS

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4 The citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae: Phyllocnistinae) (CLM), invaded Israel in 1994, as part of a worldwide expansion of the pest from its origin in Southeast Asia. Between 1994 and 1998 we imported eight parasitoids from Thailand, Taiwan, China, Australia and South America. They included the endoparasitoid *Ageniaspis citricola* Logvinovskaya (Hymenoptera: Encyrtidae) (two strains, one from Thailand, the other from Taiwan), which oviposits in the pest's eggs and first instar larvae. Also 7 Hymenoptera: Eulophidae parasitoids; the larval ectoparasitoids *Citrostichus phyllocnistoides* (Narayanan), *Quadrastichus* sp., *Semielacher petiolatus* (Girault), the endoparasitoid *Teleopterus* sp., the pupal ectoparasitoids *Cirrospilus ingenuus* Gahan, *Galeopsomyia fausta* LaSalle and the endoparasitoid *Zaommomentedon brevipetirolatus* Kamijo. All were reared in the laboratory and released in citrus groves. Three parasitoids became established. The most common parasitoid during 1997–98 was *C. phyllocnistoides*, followed by *S. petiolatus* and *C. ingenuus*. *Ageniaspis citricola*, *Quadrastichus* sp. and *Z. brevipetirolatus* were released over a period of 4 years, with no evidence of establishment. *Teleopterus* sp. and *G. fausta* were released between 1998 and 2000; only the first was ever recovered, but without evidence of establishment. Several factors appear to have affected the successful establishment of the introduced parasitoids. These included (1) The climate in the parasitoids' country of origin - *Citrostichus phyllocnistoides* and *S. petiolatus*, which are abundant in China and Australia, respectively, became established. *Cirrospilus ingenuus*, which is abundant in Asia, does not require high relative humidity, likewise became established. However, parasitoids that are important in tropical regions and were imported from Thailand and South America, failed to establish despite continuous releases since 1994. The sensitivity of *A. citricola* to low relative humidities could be the cause for its failure to establish in Israel, and the low tolerance of *Quadrastichus* sp. to low temperatures had the same effect. (2) Competition between species - In addition to its sensitivity to low temperatures, *Quadrastichus* sp. might also have failed to establish due to being outcompeted by *S. petiolatus*. The advantages of the latter are that it attacks a wider range of the host stages, it oviposits female eggs in smaller hosts and that it has a higher

oviposition rate. (3) Facultative hyperparasitism - *Quadrastichus* sp. and *C. ingenuus* are known to be facultative hyperparasitoids, although there is no evidence that this phenomenon prevented the establishment of other parasitoids. (4) Methods and number of release sites - Releases in various climatic areas and during different seasons might have influenced the chances of successful establishment. Releasing parasitoid pupae within host-infested seedlings could improve the chances of success more than the release of adults. Is the number of released parasitoid individuals an important criterion for successful establishment in a new habitat, or are the number of releases, their timing, and the number of release sites of greater significance? These factors, based on the species' ecological and biological characteristics, which relate to our methods of rearing and releasing parasitoids, will be discussed.

Session 3: Recent Successes of Classical Biological Control: An Impact Analysis

CLASSICAL BIOLOGICAL CONTROL OF THE ALEYRODIDAE (HETEROPTERA): AN ANALYSIS OF ECONOMIC AND SOCIAL IMPACT

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Numbered among the Aleyrodidae (Heteroptera) are some of the most destructive pests known, both in agriculture and in urban settings. In addition to destructive traits, members of the Aleyrodidae are among the most commonly moved pests on the globe, and invade new areas with relative ease. Classical biological control has been attempted against several of aleyrodid species. In this paper, the economic damage and impact on society of several species is reviewed, and where possible the cost or other quantification of the impact of such pests is calculated. In two recent cases of successful biological control against two different whitefly species, information on the actual cost of the biological control effort is also available. Thus, in these two cases we have quantified information on (1) the cost of the damage caused by each pest both before and (2) after the introduction of natural enemies, together with (3) the cost of the biological control program itself. In these two case studies, then, we are armed with a critical, three-pronged approach to assessing the value of a classical biological control program. The analyses presented in this paper include first an assessment of the immediate economic impact of the invasion of each pest and the subsequent impact on society, and then an evaluation of the cost of the biological control program. Having this quantitative information, a marginal rate analysis leads to an economic assessment of the cost-to-benefit ratio of the biological control program itself. The lessons learned appear to apply broadly to classical biological control, and demonstrate that classical biological control is of significant value to society, even when such quantitative assessment information is not available.

Session 3: Recent Successes of Classical Biological Control: An Impact Analysis

ESTABLISHMENT IN NEW ZEALAND OF *PSEUDAPHYCUS MACULIPENNIS* (HYMENOPTERA: ENCYRTIDAE), AND ITS IMPACT ON OBSCURE MEALYBUG, *PSEUDOCOCCUS VIBURNI* (HEMIPTERA: PSEUDOCOCCIDAE)

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6

Pseudaphycus maculipennis is one of the few known encyrtid parasitoids of *Pseudococcus viburni*. It was imported into quarantine in New Zealand in December 1997, before new environmental legislation (the Hazardous Substances and New Organisms Act) was implemented. After host testing in quarantine, application for approval to release was made to the Environmental Risk Management Authority in April 1999. Approval to release was given on 9 August 2000, after extensive consultation, provision of further technical information, and a public hearing. The first *P. maculipennis* were released in February 2001. By 2004, approximately 765,000 parasitoids had been released to nearly 50 pipfruit orchards in Hawke's Bay, Nelson/Motueka and Auckland, and to the Wellington Botanic Gardens. Using 'trap' mealybugs around the release orchards, *P. maculipennis* was recovered from up to 85% of the properties after 3 years and had dispersed at least locally at a rate of about 200 m/year. It is concluded that the species has established in New Zealand. Preliminary studies of the impact of the parasitoid on *P. viburni* populations in pipfruit orchards are described.

Session 3: Recent Successes of Classical Biological Control: An Impact Analysis

BIOLOGICAL CONTROL OF THE PINK HIBISCUS MEALYBUG IN BAHIA DE BANDERAS, NAYARIT, MEXICO

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A combination of classical and augmentative biological control program was established in the valley of Bahía de Banderas, Nayarit, Mexico, to control the recent invasive pest the Pink Hibiscus Mealybug (PHM) *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) through the introduction of three biological control agents, predator *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae), and parasitoids *Anagyrus kamali* Moursi and *Gyranusoidea indica* Shafee, Alam & Agarwal (Hymenoptera: Encyrtidae). PHM was detected in Bahía de Banderas in February 2004. Afterwards an Integrated Pest Management program was implemented by the Federal Government to contain the spread and development of this pest into commercial agriculture, urban and forest areas, including physical, cultural, chemical, legal and biological control. *C. montrouzieri* were introduced from Canada and California, USA commercial insectaries, while parasitic wasps were obtained from Belize and Puerto Rico as a cooperative program sponsored by a Central America agency OIRSA. The effectiveness of *C. montrouzieri* to control PHM and the establishment of *A. kamali* on teak were evaluated. Although, currently a total of 672,900 predators and 155,925 *A. kamali* have been released over an area of 250 hectares on this valley, this evaluation was carried out only on three commercial plantations: guava, soursop and teak. On the guava plantation (2 hectares) 2,500 and 9,500 predators were released on June and July 2004, respectively. On the soursop plantation (5 hectares) 4,500 and 5,000 predators were released on June and July 2004, respectively; while on the teak plantation (2 hectares) 4,000 and 1,000 predators were released on August and September 2004, respectively. No individuals of *A. kamali* were released at the teak plantation. Samples were taken in weekly bases from 50 trees on each plantation.

Guava. On this crop the starting PHM density recorded was 27.9 individuals/ vegetative shoot, then on August, 77 days after the first predator release the PHM density decrease drastically where the predator population density reach its maximum activity 4.3 individuals/ vegetative shoot, this resulted in a maximum decrease of 99% on the PHM density.

Soursop. On this plantation PHM density before predator release was 29.2 individuals/ vegetative shoot. Seventeen days after predator release PHM density decrease rapidly in a 78%. The maximum reduction on PHM density was 3.6 individuals/ shoot meaning an 87.6%, at this point there were 0.16 predators/ shoot.

Teak. On this plantation PHM presented the highest population densities with 119.5 individuals/ shoot. As a result of the predator activity, PHM start to decrease, up to 88.9% (13.3 individuals/ shoot) 48 days after predator first release, at this time predator density was 3.4 individuals/ shoot. The maximum reduction on PHM density 96.4% was detected 69 days after predator first release with a predator density of 0.14 individuals/ shoot. On this crop it was possible to detect *A. kamali* establishment, nevertheless this parasitic wasp was not released on this plantation but around 1 mile away on other commercial orchards and released six months before on the valley. At this time a density of 1.8 mummies/ shoot and 4.88 PHM/ shoot were detected.

Session 3: Recent Successes of Classical Biological Control: An Impact Analysis

ESTABLISHMENT OF *APROSTOCETUS VAQUITARUM* AND *QUADRASTICHUS HAITIENSIS* (HYMENOPTERA: EULOPHIDAE) IN THE U.S.A. AS MORTALITY FACTORS OF THE DIAPREPES ROOT WEEVIL (COLEOPTERA: CURCULIONIDAE)

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The weevil, *Diaprepes abbreviatus* L. (Coleoptera: Curculionidae) invaded Florida during the 70's becoming one of the most important agricultural pests of the state. Classical biological control efforts were initiated but were not successful. During 1997 a new biocontrol program was initiated. Thirteen species of egg parasitoids were introduced and tested under quarantine conditions. Among these parasitoids, the egg parasitoids *Aprostocetus vaquitarum* (Wolcott) and *Quadrastichus haitiensis* Gahan (Hymenoptera: Eulophidae) were introduced

from the Caribbean Region between 1999 and 2000. Both parasitoid species were released in different areas of Florida and their recovery assessed during 3 years. Both parasitoids have become established in the southern portion of the Florida peninsula [tropical climate, winter temperatures not lower than 18°C, constant host densities), but have failed to establish in areas with sporadic host densities and winter temperatures lower than 15°C. In the area where the ectoparasitoid, *A. vaquitarum* is established, it appears to be more prevalent than *Q. haitiensis* causing 60-100% mortality to *Diaprepes abbreviatus* eggs. Parasitoid dispersion has been observed within a 4-mile ratio from the nearest dispersion site with host mortality levels between 70-90%. It is not known if the parasitoid would be able to colonize areas of the state north of the southern tip of the peninsula.

Session 3: Recent Successes of Classical Biological Control: An Impact Analysis

BIOLOGICAL CONTROL OF THE REDGUM LERP PSYLLID IN MEXICO

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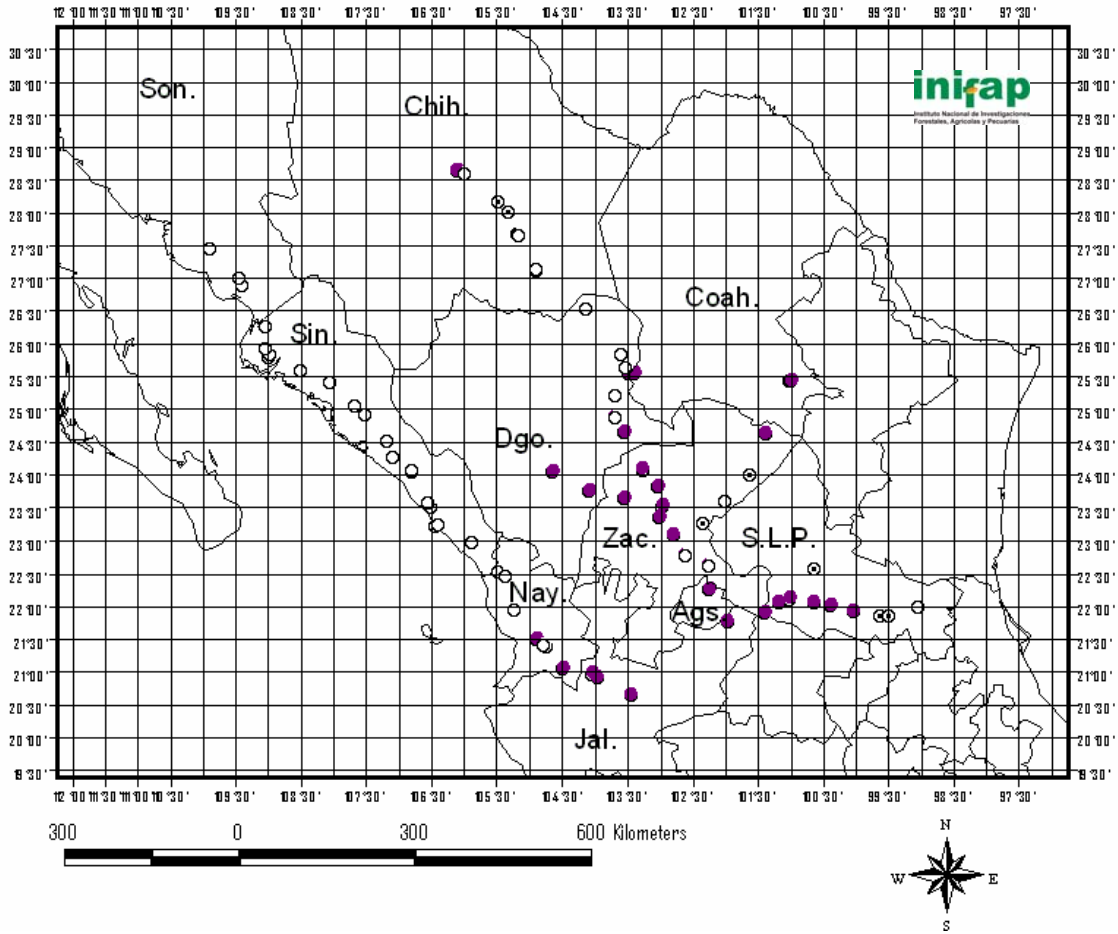
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Since the beginning of the 20th century, *Eucalyptus camaldulensis* Den. (Myrtales: Myrtaceae) and a few other *Eucalyptus* species have been widely planted in Mexico. For a long time *E. camaldulensis* was a pest free tree. However, in year 2000 the redgum lerp psyllid (*Glycaspis brimblecombei* Moore) (Homoptera: Spondylaspididae) was detected. In 2001, this psyllid became a nationwide problem. On January of 2002, a quarantine program was implemented on 21 states, and sanitary actions were mandated by law.

Two main approaches were taken for direct control of the red gum lerp psyllid:

- 1) **Biological control with local natural enemies.** Several predator insects were evaluated: *Harmonia axyridis* Pallas, *Olla v-nigrum* Mulsant (Coleoptera: Coccinellidae) *Geocoris punctipes* Say (Hemiptera: Lygaeidae) and *Chrysoperla* spp. (Neuroptera: Chrysopidae), were tested in Guadalajara, Jalisco and Pabellon de Arteaga, Aguascalientes. Additionally, the control effect of the ant *Anoplolepis longipes* (Jerd.) (Hymenoptera: Formicidae) was evaluated in Guadalajara. Only *A. longipes* appeared to exert some control. For the other species, results were equivocal.
- 2) **Classical biological control.** This strategy was started by a forestry agency in Guadalajara (FIPRODEFO), in collaboration with D. L. Dahlsten (University of California) and the National Secretariat of Environment and Natural Resources. The parasitoid *Psyllaephagus bliteus* Riek (Hymenoptera: Encyrtidae) was brought from California (USA) (previously imported from Australia) to Guadalajara in May of 2001. At that time, 75 couples were released on a recreational park. The parasitoid was reared at FIPRODEFO facilities and released at the same park in October of 2001, and later on nearby areas. Insect dispersion was monitored with yellow sticky traps. Parasitoid catches were difficult to observe at first. However, from May to July of 2002, a high percentage of parasitism by *P. bliteus* was found on tree foliage by personnel of the National Research Institute on Forestry, Agriculture and Livestock (INIFAP), at 32 locations, ca. 250 km apart from the original release point. The parasitoid was also collected at other locations more than 500 km apart from the original release point. Because of the high parasitism observed at very distant points, soon after the first releases, the senior author hypothesized that *P. bliteus* could have entered into Mexico together with the psyllid, or spread down from early releases in California (USA). However, regardless of the origin, this parasitoid is now well established in Mexico. A regional survey made by INIFAP during 2004, reports *P. bliteus* in nearly all places where the psyllid is present. Infestation levels were very low in 2004 in comparison with 2002. As by October of 2004, the psyllid was completely absent in two formerly infested coastal states and partially absent in two other states. Other factors appear to be affecting *G. brimblecombei* as well; however, *P. bliteus* is a specific parasitoid and it has found in Mexico suitable environments for its establishment.



- Both, *Glycaspis brimblecombei* and *Psyllaephagus bliteus* present.
- ◐ *Glycaspis brimblecombei* present and *P. bliteus* absent.
- *Glycaspis brimblecombei* absent.

Current distribution of *Glycaspis brimblecombei* and *Psyllaephagus bliteus* within 10 estates of Mexico. Each circle indicates the locations where insects were sampled. (INIFAP-CONAFOR-CONACYT 2004).

UPDATES ON THE BIOLOGICAL CONTROL OF THE CALIFORNIA RED SCALE IN SICILY

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The California Red Scale [*Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae)] is considered to be one of the most injurious pests to citrus groves in the Mediterranean basin. Continuous investigations on the population dynamics of the scale as well as on its main mortality factors have been carried out.

The natural enemies complex is constituted by the parasitoids *Aphytis* spp. and *Encarsia perniciosi* (Tower) (Hymenoptera: Aphelinidae) and by the predators *Chilocorus bipustulatus* (L.), *Rhyzobius lophantae* Blaisdell (Coleoptera: Coccinellidae), *Cybocephalus rufifrons* Retter (Coleoptera: Cybocephalidae) and *Lestodiplosis aonidiellae* Harris (Diptera: Cecidomyiidae). The following species of *Aphytis* are recorded in Sicily: *chilensis* Howard, *chrysomphali* (Mercet), *lignanensis* Compere, *maculicornis* (Masi), *melinus* DeBach and *proclia* (Walker). After the introduction of *A. melinus* in Sicily during the 60's, this parasitoid and *A. chrysomphali* were the predominant species in Sicilian citrus groves, but following studies have shown the substitution of *A. chrysomphali* with *A. melinus*, which was proven to be well adapted and spread out in the main citrus growing areas in Southern Italy. In 1988-90 the parasitoid *Comperiella bifasciata* Howard (Hymenoptera: Encyrtidae) was introduced and since then it has been only occasionally recovered. The results of a field survey on the presence and diffusion of *A. chrysomphali* and *C. bifasciata* in Sicily are presented.

***Aphytis chrysomphali*.** The observations were conducted on orange (cv. “Tarocco”, “Valencia Late” and “Washington Navel”) and lemon (cv. “Femminello”) in Eastern Sicily during 2003. Infested fruits, leaves and twigs of each variety were monthly collected and 500 specimens of California Red Scale per sample were observed and the *Aphytis* spp. pupae found were identified. The data collected showed that in the investigated areas, the species *A. melinus* and *A. chrysomphali* were present; the first one was predominant while the second species was occasionally recovered on colonies of California Red Scale infesting lemon trees. Furthermore, the two species showed a seasonal alternation: *A. chrysomphali* was found especially during wintertime, while *A. melinus* mainly in warmer periods.

***Comperiella bifasciata*.** The aim of the survey, which started in 2003 and is still continuing, was to confirm the establishment of the encyrtid and to draw a map of its diffusion, 15 years after its first introduction. Infested fruits (20) and twigs (4 meters, 1-2 years old) were col-

lected monthly in 10 groves in South Eastern Sicily (Siracusa province). Half of the sample was observed and the parasitized instars were isolated and reared until the adult parasitoids emerged. The remaining 50% was kept into emergence boxes and the emerging parasitoids were collected and identified. The presence of the parasitoid was also monitored using pheromone traps for the California Red Scale in different citrus groves. The data collected showed that the encyrtid is well adapted and has colonized a wide area, 50km, on average, far away from the first introduction site. The survey will be continued and expanded in the next years in order to acquire quantitative data on the parasitic activity of the encyrtid.

Session 3: Recent Successes of Classical Biological Control: An Impact Analysis

**RELEASES, RECOVERY, AND DISSEMINATION IN
NORTH AMERICA OF *LATHROLESTES ENSATOR*,
A BRACONID ENDOPARASITOID OF THE APPLE SAWFLY,
*HOPLOCAMPA TESTUDINEA***

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Introduced accidentally in New York State in 1939, the apple sawfly, *Hoplocampa testudinea* Klug (Hymenoptera: Tenthredinidae), gradually invaded apple orchards of Northeastern North America. Native from Europe *Lathrolestes ensator* Brauns is a braconid endoparasitoid that has only one host: the apple sawfly. As the apple sawfly has one host plant, the apple tree, and as no soft methods or natural enemies were known in North America, the apple sawfly was a

prime target for a biological control program, although presently no rearing methods are known. Collected in various localities in Western Europe, *L. ensator* has been shipped as parasitized cocoons to be released annually, after a quarantine check, in an insecticide-free apple orchard at Frelighsburgh, Qc, Canada, from 1995 to 1999. Collections in 1999 demonstrated that *L. ensator* had successfully established in North America. Further collections in 2000 demonstrated that the braconid parasite had extended his local distribution. In 2002 parasitized cocoons were collected in Frelighsburgh and released in a non-treated orchard of New Hampshire. In 2003 and 2004 parasitised cocoons were collected and released in two organic orchards in Quebec, one non-treated orchard in Ontario and one non-treated orchard of New Hampshire. Dissection of cocoons determined that parasitism rates in Frelighsburgh were variable, and as high as 69.7%. At such rates, apple sawfly populations would be under control. Recovery studies are planned for May 2006.

Session 4: Cultural Manipulations to Enhance Biological Control

ATTRACTIVENESS OF FLOWERING PLANTS TO APHIDOPHAGOUS HOVERFLIES: SUITABILITY AS INSECTARY PLANTS TO ENHANCE BIOLOGICAL CONTROL

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Insectary plants are increasingly being used in Conservation Biological Control to enhance predators in crops. In this study, relative attractiveness of twenty four plant species to aphidophagous hoverflies has been evaluated in an experimental field. Plant species were selected according to published results of previously examined plants and flowering time. Attractiveness was assessed by conducting timed observations of visit frequencies and also recording the observed behaviour in each plot. Plants were also inspected for aphids and syrphid larvae.