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THE CITRICULUS MEALYBUG, *PSEUDOCOCCUS CRYPTUS* HEMPEL, AND ITS NATURAL ENEMIES IN ISRAEL: HISTORY AND PRESENT SITUATION.

ABSTRACT

THE CITRICULUS MEALYBUG, *PSEUDOCOCCUS CRYPTUS* HEMPEL, AND ITS NATURAL ENEMIES IN ISRAEL: HISTORY AND PRESENT SITUATION.

The citriculus mealybug, *Pseudococcus cryptus* Hempel, was first discovered in Israel in 1937 and very rapidly became a key pest of citrus. However, since the early 1940s, the mealybug population has sharply decreased. This occurred in parallel with the establishment of the introduced parasitoid *Clausenia purpurea* Ishii, which was then believed to be the main cause of the biological control of the mealybug. Since the late 1980s, outbreaks of *P. cryptus* have been recorded mainly in new citrus varieties, such as red grapefruits, pomelo, "sweety" and several peeling varieties. The current outbreaks are probably related to the susceptibility of these mentioned varieties to *P. cryptus*, and to the adverse effects of Insect Growth Regulators to coccinellid predators, especially *Scymnus* spp. The introduced *C. purpurea* and two other local encyrtid parasitoids, *Leptomastix* near *algirica* and *Anagyrus diversicornis* Mercet, rarely emerged from samples of *P. cryptus* collected during 1996-1998. Four further parasitoid species were introduced into Israel during 1996-1997 against *P. cryptus*: from central Asia, the platygasterids *Allotropa burrelli* Muesebeck and *A. convexifrons* Muesebeck and the encyrtid, *Pseudaphycus malinus* Gahan; and from Japan, *Anagyrus sawadai* Ishii. *A. convexifrons* and *A. sawadai* successfully parasitized *P. cryptus* and, therefore, were released in the field but only *A. sawadai* has so far been recovered. A considerable reduction in population densities of the pest has been recorded since May, 1998, in the major release site of the latter species.

Key words: distribution, host plants, *Pseudococcus comstocki*, *P. citriculus*, *P. viburni*, IGR, Coccinellidae, *Planococcus citri*, *P. ficus*, *Aonidiella aurantii*, *Ceroplastes floridensis*, *Anagyrus pseudococci*, *Leptomastidia abnormis*, *Leptomastix flavus*, *Cryptolaemus montrouzieri*, Cecidomyiidae, Sympherobiidae, Chrysopidae.

THE MEALYBUG

The citriculus mealybug *Pseudococcus cryptus* Hempel (Hemiptera: Pseudococcidae) is widespread in the tropical and subtropical regions of Africa, Central and South America, East Asia, China and Japan. It is a severe pest of citrus in Japan and Israel and has been also recorded from many host plants, including the roots of coffee trees in South America, mango, avocado, banana, guava, palm trees, oleander and persimmon (Ben-Dov, 1994). Based on the distribution of its principal parasitoids, the presumed origin of *P. cryptus* is south-east Asia.

Upon its discovery in Israel, *P. cryptus* was identified as the Comstock mealybug, *Pseudococcus comstocki* (Kuwana) (Klein & Perzelan, 1940). Later studies indicated that this was a misidentification and the species was named in Israel as *Pseudococcus* aff. *citriculus* (Bodenheimer, 1951; Rivnay, 1968). Subsequently, Borchsenius (1956) identified material taken from citrus in Israel as *P. citriculus* Green. In 1992, Williams and Granara de Willink synonymized *P. citriculus* with *P. cryptus* Hempel. The mealybug material collected by us on citrus in Israel since the 1960s to the present, was studied and found to agree well with the modern redescription of *P. cryptus* by Williams & Granara de Willink (1992).

In Israeli citrus groves, *P. cryptus* usually occurs together with the citrus mealybug, *Planococcus citri* (Risso). However, *P. citri* occurs and develops on the fruits but *P. cryptus*, while it can infest all parts of the tree, is found mainly on the leaves and twigs. Damage to citrus has been associated with fruit and flower drop, wilting and general debilitation of the plant and also, importantly, with the unsightly appearance of the fruit due to the large quantities of honeydew on which sooty mould develops. When the infestation levels of *P. cryptus* are high, it tends to aggregate in dense colonies covering the leaves, twigs and trunk. In the Coastal Plain of Israel, the mealybug is able to produce 6 generations annually (Gruenberg, 1956), which allows rapid population build up.

Natural enemies of *P. cryptus*.

Fifteen species of predators, mainly coccinellids, and 12 species of hymenopterous parasitoids, mainly encyrtids, have been recorded from *P. cryptus* (Table 1). Among the recorded parasitoids, the principal ones are probably those from the Far East. Although *P. cryptus* serves as a food for many coccinellids in different regions, for most or all of them the mealybug is an accidental suitable prey.

Outbreaks of *P. cryptus* in Israel:

Late 1930s.

Pseudococcus cryptus was first recorded in Israel in 1937, in a citrus grove on the Coastal Plain, where it rapidly dispersed to most of the citrus plantations in the south (Avidov & Harpaz, 1969), becoming a devastating citrus pest. A major control project was, therefore, initiated (Bodenheimer, 1951; Rivnay, 1968). However, within 3-4 years, the populations of the mealybug in citrus groves dropped to very low levels and no further economic damage was recorded (Bodenheimer, 1951; Rivnay, 1968). This remarkable change in the pest status of *P. cryptus* in Israel was considered a case history of classical biological control, attributed to the encyrtid parasitoid *Clausenia purpurea* Ishii (Hymenoptera: Encyrtidae), which was introduced into Israel in 1940 (DeBach, 1974; Rosen, 1967).

Table 1. Natural enemies of *Pseudococcus cryptus*[1]

Order & Family	Species	Distribution	Reference
Diptera			
Cecidomyiidae	*Diplosis* sp.	Far East	Bodenheimer, 1951
Neuroptera			
Sympherobiidae	*Sympherobius sanctus* (Tjeder)	Mediterranean	Rivnay, 1968
Chrysopidae	*Chrysoperla carnea* (Stephens)	Cosmopolitan	Present study (1996-1998)
Coleoptera			
Coccinellidae	*Hyperaspis quinquenotata* Mulsant	South America	de Moraes (pers. comm)
	H. pumila Mulsant	Mediterranean	Rivnay, 1968
	Oxynychus marmottani Sairm	Mediterranean	Bodenheimer, 1951
	Pentilia sp.	South America	de Moraes (pers. comm.)
	Scymnus bipunctata Kugelan	Far East	Bodenheimer, 1951
	S. fenestratus Sahlberg	Mediterranean	Rivnay, 1968
	S. suturalis Thunberg	Mediterranean	Rivnay, 1968
	S. quadrimaculatus Hbst.	Mediterranean	Rivnay, 1968
	S. apetzi Mulsant	Mediterranean	Bodenheimer, 1951
	S. pallidivestis Mulsant	Mediterranean	Kehat & Greenberg, 1975
	S. includens Kirsch	Mediterranean	Rivnay, 1968
	Cryptolaemus montrouzieri Mulsant	Australia	Mendel *et al.* 1992
Hymenoptera			
Encyrtidae	*Anagyrus diversicornis* Mercet	Cosmopolitan	Noyes & Hayat, 1988
	A. pseudococci (Girault)	Mediterranean	Rivnay, 1968
	A. sawadai Ishii	Far East	Noyes & Hayat, 1988
	Clausenia purpurea Ishii	Far East	Rivnay, 1968
	Cryptanusia albiclava Girault	South-east Asia	Noyes & Hayat, 1988
	Leptomastidea abnormis (Girault)	Mediterranean	Bodenheimer, 1951
	Leptomastix nr *algirica* Trjapitzin	Mediterranean	Present study
	L. citri Ishii	Far East	Bodenheimer, 1951
	L. epona (Walker)	?	Noyes (pers. comm)
	L. flavus Mercet	West Palaearctic	Bodenheimer, 1951
	Chrysoplatycerus flavicollis (De Santis)	?	Hall, 1974
Platygasteridae	*Allotropa convexifrons* Muesebeck	Turkmenistan	Present study

[1] indicates association between the listed natural enemy and *P. cryptus*

The 1990s.

Since the early 1990s, severe outbreaks of *P. cryptus* have been recorded in the Coastal Plain, in Western Galilee and in the Yizre'el Valley, where damage has been mainly caused to red grapefruits, pomelo, "sweety" and several peeling varieties. Such outbreaks occurred also in citrus groves maintained strictly under biological control management and, therefore, the tendency was not to relate the outbreaks to the disruption of biological balance. Currently, chemical control of *P. cryptus* in Israel is achieved by applications of the organophosphate insecticide chlorpyriphos.

There are two possible reasons for the present outbreaks of *P. cryptus* in Israeli citrus plantations: the first is the increasing and intensive use of Insect Growth Regulators (IGRs) for the control of armoured and soft scale insects in citrus, as well as whiteflies and lepidopteran pests in adjacent cotton fields. The adverse effects of IGRs on natural enemies of scale insects, mainly predators, were demonstrated in several studies conducted in recent years (Mendel *et al.*, 1994; Peleg, 1983). IGRs differ in their toxicity to natural enemies of different groups and species; coccinellids are apparently more sensitive to these chemicals than hymenopteran parasitoids (Mendel *et al.* 1994; Peleg & Gothilf, 1980). IGRs affect coccinellids throughout their life cycle, some are highly residual and, therefore, their adverse effects on lady beetles may last for longer than that of the conventional organophosphate or carbamates used in Israel. Coccinellids are highly susceptible to pyriproxifen (Mendel *et al.* 1994), an IGR chemical which is commonly used in Israel for the control of the California red scale, *Aonidiella aurantii* (Maskell) and the Florida wax scale, *Ceroplastes floridensis* Comstock (Peleg & Bar-Zacay, 1995). The second reason for outbreaks is the susceptibility of the new citrus varieties to mealybugs. Since the 1970s, new citrus varieties, such as red grapefruit, "sweety", pomelo and peeling varieties, have been planted in Israel. Outbreaks are far more frequent in orchards planted with the new varieties than in those planted with the traditional ones, such as Shamouti, Valencia or Navel oranges (Table 2).

Biological control of *P. cryptus* in Israel

Local natural enemies.

Soon after the first outbreak of *P. cryptus* in 1937, a survey of natural enemies of the pest was initiated (Rivnay, 1968). The predator fauna included four lady beetles of the genus *Scymnus*, namely *S. fenestratus* Sahlb., *S. suturalis* Thumb., *S. includens* Kirsch and *S. quadrimaculatus* Hbst., which were abundant in the spring and early summer and which, in these seasons, succeeded in keeping the population of the mealybug at a low level (Rivnay, 1968). These coccinellids are also common predators of *P. citri* in Israel.

Three encyrtid parasitoids were recorded from *P. cryptus* in the early 1940s: *Anagyrus pseudococci* (Girault), *Leptomastidea abnormis* (Girault) and *Leptomastix flavus* Mercet. The first two species are common parasitoids of *P. citri* in the Mediterranean, whereas the latter species was collected from the Mediterranean vine mealybug, *Planococcus ficus* (Signoret) in the Negev, Southern Israel (Berlinger, 1977).

Table 2. Infestation level (Number of infested plots) of *P. cryptus* on various citrus varieties in 1996-1997

Citrus variety	No. of plots examined	Infestation level		
		None	Low	High
Red Grapefruit	5	0	3	2
"Sweety"	7	0	2	5
Pomelo	7	0	1	6
Peeling Varieties	21	0	2	19
Shamouti Orange	13	10	2	1
Valencia Orange	5	0	0	0

Table 3. Parasitoids introduced into Israel in 1996-1997 for the control of *P. cryptus.*

Natural enemy	Area of collection - year of introduction (Host mealybug)	Successfully reared on *P. cryptus*	Successfully established in citrus groves in Israel.
Platygasteridae			
Allotropa burrelli Mues.	Republic of Georgia - 1996 (*P. comstocki*)	No	No
Allotropa convexifrons Mues.	Turkmenistan - 1997 (*P. comstocki*)	Yes	No
Encyrtidae			
Pseudaphycus malinus Gahan	Republic of Georgia - 1996 (*P. cryptus*)	No	No
Anagyrus sawadai Ishii	Japan - 1997 (*P. cryptus*)	Yes	Yes

In the present study (1996-1998), only *A. pseudococci* and *L. flavus* were collected in mid-summer and always in very small numbers. In 1997, two additional encyrtid parasitoids were recorded for the first time in Israel from samples of *P. cryptus,* namely *Anagyrus diversicornis* Mercet and *Leptomastix* near *algirica* Trjapitzin. *Anagyrus diversicornis* is distributed in Europe and

Asia, where it parasitizes many mealybug species of various genera (Noyes & Hayat, 1988). John Noyes (pers. comm.) indicated that *L.* near *algirica* is very close to *Leptomastix epona* (Walker). The latter is used in augmentative releases against *Pseudococcus viburni* (Signoret) in tomato greenhouses in western Europe, and was successfully reared on *P. cryptus* in our laboratory.

Introduction and release of exotic parasitoids:

The search for exotic parasitoids in the 1940s was based on the misidentification in Israel of the mealybug discovered in 1937. Therefore, the emphasis was on parasitoids of *P. comstocki* rather than of *P. cryptus*. Three parasitoid species were imported from Japan in 1940, namely *Clausenia purpurea* Ishii (Encyrtidae), *Leptomastix* sp. (Encyrtidae) and *Allotropa burelli* Muesebeck (Platygasteridae), but only *C. purpurea* was mass-reared in Israel (Bodenheimer, 1951; Rivnay, 1968). *Clausenia purpurea* was released in large numbers and rapidly became established in many of the infested sites. High parasitization rates were reported within less than two years (Rivnay, 1968). Based on the rapid establishment of *C. purpurea*, Gruenberg (1956) regarded *C. purpurea* one of the major factors that contributed to the complete control of this pest in many parts of the Coastal Plain during the 1940s.

In the course of this study (1996-1998), *C. purpurea* emerged from samples of *P. cryptus*, collected from most of the infested citrus plantations surveyed. However, although *C. purpurea* was more common than other parasitoids, only small numbers were recorded during the second half of the summer and parasitism by this parasitoid was always below 0.5%.

Six attempts at establishing *Cryptolaemus montrouzieri* Mulsant in Israel to improve the control of mealybugs in citrus groves, have been conducted during the last 70 years, including an introduction from eastern Australia, its native area. Successful establishment has been achieved with material collected in Spain in the late 1987 (Manes Wysoki, pers. comm.) but the beetle is not an important biocontrol agent of mealybugs (Mendel *et al.*, 1992) and has rarely been observed in populations of *P. cryptus*.

Four parasitoid species were introduced into Israel during 1996-1997 for the control of *P. cryptus* (Table 3). These were: *Allotropa burrelli* Mues. and *Pseudaphycus malinus* Gahan from the Republic of Georgia, *Allotropa convexifrons* Mues. from Turkmenistan and *Anagyrus sawadai* Ishii from Japan. The first two parasitoids were collected from colonies of *P. comstocki*, while the last two species were reared from *P. cryptus*. Only *A. convexifrons* and *A. sawadai* have successfully parasitised *P. cryptus* in Israel. They were, therefore, reared in our laboratory and released in the infested orchards. For rearing purposes, small lemon twigs attached to the fruit and heavily infested with *P. cryptus* were used. However, due to difficulties in their mass-rearing, we were able to release only small numbers of each of these two parasitoids. Releases of about 1,500 *A. sawadai* were made during April-May, 1997, and of about 200 individuals of *A. convexifrons* during April-September, 1997.

So far, only *A. sawadai* has become established in a release site in the Yizre'el Valley. The first recovery was recorded by the end of July, 1997, less than four months after the first release in late March. Since then, large numbers of *A. sawadai* have emerged in all samples of the mealybug collected at the major release site. The recovery of this new parasitoid in January and in February, 1998, and especially the large numbers of adults that emerged during June, 1998, undoubtedly indicates that they survived the cold season and so were not adversely affected by the low winter temperatures. In June, 1998, the parasitoid also emerged in large numbers in several infested plots adjacent to the release site and were the dominant parasitoid in all samples of *P. cryptus* taken from the release site. In July, 1998, *A. sawadai* was recorded in a sample of the mealybug collected in the southern Coastal Plain, following a single release of 300 individuals in March, 1998.

DISCUSSION

When introduced into Israel in 1937, *P. cryptus* was not accompanied by any of its principal natural enemies. Chemical control was not effective and, therefore, efforts were made toward biological control of the mealybug. Biological control studies included a survey of local natural enemies and the importation of exotic parasitoids (Bodenheimer, 1951; Rivnay, 1968). The parasitoid, *C. purpurea* was imported into Israel in 1940 and was released in several infested groves. However, before major releases were conducted, a reduction in the pest population levels was recorded in many of the infested plots (Gruenberg, 1956). We assume, therefore, that the reduction in the pest population could not be related to the effect of the parasitoid, although Gruenberg (1956) considered that *C. purpurea* was an efficient parasitoid, very well adapted to *P. cryptus*, and believed that it ad been the major factor responsible for the control of the mealybug in many areas in the Coastal Plain in Israel. This conclusion was subsequently accepted as a case history of classical biological control of an exotic pest (Harpaz & Rosen, 1971; DeBach, 1974). On the other hand, Bodenheimer (1951) suggested that the role of *Scymnus* spp. was extremely valuable in the biological control of *P. cryptus*, and he had expressed doubts as to the crucial role of *C. purpurea* in its successful control. He stated that "if *Clausenia* had not been introduced, the final result would have been rather similar. Perhaps the regression of the mealybug would not have been as quick as it actually was". Moreover, Bodenheimer (1951) also reported that the introduction of the mealybug into Cyprus without the introduction of *C. purpurea* was not accompanied by any major outbreak. Rivnay (1968) pointed out that there was competition for *P. cryptus* between the various natural enemies; in one grove, *Anagyrus pseudococci* was dominant while *L. flavus* was more prevalent in another. In another grove, *Scymnus* spp. were dominant and the pest was overcome before *C. purpurea* could become established.

Although we can not exclude the contribution of *C. purpurea* to the successful control of *P. cryptus* in the 1940s, its very low abundance in our present study (1996-1998) in most of the infested groves, and the fact that it was not able to prevent the present and continuous (1990-1998) outbreak, also support the opinion that its role in the 1940s was minor.

The role of *A. pseudococci* and *L. flavus* in the 1940s is also questionable. Rivnay (1968) suggested that these parasitoids, together with the activity of *Scymnus* spp., played an important role in the control of *P. cryptus*. *Anagyrus pseudococci* is mainly a parasitoid of *Planococcus* spp. and, in the present study, rarely emerged from large samples of *P. cryptus*. *Leptomastix flavus* is extremely rare in local groves and does not play any role in the reduction of the population level of *P. cryptus*.

Unlike the citrus mealybug, *P. cryptus* develops in clumps, forming large aggregates on leaves, branches and stems. Thus, these colonies are easy targets for coccinellid predators. The adverse effects of IGRs on these predators may well explain the recent outbreaks of *P. cryptus*. IGRs do not seem to have any critical effects on the parasitoid fauna in the groves (Mendel *et al.* 1994). Although their effects on *C. purpurea* were not investigated, we assume that, like other parasitoids, it is less susceptible to IGRs than coccinellids. Therefore, the consistent low prevalence of *C. purpurea* in most of the citrus groves is here considered not to be due to the negative effects of IGRs.

The successful establishment of *A. sawadai* in 1997-1998 may have contributed to the improvement of the biological control of *P. cryptus*. However, it is difficult to forecast whether a reduction in the use of IGRs in the citrus grove will enable *A. sawadai* to efficiently control the mealybug on susceptible varieties. It is also too early to evaluate the role of this parasitoid in the control of *P. cryptus* in Israel.

Several species of *Scymnus* were very abundant in the *A. sawadai*-release sites, and probably contributed to the reduction in the population densities of the pest recorded since May, 1998, in these sites. *Scymnus* spp. are at low densities during the winter and spring (Bodenheimer 1951) and they are unable to multiply fast enough to limit the rapid build-up of *P. cryptus* populations on susceptible citrus varieties until the second half of the summer. Hence, effective biological control of the mealybug on susceptible varieties may be achieved if the interference of IGRs in the ecosystem is markedly reduced.

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REFERENCES

Avidov, Z., Harpaz, I., 1969 - Plant Pests of Israel. Israel Universities Press. 549pp.

Ben-Dov, Y., 1994 - A Systematic Catalogue of the Mealybugs of the World (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae), with Data on Geographical Distribution, Host Plants, Biology and Economic Importance. Intercept Ltd Andover. 686pp.

Berlinger. M.J., 1977 - The Mediterranean vine mealybug and its natural enemies in southern Israel. *Phytoparasitica*, 5: 3-14.

Bodenheimer, F.S., 1951 - Citrus Entomology in the Middle East. Junk, The Hague, The Netherlands. 663pp.

Borchsenius, N.S., 1956 - Contribution to the question of the species composition of scale insects harming citrus in Israel (Insecta: Coccoidea) (In Russian). *Zoologicheskii Zhurnal*, 35: 863-887.

DeBach, P., 1974 - Biological Control by Natural Enemies. Cambridge University Press. 323pp.

Gruenberg, A., 1956 - Citrus Pests and Their Control. Chachik Publishers, Tel-Aviv. 169pp. (In Hebrew).

Hall, J.C., 1974 - A new genus and species of mealybug parasite from Paraguay (Hymenoptera: Encyrtidae). *Entomological News*, 85: 19-20.

Klein, H.Z., Perzelan, J., 1940 - A contribution to the study of *Pseudococcus comstocki* in Palestine. *Hadar*, 13: 69-71. (In Hebrew).

Mendel, Z., Blumberg, D., Wysoki, M., 1992 - Biological control of four homopterans in Israeli horticulture: achievements and problems. *Phytoparasitica* Suppl., 20: 45-49.

Mendel, Z., Blumberg, D., Ishaaya, I., 1994 - Effects of some Insect Growth Regulators on natural enemies of scale insects (Hom.: Coccoidea). *Entomophaga*, 39: 199-209.

Noyes, J.S., Hayat, M., 1988 - Oriental mealybug parasitoids of the Anagyrini. CAB International, London. 554pp.

Peleg, B.A., 1983 - Effect of three insect growth regulators on larval development and egg viability of the coccinellid *Chilocorus bipustulatus* (Col. Coccinellidae). *Entomophaga*, 28: 117-121.

Peleg, B.A., Bar-Zakay, I., 1995 - The pest status of citrus scale insects in Israel (1984-1994). *Israel Journal of Entomology*, 29: 261-264.

Peleg, B.A., Gothilf, S., 1980 - Effect of the juvenoid altozid on the development of three hymenopterous parasites. *Entomophaga*, 25: 323-327.

Rivnay, E. 1968 - A review of biological control (and related subjects) in Israel. *Israel Journal of Entomology*, 3: 1-156.

Rosen, D., 1967 - Biological and integrated control of citrus pests in Israel. *Journal of Economic Entomology*, 60: 1422-1427.

Williams, D.J., Granara de Willink, M.C., 1992 - Mealybugs of Central and South America. CAB International, Wallingford. 635pp.