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INTEGRATED CONTROL METHODS OF THE CITRUS MEALYBUG, *PLANOCOCCVS CITRI* (RISSO) IN CRETE, GREECE

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ABSTRACT

The citrus mealybug *Planococcus citri* (Risso) (Coccoidea: Pseudococcidae) is a major pest of citrus orchards in Crete. In order to reduce the use of chemical insecticides, experiments were carried out in Crete to introduce integrated control methods of the pest. The predator *Ciyptolaemus montrouzieri* Mulsant was released at three predator:prey ratios (1:10, 1:15 and 1:30) on potted orange trees, which were kept in a rain-protected shack. The releases at 1:15 reduced the population of the mealybug significantly. The controlling effect of *C. montrouzieri* was compared with that of the predator *Nephus reunioni* Ftirsh (at a ratio of 1:15) and with the insecticide methidathion (at a concentration of 0.1 %), under controlled conditions (25-30°C and 55-70% RH). The mealybug was maintained on pumpkin squash, *Cucurbita moschata* Duch. *C. montrouzieri* reduced the mealybug population better than *N. reunioni-*, the highest reduction, however, was obtained by methidathion. We evaluated the possibility of preventing grapefruit infestation by interfering with the migration of the mealybug from the roots to upper parts of trees. Smearing an adhesive material around the trunks significantly reduced the level of mealybug populations on fruits. This physical control method can be combined with other methods into the integrated pest management of the citrus mealybug. The insecticidal effect of petroleum oil (at concentrations of 1.5% and 2%) was compared with that of methidathion (0.15%) in a mandarin orchard. Oil application in August was not effective in reducing the population; however, the 2% spray was more effective than the 1.5% one.

KEYWORDS: Citrus, Pseudococcidae, *Planococcus citri,* biological control, chemical control, *Ciyptolaemus montrouzieri, Nephus reunioni,* adhesives.

INTRODUCTION

The citrus mealybug, *Planococcus citri* (Risso) (Coccoidea: Pseudococcidae), is a serious pest of a wide variety of agricultural crops (Bodenheimer, 1951; Cox, 1981). It is reported to be the most harmful citrus pest in Crete, causing major damage to navel oranges and grapefruit (Alexandrakis, 1984, 1986). Although the citrus mealybug attacks a wide range of host plants, biological control strategies in commercial greenhouse crops have not been implemented widely since 1967 (McKenzie, 1967). The ability of several natural enemies (including C. *montrouzieri)* to suppress mealybug populations in greenhouse ornamentals by periodic releases has been demonstrated (Whitcomb, 1940; Doutt, 1951, 1952; Tumbull and Chant, 1961; McLeod, 1962).

Chemical control of the citrus mealybug is difficult because of the waxy material covering the eggs and the adult females and due to the cryptic behaviour of the developmental stages. Outbreaks of citrus mealybug are partially the result of the continuous application of broad-spectrum organophosphate pesticides.

Occasionally, the application of chemical insecticides prevents the colonization and buildup of parasites and predators in sufficient numbers to control mealybug populations (Bivins and Deal, 1973). In spite of the ecological consequences of chemical control measures, especially of broad-spectrum insecticides, selective chemicals are used to suppress sudden outbreaks of mealybug populations. Chemicals such as sulfotepp, malathion, diazinon and aldicarb have been used to control the citrus mealybug (Bivins and Deal, 1973).

The selective toxicity of petroleum oil makes it preferable to synthetic insecticides for application in combination with parasites and predators in integrated pest management of citrus pests. Pest resurgence may be prevented where oil is applied (Furness, 1983; Ohkubo, 1983).

In this study we evaluated the regulatory effect of the predator *C. montrouzieri* on citrus mealybug populations infesting orange trees under greenhouse conditions. The effect of *C. montrouzieri* was also compared with that of *N. reunioni* and methidathion (Ultracide) on mealybug populations under controlled conditions of temperature and relative humidity. We also tested the possibility to reduce mealybug infestation of the fruits by preventing mealybug movement from the roots. The controlling effect of petroleum oil on the citrus mealybug was also investigated in this study.

MATERIALS AND METHODS

Release of *C. montrouzieri* at three predator:prey ratios. The experiment was conducted in a greenhouse at the Agricultural Research Centre of Crete and Islands in Chania, Greece (hereafter abbreviated as ARCG), on potted orange seedlings. The population of the citrus mealybug on the trees included mainly young immature stages. Each tree was covered by a 2-mm-mesh nylon net supported by a $1.75 \times 1 \times 1$ m metal frame to ensure full separation between trees, exclude other insects and confine the predator within the net.

Adults of *C. montrouzieri* were obtained from the Institute's insectary, where they were reared on citrus mealybug maintained on pumpkin fruits (*Cucurbita moschata*).

Three predator:prey ratios were tested, 1:10 (9 beetles released), 1:15 (6 beetles released) and 1:30 (3 beetles released); the fourth treatment was the control. The trees were placed in a four-block randomly selected arrangement. Release was on November 8, 1991. Live mealybugs of all stages were counted. The number of adult beetles was kept constant in each treatment throughout the experimental period. Duncan's Multiple Range Test was used for means separation in all experiments.

Comparison of the effect of *C. montrouzieri* with *N. reunioni* and methidathion (Ultracide) under controlled conditions of temperature and relative humidity. The experiment was conducted in the insectary of the ARCG. Pumpkin fruits were infested with the citrus mealybug. Initially, the mealybug populations were not homogeneous; therefore mealybugs were removed from some fruits to compensate for the differences. The fruits were kept in rearing cages with a controlled atmosphere (25–30°C, 55–70% RH). Four treatments, in four replicates (randomly designed), were applied: *C. montrouzieri*, *N. reunioni*, methidathion (Ciba Geigy EC 200 or 400 g a.i./litre) and the control. In treatments involving the release of predators (obtained from the Institute's insectary), five adult beetles were released in each cage. Methidathion was applied at a concentration of 0.1% with a hand sprayer. Only live mealybugs were counted; numbers of beetles were kept constant by additional releases of adult beetles throughout the experiment. The completely randomised design was applied for data analysis.

Prevention of citrus mealybug movement as a measure of control. The experiment was conducted in the orchard of the ARCG. Two plots of twenty grapefruit trees each at the flowering stage were selected; half of the trees in each plot received the treatment, the other half being the control. Tangle-Trap Insect Trapping Adhesive (Tanglefoot Company, Grand Rapids, Michigan 49504, USA) was smeared on the trunk of each of the twenty treated trees in a 5-cm-wide band, 40–60 cm above the ground, on May 1, 1992 and renewed every three weeks. Weeds underneath the trees were removed. Twigs touching neighbouring trees and those close to the ground were trimmed. One day before the renewal of the glue band, mealybugs stuck to its upper and lower edges were counted.

The mealybug population was sampled on fruits collected from the sides of the trees facing adjacent rows. The first sample was taken on May 22, 1992 and consisted of twenty fruits collected from each tree. Additional samples of ten fruits per tree were collected.

Fruits were examined under a stereoscope for the presence of live and parasitised young larvae, live and parasitised females, and egg masses. The percentage of parasitised larvae and adult females was calculated from the total number of mealybug larvae and adult females, respectively.

Before fruit picking, twenty fruits per tree were collected to evaluate sooty mould contamination. Sampled fruits were graded in three categories: (a) clean, (b) with sooty mould around the calyx, and (c) with sooty mould on at least half of the fruit surface.

Petroleum oil sprays for the control of citrus mealybug. The experiment was conducted in a mandarin orchard, cultivar Encore, of 209 trees, 5 km from Chania. The orchard was divided into five blocks. Each block was further subdivided into four plots of nine trees. In each plot, a tree (usually the central one) with an appreciable load of fruits was selected for sample collection. The petroleum oil used was Citrole 60 (TOTAL), applied at both 1.5% and 2% in water suspension; the other treatments were 0.15% methidathion and control. Treatments were applied on August 27, 1992. Ten fruits per tree were sampled: a pre-treatment sample determined the level of infestation, and a second sample was collected two weeks after treatment. Sampled fruits were examined under a stereoscope for the presence of live mature and immature stages of the mealybug. The efficiency of each treatment was expressed by percentage as calculated by the Henderson-Titlon formula (on the basis of numbers of live mealybugs) (Anonymous, 1981).

RESULTS

Release of *C. montrouzieri* at three predator:prey ratios

In the plots in which the predator was released, the mealybug population mostly decreased in the months following the initial release, whereas in the control plots an increase was recorded. Release at the predator:prey ratio 1:15 caused significant reduction in mealybug populations as compared to the 1:30 ratio (Table 1).

TABLE 1
The effect of the predator *C. montrouzieri* on populations of the citrus mealybug, *Planococcus citri*, at three predator/prey ratios, at Chania, Crete, Greece, 1991–1992

Month	Predator:prey ratio 1:10	1:15	1:30	Control
November	98.2	100.4	155.7	275.4
December	105.8	77.1	146.6	487.9
January	75.2	59.4	88.2	497.2
Mean	93.1 cd	79.0 d	130.2 bc	420.2 a

Means followed by the same letter are not significantly different by Duncan's Multiple Range Test ($p = 0.05$).

Comparison of the effect of *C. montrouzieri* with that of *N. reunioni* and methidathion (Ultracide) under controlled temperature and relative humidity

Significant differences were detected between the different treatments. Pumpkin fruits with *C. montrouzieri* had significantly lower mealybug populations than those with *N. reunioni*. The lowest mealybug populations, however, was recorded on pumpkins treated with methidathion. Control pumpkins exhibited the highest mealybug populations (Table 2).

Methidathion caused effective and immediate suppression of mealybug populations during the experimental period. *C. montrouzieri* first reduced mealybug populations to a low level (observation of November 22) but then the population increased again. *N. reunioni* did not reduce the mealybug populations, which remained at a steady level throughout the experiment.

TABLE 2
Mean numbers of living citrus mealybug, *Planococcus citri*, on pumpkin fruits as influenced by *Cryptolaemus montrouzieri*, *Nephus reunioni* and methidathion; at Chania, Crete, Greece

Date of sampling	Mean numbers of mealybug *C. montrouzieri*	N. *reunioni*	Methidathion	Control
November 12	1965.9	4963.2	138.3	6089.5
November 22	865.6	6096.3	96.9	11208.0
December 2	1156.1	5687.5	33.6	7860.5
December 12	1369.4	5612.7	45.0	12462.1
Mean	1339.2 c	5588.2 b	78.4 d	9406.7 a

Means followed by the same letter are not significantly different by Duncan's Multiple Range Test ($p = 0.05$).

Prevention of citrus mealybug movement as a measure of control

Smearing of glue on trunks significantly reduced mealybug infestation of both mature and immature stages on fruits of treated trees. Fruits collected from treated trees had significantly fewer live larvae, live females and egg masses than fruits sampled on untreated trees (e.g. the mean number of live larvae per fruit was 1.6 in treated trees and 3.0 in the control).

The percentage of fruits infested with mature and immature mealybugs reached a peak in mid August on all trees. After that period, the percentage of infested fruits declined until the end of the experiment. The numbers of mealybugs stuck to the glue band on the trunks were higher at the upper edge of the band than on the lower one, indicating the tendency of mealybugs to move at that period from the periphery of the tree canopy (mainly from fruits) to its centre and down the trunk, a tendency which increased toward the end of the summer (Fig. 1).

Clean fruits (free of sooty mould) were sampled at a higher rate from treated trees than from untreated ones (23.3% and 13.8%, respectively). Among contaminated fruits from treated trees, 53.5% developed sooty mould around the sepals, this percentage being slightly lower than the rate of fruits from untreated trees (56.5%); 23.3% of the fruits from treated trees developed sooty mould on at least half the surface of the fruit, which was less than on fruits from untreated trees (29.8%).

Ants were observed in mealybug colonies on fruits from untreated trees, but were absent in those from treated trees, because they were prevented by the glue from interfering with the activity of natural enemies. However, no significant differences were observed in percentage parasitism between treated and untreated plots. The parasitism increased gradually from May, reaching a peak of 66% in October.

Petroleum oil sprays for the control of citrus mealybug

Application of methidathion and of 2% oil reduced the mealybug populations more efficiently than 1.5% oil two weeks after spraying. Percentage efficacy was least for 1.5% oil (46.1%); methidathion was the most efficient in this experiment (76.7%). Spraying with 2% oil was slightly less efficacious than methidathion (73.2%).

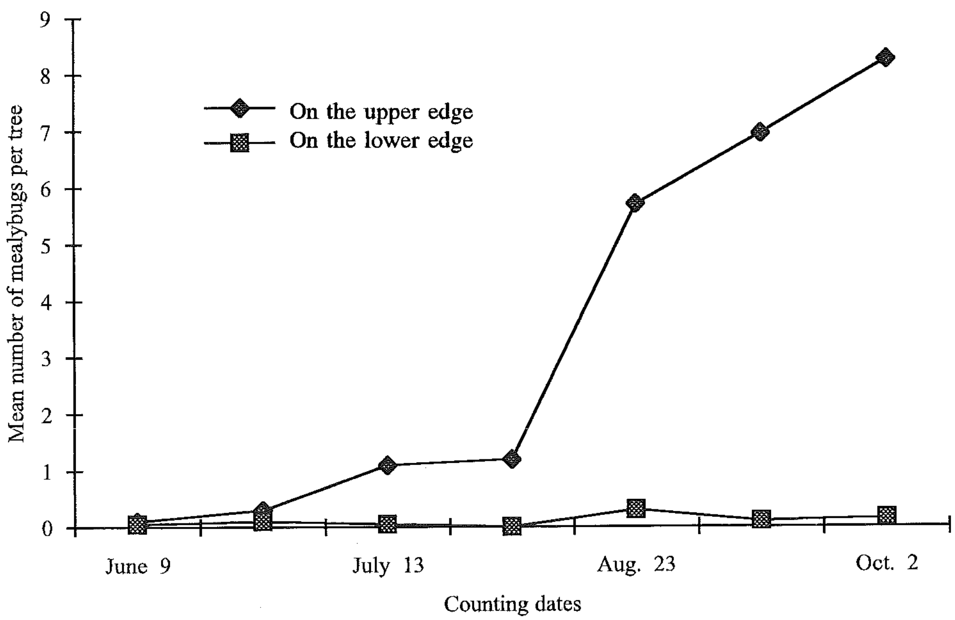

Fig 1. Mean numbers of mealybugs (per grapefruit tree) stuck to the edges of glue bands; Chania, Crete, Greece, 1992.

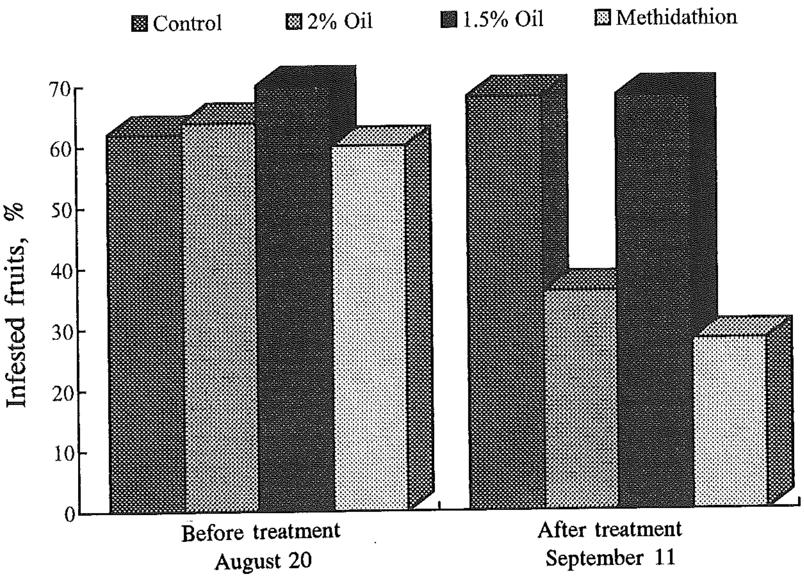

Fig. 2. The rate (in %) of infested mandarin fruits before and after spray of petroleum oil and methidathion; August–September 1992, Chania, Crete, Greece.

The percentage of infested fruits before spraying was similar in all plots (August 20). After treatment, plots sprayed with 1.5% oil showed a slight decrease in the number of infested fruits, but those treated with 2% oil or methidathion showed a high rate of decrease (Fig. 2). Control plots exhibited a slight increase in the percentage of fruit infestation.

DISCUSSION

The experiments demonstrated the effectiveness of the predator *C. montrouzieri* in reducing citrus mealybug populations under the experimental conditions; it is reported to be the most efficient predator in heavy infestations of mealybugs on citrus (Bartlett, 1957; Bartlett and Lloyd, 1958; Cilliers and Bedford, 1978). The predators were unable to survive the winter conditions of our experiment (8–10°C) and many of them died. Clausen (1978) noted a high winter mortality of the predator; Whitcomb (1940) found that the development of the beetle was unsatisfactory at temperatures below 21.1°C. The predator is, however, more effective when its activity coincides with heavy mealybug infestation of citrus (Bartlett, 1957). The effect of *C. montrouzieri* in reducing mealybug populations during our experiment was due mainly to the presence of many beetle larvae. The inefficiency of *N. reunioni* in reducing mealybug populations may have been due to the fact that its activity is restricted to the period between March and early June (Bodenheimer, 1951) under field conditions, and the conditions of our experiment did not increase its efficiency. The reduced feeding ability of *N. reunioni*, in addition to the absence of oviposition at low temperatures, decreased its efficiency (Bodenheimer, 1951). The peak of the mealybug population during August and September was mainly due to high numbers of the larvae. Ortu (1986) also noted the presence of large numbers of mealybugs in Italy during the same period, as indicated by male captures. The decline in mealybug populations in October is due, among other factors, to the increased activity of natural enemies during this period, when chemical application should be reduced to avoid the elimination of natural enemies (Bodenheimer, 1951; Cilliers and Bedford, 1978). The increased number of mealybugs leaving fruits and moving to the trunk is among the causes of the decline in mealybug populations on fruits after mid August.

The sooty mould of the contaminated fruits occurred mainly around the sepals, indicating that the presence of mealybugs is restricted to the area under the calyx. Few insects were also found on the fruit surface at sites, where fruits were in contact with leaves or other fruits. Meyerdirk et al. (1981) found that the best site for indexing populations of the citrus mealybug in grapefruit is under the calyx; the mealybugs which developed under the calyx were deformed and smaller than those on the surface of the fruit, because their growth was restricted by the limited space for development.

Methidathion has been recommended for use against the citrus mealybug in South Africa (Cilliers and Bedford, 1978). It was effective in suppressing diaspidid insects and mealybug populations, and reduced the latter satisfactorily in the present study, due to the presence of large numbers of susceptible (immature) mealybugs on the surface of mandarin fruits.

The oil spray was applied as late as August 27, and this may have affected its efficiency against mealybug populations. Satisfactory results can be obtained when petroleum oil is applied during winter and early summer (Ohkubo, 1983). Furness (1983) noted that the effect of petroleum oil sprays on the population dynamics of the insect pest and of beneficial insects may be influenced by the timing of application, oil concentration, spray coverage and spray drift. Spray coverage of oil in this study may have been affected by the low concentration of oil used, since sufficient control of key pests can be achieved with oil applied at rates >7.5 litre/ mature tree. Toxicity of petroleum oils to pests depends on the extent of coverage on citrus leaves (Ohkubo, 1983). The low oil concentration (1.5%) along with the high temperature (23°C) at the application time have decreased the efficiency of oil in reducing mealybug populations. No phytotoxic effects were recorded following oil or methidathion sprayings. Similarly, Calabretta et al. (1986) did not observe phytotoxicity from white oil applied in summer.

Bartlett (1957) concluded that oil sprays were inefficient mealybug insecticides, if applied when such populations were at their lowest densities. Furness (1983), however, stated that oil sprays were the main material in pest management on citrus in Australia, when natural enemies alone were insufficient to reduce the pest populations.

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