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Management of Scale Pests Through Utilization of their Pheromone

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Management of scale pests through utilization of their pheromone

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ABSTRACT

The research program had two main objectives: identification and synthesis of the sex pheromones of five coccid pests, and management of the California red scale, Aonidiella urantii, with its synthetic pheromone. To achieve the first objective, cultures of the purple scale (Lepidosaphes beckii), chaff scale (Parlatoria pergandei (in Israel), the oleander scale (Aspidiotus nerii) and the Florida red scale (Chrysomphalus ficus) (in the U.S.A.) were kept throughout the 3 years of this project; virgin females of the pine coccid (Matsucoccus josephi) were collected from heavily infested pine twigs. Airborne volatiles emitted by females of the above mentioned coccid species were collected. Aliquots of pheromones from each species were bioassayed and field tested for their attractancy. The crude pheromones from effluvium of L. beckii gave six fractions, two of them active. In 24 fractions from P. pergandei nos. 2-4 and 9-12 were active. The active material of M. josephi was repeatedly fractionated and the last fraction was analyzed and contained one sharp active peak. The sex pheromones of both A. nerii and Ch. ficus were isolated after careful purification, but at the end of the third year of this program the analytical data were still insufficient for final identification of these pheromones, and their chemical structures.

To achieve control of the California red scale, commercial field experiments on monitoring, and preliminary trials on direct control of this pest by male mass trapping, were carried out. A trap baited with a rubber septum dispenser, loaded with 100 µg pheromone, caught about nine times as many males as a trap baited with a lemon fruit infested with about 150 virgin females. The dispenser was attractive for 4-6 months in the warm dry summer season, in the Jordan Valley. For monitoring the occurrence of the red scale, two thresholds of male catch per two traps/7-10 days/2 ha were compared: a low threshold (400-800) and a high one (> 800 males). Spraying according to the low threshold gave significantly better results regarding both re-infestation and fruit culling. All citrus orchards in

in the Jordan Valley are now sprayed commercially according to this method. In experiments on the control of the California red scale in citrus groves of the Bet She'an Valley, it was shown that mass trapping of males enhanced the parasitic wasp populations of this pest. An average of 10% (Comperiella bifasciata) and 22% (Aphytis spp.) higher active parasitization was found in plots treated with traps vs. nil in untreated plots. Thus, adequate control of this pest can be achieved by male mass trapping.

INTRODUCTION

The coccid species investigated in this research were: the California red scale, Anidiella aurantii (Maskell); the Florida red scale, Chrysomphalus ficus Ashmead; the purple scale, Lepidosaphes beckii (Newman); the chaff scale, Parlatoria pergandei (Comstock); and the oleander scale, Aspidiotus nerii Bouché (= A. hederæ Vallot). These species have some characteristics in common. They are all polyphagous (e.g. the Florida red scale occurs on 630 plant species), but citrus - on which all five species cause severe damage - is the most important host plant. All five species are distributed throughout the world, including the U.S.A. and Israel. The oleander scale causes severe damage also to olives, apples, palm trees, mango and many ornamentals. Its distribution in the U.S.A. is limited to California and Florida, where it has uniparental reproduction; in other parts of the world it generally has a biparental sexual reproduction.

The pine wood coccid, Matsucoccus josephi Bodenh. & Harp., which was also studied in this project, is, contrary to the scale species mentioned above, monophagous and endemic to Israel. It causes severe damage to pines in Israel, destroying large wooded areas during outbreaks of infestation. Many Matsucoccus spp. occur also in the U.S.A., and some of them cause much damage to pine trees.

Adequate control of the above insect pests can be achieved with organic phosphates, but they are expensive and may cause much harm to the environment including beneficial insects, livestock and human beings. The timing of sprays against the scale insect pests is based on a time-consuming search for crawlers and other stages of the scales infesting leaves, twigs and fruits. The use of pheromones of each of the above mentioned coccid species may be the best solution for pest management: (1) by monitoring based on traps baited with their synthetic pheromone, which may be less expensive and

more reliable than direct field observations; and (ii) by an integrated control program based on both the use of pheromones and the effect of beneficial insects, which can also be more reliable and less expensive than insecticides.

Identification and synthesis of the pheromones of the above pest species were therefore the main objectives of this research. Another objective was development of a suitable and practical method of controlling the California red scale based on its pheromone, can be used as a model for controlling other scale or coccid pests.

MATERIALS AND METHODS

A. Cultures of scale insects

Cultures of the purple scale, Lepidosaphes beckii, and of the chaff scale, Parlatoria pergandei, were kept throughout the 3 years of the research project in the Bet Dagan (Israel) laboratories. Cultures of the oleander scale, Aspidiotus nerii, and of the Florida red scale, Chrysomphalus ficus (=aonidum), were established in the Geneva (U.S.A.) laboratories. Adult male and female populations of the pine coccid, Matsucoccus josephi, were collected from pine twigs heavily infested with the coccids. For pheromone collection and field experiments, large numbers of specimens were required. Thus, we had to tackle problems of their reproduction.

The first three species were reared successfully on potatoes and squash fruits, and Parlatoria sp. on squash fruit only.

Laboratory rearing of P. pergandei often proceeded with difficulty. The scale did not settle or survive on potato tubers, like the other scale species. So far, it could be reared only on squash fruits, which are less convenient. The duration of one generation, from egg to adult,

lasted about 6 months at 24°C ($\pm 1^\circ\text{C}$) and 70-80% RH. Another problem was the occurrence of an additional sympatric chaff scale species, P. cinerea, together with P. pergandei in mixed populations, especially in citrus groves of the coastal plain north of Rehovot. Efforts were made to avoid mixed rearing of these very similar scale species on the same squash fruit. Therefore, at least once a week adult females were sampled from each fruit. Quick microscopic preparations in Nesbitt's solution were made and the specimens were examined under a phase contrast microscope. To date, only P. pergandei chaff scales were used for airborne collections.

Matsucoccus was reared easily on pine samplings but after a heavy infestation the pines usually died. Adult females and males were therefore obtained from heavily infested pine twigs, and the last larval stage was collected in woods. The twigs were kept in glasshouses in pipes filled with water, and checked daily for migrating virgin females or last larval instar males before pupation. For pheromone collection, 500-1000 virgin females were placed on pieces of filter paper, which were moistened with distilled water and laid in a tube of copper screen wire held in a modified washing bottle. The adults of this species have no mouth parts or alimentary canal, and do not need food. All other species remained on potatoes or squash fruits but, prior to pheromone collection, the males were removed and used for bioassays.

B. Isolation of crude pheromone

Several apparatus for airborne collections (5) of volatiles emitted by virgin females were assembled. A Capex 2D pump (Charles Austin Pumps, Ltd., Weybridge, Surrey England) was used to pull purified air at a velocity of 1.5 l/min (filtered through a 20 cm x 2 cm tube filled with BDH charcoal, activated for gas absorption, 10-18 mesh) into the chamber holding the coccids and then through a purified (2) Porapak Q tube (10 cm

x 1.5 cm). Airborne collections from each of the above mentioned species were accumulated over a 3-year period in Israel and the U.S.A. Each experiment was run for about 3 weeks, from 2 p.m. to 8 a.m. The absorbed volatiles were eluted by Soxhlet extraction with 200 ml of redistilled analytical hexane for 12 h. Later the extraction was achieved by slowly passing 150 ml hexane through the Porapak column. The solutions were concentrated to 5 ml on a Rotavapor without external heating, which resulted in gradual cooling of the flask. Aliquots were removed for bioassays and field tests. For chromatography, the solutions were further concentrated by Rotavapor and finally by a stream of nitrogen to the desired small volume.

Florisil chromatography: Several active batches were combined and submitted to chromatography on a column (20 cm x 1.5 cm absorbent) of florisil, 60-100 mesh. Elution was accomplished with hexane and mixtures of hexane and 2%, 5%, 10%, 25% or 50% ether. In some cases chromatography was performed on a small column (7-10 g florisil containing 7% water) and elution was done with hexane and mixtures of hexane and 3%, 5% or 50% ether, and subsequent elution with methanol.

Gas chromatography (GC): Separations were performed on a 3% OV 1 column (2 m x 2 mm) or on a 3% OV 101 column (2 m x 4 mm). In the first case, affluent splitter with a ratio of 1/25 was used and collection was monitored by the appearance of peaks; in the second case, all the material was collected on a time basis.

C. Laboratory bioassays and field tests

Selected fractions, obtained in Israel and in the U.S.A., were bioassayed for their biological activity in laboratory and field tests. Three methods of laboratory bioassays were used.

- 1) A single male was placed on a petri dish with white filter paper, and a 5 μ l Microcap (Drummond Scientific Co., Broomall, PA, USA) was

dipped in a pheromone solution, taking up 2 μ l. After the solvent had evaporated, the Microcap was placed close to the front of a male under a stereomicroscope. An attracted male raised his antennae and wings and moved toward the source of the scent in any direction the Microcap was turned. One male was used for two or three different fractions or pheromones, then placed in a dark place and, after 1 h, if still active, used once again. Each fraction or pheromone was tested on three to five males.

2) A four-armed olfactometer was constructed (Fig. 1). Filter papers impregnated with 5-10 μ l solution of fraction were placed into the four arms and then the 25-cm tubes were connected. At the end of each tube four to ten male scales were placed, and covered with a net. Air from a compressor was pumped through water into the single arm containing active carbon and a glass wool plug. The wetted air passed through the filter papers, carrying a plume of the tested fractions toward the males at the end of the tubes. A reaction was considered positive if the males moved upwind toward the filter paper. Each test lasted 10-30 minutes and each fraction was tested three to five times, on four to ten different male scales.

3) A turntable, 1.2 m in diameter, was used. The table was positioned in an air-conditioned room ($25^{\circ} \pm 2^{\circ}\text{C}$) and the infested citrus fruits with the tested scales were kept on shelves around the sides of the room. The traps consisted of 7 x 12 cm sticky plates with a hole in the center (2 cm in diameter), into which a rubber septum loaded with test solution was inserted. The traps were positioned on the perimeter of the turntable. The latter completed four revolutions every hour and each trial lasted 3-4 days. The sticky plates were checked every day for male catches.

D. Field tests

For field tests rubber septa were loaded with 50-100 μ l of pheromone solution each. The septa were hung in deltoid sticky traps with a removable

Fig. 1. A four-armed olfactometer. The 25-cm long and 2-cm ID glass tubes of the four arms, were replaced in each new trial.

Fig. 2. A deltoid polypropylene trap (10+10+10/15 cm). On its floor is a removable transparent plastic plate, coated with "Rimifoot 15" (polyisobutane a product of Jawnin & Joffe, Tel Aviv, Israel). From the trap roof is hung a rubber septum dispenser.

plate on the trap floor (Fig. 2), with three to six replications per treatment. The sticky plates were checked every 7-10 days, under a stereomicroscope, and the captured males were counted.

RESULTS AND DISCUSSION

1. The California red scale: Field experiments

First studies of population fluctuations and activity of the California red scale (CRS) were based on male catches in traps baited with a lemon fruit infested with 100-200 virgin females. Based on these traps, which were located in different parts of the country, the number of generations observed was three to six, the same number as known from rearing both males and females (1). In traps baited with virgin females, large numbers of the CRS parasitic wasps were captured (6), but citrus groves sprayed more than once a year - contrary to those sprayed only once or left unsprayed - showed no parasite capture. The treatments with insecticides against the CRS were based on two thresholds, a high one of > 200 males captured/2 traps/7-10 days, in comparison with a low one of 50-200 males captured/2 traps/7-10 days. Reinfestation and the percentage of fruit culling were much higher in groves sprayed according to the high threshold.

From 1978, trials with the synthetic sex pheromone of the CRS, which was identified and synthesized by Roelofs et al. (5), gave the following results: (a) In the comparison between various pheromone loadings and their effect on male catch, 10, 25, 50, 100, 200 and 400 μg were tested and no significant differences were observed between them. (b) In a comparison of traps baited with the synthetic pheromone and those baited with 100-200 virgin females (seven per treatment), the former were, on the average, nine (range 2-16) times more efficient than the latter. (c) In an estimation of the longevity of attractancy of dispensers loaded with various amounts of pheromone (10-400 μg) which were exposed to environmental field conditions, the dispensers loaded with 100-400 μg were attractive for 4-6 months during the summer, in the dry climate of the Jordan Valley.

(d) In a comparison between level of tree infestation estimated by traps and by visual counting of different stages of the red scale, no correlation was observed. (e) In tests of the attractancy of the synthetic pheromone as a kairomone to wasps parasitic to the red scale (6), it was found that the synthetic pheromone, contrary to the virgin females, did not attract the wasps.

The use of synthetic pheromone in management of the California red scale

Deltoid sticky traps were used in field experiments with the synthetic pheromone of the CRS and thus adequate control of this pest could be achieved. The experiments were carried out in a joint project with Dr. Ben-Ami Peleg (Institute of Biological Control, Citrus Marketing Board, Rehovot), Izhaq Bar Zakkai, Amir Rochel and Yehuda Szivos (Extension Service, Israel Ministry of Agriculture). The synthetic pheromone was kindly supplied by DR. B. Lindgren (Zoecon Company, Palo Alto, CA, U.S.A.).

The experiments were carried out in citrus groves of the BetShe'an Valley during 2 years. In the first year 400 traps/400 trees were tested, and in the second year 900 traps/900 trees, divided into three plots, were compared with three other untreated plots. To avoid bias in the second-year experiments, the plots left untreated in the first year were treated with pheromone traps in the second year, and vice versa. The results in both years were quite similar. In the plots treated with pheromone, an increase in parasitization of the CRS by Comperiella bifasciata wasps was observed. An average of 10% (1-18.48%) higher parasitization was found in treated plots vs. nil in untreated plots; the active parasitization of Aphytis spp. in plots treated with traps was 22% (17.54-26.88%) vs. nil in untreated plots (4). The comparable high active parasitization of Aphytis spp. wasps was observed for the first time in 1982. Because of very low infestation of fruits with the CRS throughout 1982, no differences in fruit culling between untreated plots and those treated with pheromone traps were noted.

Also, no differences in the increase of virgin female populations between treated and untreated plots were observed in the 1982 experiments. This was contrary to the situation in 1981, when 5.2-9.7% more virgin females were found in treated than in untreated plots (4). Based on mean catch of males/trap/night in plots equipped with traps for mass trapping, in comparison with untreated plots, a large reduction was observed in the male population in the treated plots.

2. The Purple Scale

Field tests using 100 μ l aliquots (from 5 ml solution of crude pheromone) showed that only females raised on potatoes released pheromone in measurable quantities. The comparison of six collections from squash and potatoes in effluvia of 1000-1500 females per collection, gave the following results: the mean male catch from three replicates/3 days was 3.7 with squash and 125 with potato effluvia. Following this test, the L. beckii scales were raised on potatoes only. Several batches of crude pheromone were combined and submitted to florisil chromatography (see Materials and Methods). Eight fractions were collected and the aliquots were field tested and the total number of males caught/3/traps/7 days was as follows: fractions 1-4 caught 44, 30, 88 and 16 males, and fractions 5-8 caught 11, 6, 2 and 0 males, respectively.

Later separations were performed on 7-10 florisil and only five fractions were eluted, with hexane, hexane + 3% ether, hexane + 5% ether, hexane + 50% ether, and methanol. Activity was found mainly in fractions 2 and 3. These two fractions were combined and submitted to GLC fractionation on a 3% OV 101 column (glass, 2 m x 4 mm) starting at 50°C and progressing to 185°C, at 5°/min. Nine fractions were collected every 3 minutes, and at the end of two 10-min fractions were collected.

These GLC fractions were bioassayed using the turntable method, and the results obtained confirmed to some extent those given in Table 2.

3. The Chaff Scale

Several active batches (field-tested) were combined and submitted to chromatography on florisil (large column). Twenty-four fractions were concentrated to 2 ml each and aliquots were removed for field tests. Only low catches were observed during several trials. Relatively broad ranges of activity were found: the first in fractions 7-11 and the second in 19-20. Repeated field tests with single fractions or combinations thereof, in order to obtain more information on the activity of these fractions, failed.

A bioassay in the laboratory, using a four-arm olfactometer, confirmed that the main activity was in fractions 7-10, but again, activity was low. These fractions were combined and submitted to GLC separation on a 3% OV 101 column (glass, 2 m x 4 mm, starting at 50°C and programmed to 250°C, at 7°/min). Ten fractions were collected, one every 3 minutes; they were not tested.

4. The Oleander Scale

A culture was established in the Geneva (U.S.A.) laboratory from Israeli stock. Airborne collections were made for approximately 2 years to obtain crude female effluvium. The crude material was first fractionated by washing the Porapak Q airborne collection columns with skelly B and running this wash through a florisil column (3 g, treated with 7% H₂O). The florisil column was eluted with 10 ml each of 0%, 3%, 5% or 50% diethyl ether in skelly B, and then with methanol. Greenhouse bioassays showed male attraction activity of several thousand male scales in the 3% and 5% fractions, with very little activity in the remaining fractions. These two fractions were combined and analyzed by GLC. Fractions collected from a polar XF-1150 column (C 120°) showed bioassay activity in a fraction collected at between 9 and 13 min after start. A single major peak, with a Kovacs Retention Index (KRI) of 1741m was seen in that fraction.

A portion of the collected material was saponified with NaOH in 95% EtOH (100 μ l of EtOH and two drops of 10% NaOH). It was stirred at room temperature for 0.5 h and analyzed by GLC. It was not complete, and therefore was left to stand for 1 h. The reaction was worked up by adding 1 ml of H₂O and 1 ml of skelly B and shaking the vial to mix the liquids. The skelly B. layer was removed and concentrated. The hydrolyzed product had a KRI of 1647.

An aliquot of the hydrolyzed product (Os.OH) was hydrogenated by evaporating the solvent and adding a few drops of 95% EtOH containing some PtO₂ catalyst. Hydrogen was bubbled into the mixture and analyzed by GLC until the reaction was complete. The solvent was evaporated and the product taken up in skelly B and analyzed on GLC. The hydrogenated product had a KRI of 1611.

An aliquot of the hydrogenated product was then converted to the corresponding hydrocarbon skeleton by converting it to a bromide and reacting that with lithium aluminum hydride. The first step was carried out by adding two or three drops of triphenylphosphonium bromide solution in methylene chloride and allowing this to set at room temperature overnight. Water was added and the mixture was extracted with skelly B. The skelly B layer was treated with lithium aluminum hydride in diethyl ether after removing the skelly B solvent. The product from these reactions had a KRI of 1340.

In order to prove that the active material was acetate, the material was saponified and re-acetylated. This was accomplished by hydrolyzing active material with NaOH in 95% EtOH and re-actylating it with two drops of pyridine and two drops of acetic anhydride at room temperature. The reaction was washed with saturated aqueous solution of NaHCO₃ and extracted with skelly B. Bioassays of these reactions showed that the hydrolyzed material was inactive and that the re-acetylated material was as active as

as the starting material. The retention times of the starting material and the re-acetylated material were identical.

Mass spectra - both EI and CI - were obtained on all the derivatives described above. NMR spectra were obtained on the active acetate and on the hydrolyzed product - along with spin-spin decoupling of the various protons. An UV spectrum was obtained on the active material and the sample was submitted for C^{13} NMR analysis.

Although much data have been assembled on this compound, the numerous structural possibilities still do not allow the synthesis of a postulated structure.

5. The Florida Red Scale

A culture was established in the Geneva (U.S.A.) laboratories and airborne collections were made over a 2-year period. The crude female effluvium was fractionated on a florisil column and the fractions were bioassayed in the greenhouse. Activity was found in fractions 15-18, indicating a possible ester compound. Fractionation of the active material on an $AgNO_3$ -silica gel column yielded one area of activity in fractions 6-14. The active area from $AgNO_3$ was collected from an OV 101 GLC column, and the active fraction collected from an XF-1150 GLC column - the only purified material - showed a single peak on both columns. It was saponified to give a loss of biological activity. Reaction of the saponified material to produce a formate regenerated the activity and produced a compound identical to the natural substance by CI and EI mass spectrometry. Mass spectra were obtained with the natural formate, the alcohol, the corresponding ketone, the hydrogenated derivatives, and a TMS derivative of the alcohol. A 300 MHz NMR spectrum was obtained on the formate and the alcohol.

A structure was proposed from the above data and it was synthesized by scientists at the Zoecon Corp., but it was not identical to the natural

material. Attempts were made to obtain an x-ray crystallography analysis of a derivative of the natural material, but they were not successful. Further data must be obtained to define the structure better.

The Pine Coccid

The active crude material was separated into 24 fractions on a large florisil column. A preliminary electroantennogram (EAG) screening showed main activity in fractions 10-12, and in some cases there was activity also in fractions 5-6. The EAG measurements were performed by Dr. I. Moore (ARO, Bet Dagan, Israel), using his technique of connecting antennae in line (3). This is the first case of such measurements in scale insects. In order to confirm activity found by EAG, one set of fractions from the florisil separation (2200 females) was field tested. Rubber septa impregnated with 2% of each fraction were used in sticky traps in a test run at Kefar Batya from 25.X to 9.VI.81. The results are summarized in Table 1.

Table 1. Male catch with natural pheromone from effluvia of 2200 Matsucoccus josephi females

Fraction No.	3	5	6	7	8	9	10	11	12	14	17	20
Total catch	0	0	0	0	1	0	1	80	13	0	2	0

This field experiment showed that activity is concentrated in a relatively narrow band, corresponding to elution with 2-5% ether in hexane. The field results confirmed the EAG measurements.

The active fraction from the florisil purification was submitted to GLC separation on the OV 1 column. Separation was started at a temperature of 170° (for 9 min) and then raised to 220°C, at 20°/min. Fifteen fractions were collected, some with single peaks and others with several peaks together. EAG screening showed that only fraction 2 was active. This fraction contained three peaks, and therefore a second GLC separation was performed at 155°C and each peak of fraction 2 was collected separately. The first five fractions were tested by EAG, which showed that most of the activity was in one peak (Table 2).

Table 2. EAG of GLC fractions

GLC-fraction No.	Average signal from four tests (mV)
1	0.91
2	2.19
3	0.55
4	0.43
5	0.35
blank	0.28

The separation was very difficult, because the active material was one of the small peaks. Analysis of the active material on a capillary column of PCP-sil (30 m x 0.25 mm) at 100°C, programmed at 30°/min to 150°C, showed that this active fraction consisted mostly of one sharp peak. The total amount of purified material, unfortunately, was not enough to run a field test. During the program only 11,500 females could be collected. For further progress, much more active material must be accumulated in order to confirm activity in the field and to identify this compound, if possible.

CONCLUSIONS

This program had two main objectives:

1. The identification and synthesis of the sex pheromones from the following coccid pests: Lepidosaphes beckii, Parlatoria pergandei, Aspidiotus nerii, Chrysomphalus ficus and Matsucoccus josephi.

To achieve this objective it was necessary to overcome the difficulties involved in mass breeding, in particular of L. beckii, P. pergandei and M. josephi. Ultimately it was found that breeding of M. josephi was impractical and therefore collection of live material from infested pine wood was necessary. Due to these limitations the number of virgin females collected during this program was spread over different periods of the year and did not exceed several thousand per year. Another obstacle was the short life span of coccid males (a few hours only),, which caused many difficulties in the laboratory bioassay.

- The crude pheromone collected from effluvia of L. beckii and P. pergandei was fractioned and a few of these fractions attracted males in laboratory and field tests. The crude pheromone from M. josephi was repeatedly fractionated and activity was monitored by EAG and in field tests. To the best of our knowledge, this is the first case of EAG measurements in any coccid species. In the case of A. nerii and Ch. ficus, the sex pheromone was isolated after careful purification. The structures of these pheromones were complicated and all analytical data measured were insufficient for final identification. Due to termination of the three-year research program identification of all these new pheromones was halted.
2. Management of the California red scale (Aonidiella auranti) with its synthetic pheromone.

The synthetic pheromone caught consistently more males than did virgin females. A trap baited with 100 µg of pheromone caught about nine times as many males as a trap baited with a lemon infested with 100-150 virgin females.

Different loadings of pheromone were tested and it was found that 100-400 µg was attractive for 4-6 months in the dry summer conditions of the Jordan Valley. Monitoring of the occurrence of the California red scale with the synthetic pheromone enabled more correct timing of insecticide sprayings. Two thresholds of male catch per two traps/7-10 days/2 ha were compared: a low threshold (400-800 males) and a high one (> 800 males). Spraying according to the low threshold gave significantly ($P=0.05$) better results regarding both tree re-infestation and fruit culling (7,8,9). All the citrus orchards in the Jordan Valley are now sprayed commercially according to this criterion. In field experiments with the synthetic pheromone of the California red scale, carried out in citrus groves of the Bet She'an Valley, it was shown that mass trapping of males enhanced the parasitic wasp populations. An average of 10% (Comperiella bifasciata) and 22% (Aphytis spp.) higher active parasitization was found in plots treated with traps vs. nil in untreated plots. Thus, adequate control of this pest can be achieved by male mass trapping.

DESCRIPTION OF COOPERATION

The close cooperation between the two partners of the U.S.A. and Israel in the research program, is mentioned among others, in pages 2 and 10-16.

LIST OF PUBLICATIONS

The publications relative to the research program include REFERENCES no. 7-9, and the following:

Bar Zakkai, I. Peleg, B.A., Sternlicht, M. and Rochel, A. (1983) Further trials on mass trapping of Aonidiella aurantii males to enhance parasitic wasp activity. Phytoparasitica 11:137-138 (abstr.).

REFERENCES

1. Bodenheimer, F.S. (1951) Citrus Entomology in the Middle East.
W. Junk, S-Gravenhage.
2. Byrne, K.J., Gore, W.E., Pierce, G.T. and Silverstein, R.M. (1975)
Poropak-Q collection of airborne organic compounds serving
as a model for insect pheromones. J. chem. Ecol. 1:1-7.
3. Moore, I. (1981) Biological amplification for increasing electro-
antennogram discrimination between two female sex pheromones
of Spodoptera littoralis (Lepidoptera: Noctuidae). J. chem.
Ecol. 7:791-798.
4. Peleg, B.A., Sternlicht, M., Bar Zakkai, I. and Rochel, A. (1982)
Mass trapping of Aonidiella aurantii males to enhance parasitic
wasp activity. Phytoparasitica 10:139 (abstr.)
5. Roelofs, W., Gieselmann, M., Carde, A., Tashiro, H., Moreno, D.S.,
Henrick, C.A. and Anderson, R.J. (1978) Identification of
the California red scale sex pheromone. J. chem. Ecol.
4:211-224.
6. Sternlicht, M. (1973) Parasitic wasps attracted by the sex pheromone
of their coccid host. Entomophaga 18:339-342.
7. Sternlicht, M., Bar Zakkai, I., Szivos, Y. and Dunkelblum, E. (1980)
[The use of sex pheromone of the California red scale, Aonidiella
aurantii (Maskell), in the pest's management.] Alon HaNotea
34:661-680. (in Hebrew)
8. Sternlicht, M., Bar Zakkai, I., Szivos, Y. and Dunkelblum, E. (1981)
Management of the California red scale, Aonidiella aurantii, by
its sex pheromone. Phytoparasitica 9:80 (abstr.)
9. Sternlicht, M., Bar Zakkai, I., Szivos, Y. and Dunkelblum, E. (1983)
Prediction of infestation by and control of the California red
scale, Aonidiella aurantii (Maskell), through use of its
pheromone. Proc. Int. Soc. Citriculture (Tokyo, 1981). Vol. 2.

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