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Evaluation of the mating disruption method for the control of the pink bollworm *Pectinophora gossypiella* (Saund.) (Lepidoptera: Gelechiidae) and comparison of this method with insecticidal treatments

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Abstract: In a cotton field in Central Greece, the mating disruption method was applied aiming to the control of the pink bollworm *Pectinophora gossypiella*. For this reason, two commercially available slow release pheromone formulations, PB-Rope and SELIBATE, were used. The effectiveness of the method was compared to the infestation levels recorded at a neighboring cotton field of equal size, where three insecticidal treatments had taken place. Every field was divided in six blocks of equal size and two pheromone traps were placed in each of these blocks. The seed used belonged to Zeta-2 and Allegria cotton varieties. The traps were checked daily while 100 fruiting bodies and 20 leaves per block were randomly collected every week. In two of the blocks of the pheromone-treated field an insecticidal spray was applied in mid-August. The infestation rates in these two blocks were not significantly different compared to the rates recorded in the untreated blocks. At the same time, treatments resulted in an abrupt increase of the population of leaf feeding insects, mainly of aphids. Moth catches in the pheromone-treated field were recorded after the first week of September while in the insecticide-treated field the number of moths caught was very high, even between treatments. No significant difference was noticed between the two methods; also, no significant differences were found in the infestation levels between the two cotton varieties used. A considerably greater number of larvae were found in pheromone-treated than in insecticide-treated blocks, in unharvested bolls which were collected in mid-October.

Key words: *Pectinophora gossypiella*, gossyplure, mating disruption

Introduction

The pink bollworm, *Pectinophora gossypiella* is one of the most threatening pests of cotton in Greece (Davaris et al. 1992, Buchelos et al. 1999). It can cause very important quantitative losses and qualitative degradations, while at the same time high population densities can be built up very quickly (Henneberry and Clayton 1980, Henneberry 1986, Hutchinson et al. 1991). This fact, forces growers in Greece, in order to control this pest, to conduct sprays with several insecticides; usually 3 to 5 at 10-15 day intervals. One of the most common side effects of these applications is the concomitant increase of the populations of several other cotton pests (such as aphids and mites). The most common decision criterion is practically the larval infestation in the plant's fruiting bodies (mainly bolls). Many critical values for the infestation in bolls have been suggested so far; however, the proposed threshold varies from 5-10 % (Henneberry and Clayton 1982, Hutchison et al. 1988, Buchelos et al. 1999). The validation of larval infestation meets several difficulties, because a) in middle and late season, eggs and larvae are usually protected from direct contact with insecticides b) most eggs are laid under calyces and bracts of bolls c) young larvae usually enter bolls within 20-30 min upon hatching and d) females can lay up to 85 % of their total egg complement in 7-10 days, and as a result, larval infestation can become well established between applications (Hutchison et al. 1988, 1991).

During the last two decades gossyplure, the sex pheromone of the pink bollworm, is widely used for monitoring and timing of the insecticidal applications. However, due to several reasons, trap catches do not always correspond to actual changes in infestation levels (Henneberry and Clayton 1982, Flint et al. 1993, Beasley and Adams 1994, Buchelos et al. 1999). On the other hand, the use of gossyplure for mating disruption has been proposed from several researchers, as an alternative for the control of *P. gossypiella* (Staten et al. 1987, Flint et al. 1993, Cardé and Minks 1995, Cardé et al. 1998). The application of this method has given very promising results so far (Flint and Merkle 1983, Chamberlain et al. 1994, Cardé et al. 1998). Nevertheless, its evaluation still has several implications, mainly because the immigration of mated females for neighboring crops can not be totally avoided (Jones 1998). In Greece, mating disruption has been tested successfully, during the last few years (Kyriakidou and Recca 1991, Yamvrias and Foundoulakis 1995). However, insecticidal sprays practically remain the main control measure for the control of the pink bollworm in Greece (Davaris et al. 1992).

Materials and Methods

The experiment was carried out in the region of Farsala (Thessaly, Central Greece), during the 1998 growing season. In this region, cotton is the main cultivation and *P. gossypiella* is the main cotton pest. Two adjacent rectangular cotton fields, 120000 m^2 each, were used for experimentation. These two fields were surrounded by beets, wheat, industrial tomato and wheat fields, from East, West, North and South, respectively.

Each field was divided into 6 blocks of equal size. On the first field, three insecticidal spays took place a) bifenthrin (28 July) b) alpha cypermethrin (12 August) and

c) permethrin (26 August). On the second field, two commercially available slow release disruptant formulations of technical gossyplure (Δ,Δ-7,11-hexadecadienyl acetate) were applied (3 blocks each): a) PBW rope at a rate of 120 dispensers/1000 m^2 (Shin-Etsu, Japan) and b) SELIBATE EXTRA at a rate of 40 dispensers/1000 m^2 (Agrisense BCS, UK). These dispensers were hand-adapted around the main stem of the cotton plants, on the 29th of June. Two varieties were used on each field (3 blocks per field) a) Zeta 2, which is a Greek variety of Acala-type (KESPY, Greece) and b) Allegria (Stoneville, USA). The seeding was carried out on 20 and 21 of April 1998 (approx. 15 plants per meter on the row, 1 m between rows), followed by standard cultivation care. In addition, two adhesive pheromone traps (Delta trap, Agrisense BCS, UK) were placed in each block on 20/5. Counting of adults captured was conducted daily, while the replacement of the pheromone was taking place every 20 days. On the 16th of August, two blocks (one block per variety) of the second (untreated) field were sprayed with bifenthrin, in order to determine the influence of a single insecticidal application late in the season combined with the method's application (for preventing boll infestations late in the season). No chemical defoliation or plant growth regulators were applied late in the sampling period.

Each week, from late May until early October, 100 fruiting bodies were collected randomly from each block. Due to flower absence, during the first two weeks of sampling, pinhead squares were collected; during the following two weeks, flowers and during the last ten, bolls. These fruiting bodies were checked in the laboratory for infestation by *P. gossypiella* larvae, and the number of larvae per boll was recorded. Additionally, during the same period, 20 leaves were collected randomly from each block, at weekly intervals (one leaf per plant). Each leaf was placed separately in a plastic bag. These bags were then brought to the laboratory, and checked for insects, in order to determine differences among treatments. Aphid mummies, attached on a leaf piece were placed in small plastic boxes at 22^{o} C and 65 % rh, in order to collect the parasitoids (Kavallieratos and Lycouressis 1999). The seed cotton was harvested mechanically on 14th of October. Finally, on the 20th of October, from each block 100 uncollected bolls were examined, and the presence of *P. gossypiella* larvae (usually internally of the cottonseed) was recorded.

Leaf counts were expressed as mean number of individuals per leaf (adults and immature stages combined). Before the analysis of variance, data were transformed to standardize means and homogenize variances (Little and Hills 1978). For means' comparison, the Duncan's multiple range test was used (Duncan 1955). The statistical package JMP (SAS 1989) was used, at a significance level of p=0.05.

Results

a. Trap catches. Early in the season captures were higher than 20 males per trap (Fig. 1.). In the insecticide-treated field trap catches were notably high, regardless of the sprays' application. Two additional peaks were observed: in late July (>35 males/trap) and early in September (>20 males per trap). One the other hand, in the pheromone-treated field, captures were totally suppressed, from the day of dispensers' placement and on. In this field catches were gradually increased early in September, but numbers of captured males continued to be lower than the ones in the insecticide-treated field. No significant differences were noted on the trap catches between cotton varieties (*df*=1.190, *F*=0.017, *P*=0.893).

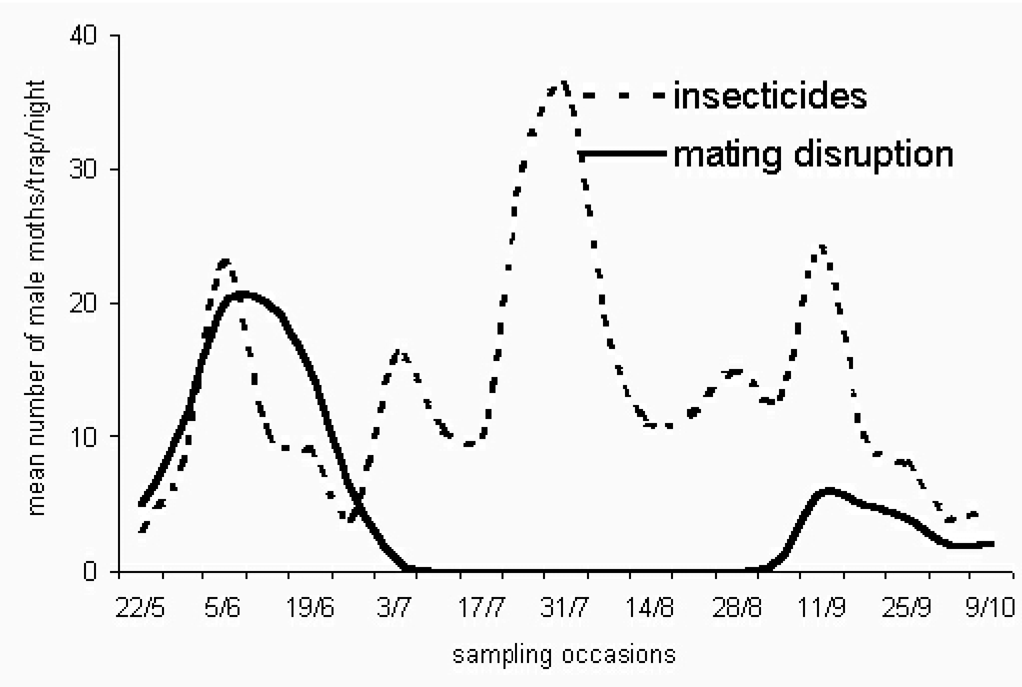

Figure 1. Captures of *P. gossypiella* male adults in gossyplure-baited sticky traps, during the sampling period, in the pheromone-treated and the insecticide-treated blocks.

b. Infestation level. During the entire sampling period, infestation level was below 10 % (Fig. 2). During the first weeks, relatively higher percentage of larval infestation was noted in the insecticide-treated field. This fact is reversed during the last sampling occasions. Despite this, no significant differences were recorded between the two fields (*df*=1.30, *F*=0.046, *P*=0.830). Additionally, no significant differences were noted between the insecticide treated and the insecticide free blocks of the pheromone-treated field, from the date of the insecticidal application and on (*df*=1.14, *F*=0.287, *P*=0.601). As infestation level increased, the mean number of larvae per boll was exponentially increased (Fig. 3). Additionally, the rate of this increase was more intense in the insecticide treated field. However, more than one larvae per boll were common only in high infestation levels (>20 %). Significant differences were recorded among treatments (pheromone, insecticide, pheromone + insecticide), in the number of *P. gossypiella* larvae found in uncollected bolls (*df*=2. 297; *F*=3.25; *P*=0.0401). Nevertheless, although significantly higher numbers of larvae were noted in the pheromone-treated blocks, the percentage of larval presence at this stage was rather low (< 0,1 larvae per boll).

Figure 2. Mean percentage (%) of infested fruiting bodies by *P. gossypiella* larvae, during the sampling period, in the pheromone-treated and the insecticide-treated blocks.

c. Differences among varieties and formulations. The mean percentage of infested bolls by *P. gossypiella* larvae was relatively higher in the blocks with Zeta-2 than those with Allegria in the insecticide-treated field (6.74 % against 6.07 %) as well as in the pheromone-treated field (5.90 % against 5.53 %). However, no significant differences were observed between the two varieties used (*df*=1.190, *F*=0.510, *P*=0.476 for the insecticide-treated blocks and *df*=1.190, *F*=0.132, *P*=0.715 for the pheromone-treated blocks). Moreover, no significant differences were observed on the infestation level between the two pheromone formulations used (*df*=1.94, *F*=1.001, *P*=0.319).

d. Other insects. More than forty insect species were found on the cotton leaves examined (including Collembola, Diptera and others); the most abundant are presented on Table 1. Most of them are cotton pests; yet a considerable number of beneficial insects were found. In general, predators and parasitoids were found mainly in the insecticide-free blocks.

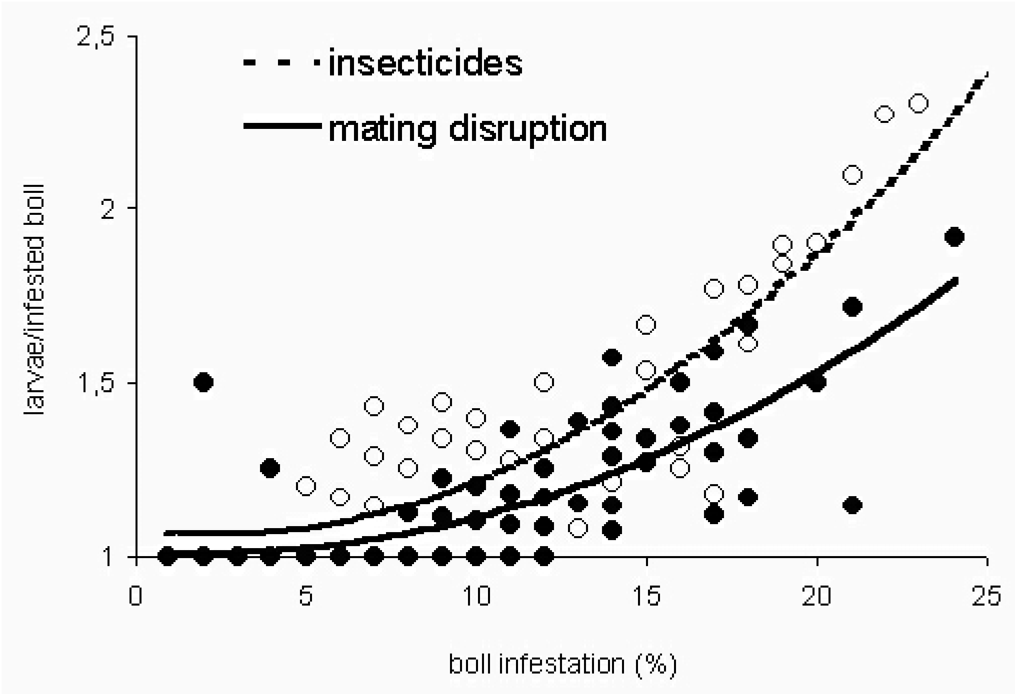

Figure 3. Relationship between boll infestation (%) and mean number of *P. gossypiella* larvae per boll, in the pheromone-treated and the insecticide-treated blocks.

A. gossypii was the most abundant aphid species during the entire sampling period. On the other hand, most of *M. persicae* individuals were found early in the season (first four sampling occasions), while *A. fabae* was found mainly during August. Significantly higher numbers of *A. gossypii* individuals were found in the insecticide-treated blocks, while sprays did not manage to suppress aphid population (Fig 4). Furthermore, in the sprayed pheromone-treated blocks aphids were found in high numbers, from mid-August (date of the bifenthrin application) and on.

The most numerous thrip species were *T. tabaci* and *F. occidentalis*. However, *F. intonsa*, *F. tritici* and *Aeolothrips* sp. were found in small numbers during the sampling season. *T. tabaci* fluctuation results were similar to that of *A. gossypii* (Fig. 5); after the insecticidal treatments population density was increased rapidly. On the other hand, in the insecticide-free blocks *T. tabaci* presence was constantly reduced (<1 ind. per leaf).

On the other hand, most *E. decedens* individuals were found in the insecticide-free blocks (Fig. 6). Hence, in the insecticide-treated blocks, *E. decedens* presence was low, mainly between applications.

Table 1 (overleaf). Mean number of individuals per leaf for each species found, in the pheromone-treated, insecticide-treated and the sprayed pheromone-treated blocks. Means on the same row followed by the same letter, are not significantly different (Duncan’s multiple range test at _=0.05). Only the species with more than 0.01 individuals per leaf were statistically compared.

Species	Pheromone	Insecticide	Pheromone+Insecticide
HEMIPTERA			
Aphididae			
Aphis fabae Scopoli	<0,001	<0,001	<0,001
Aphis gossypii Glover	1,92a	8,14c	3,89b
Myzus persicae (Sulzer)	0,012a	0,010a	0,017a
Cicadellidae			
Empoasca decedens Paoli	1.09a	0.73a	0.98a
Empoasca decipiens Paoli	<0,001	<0,001	<0,001
Nabidae			
Nabis ferus *(L.)*	0,008	<0,001	0,002
Miridae			
Lygus sp.	<0,001	<0,001	<0,001
Macrolophus sp.	<0,001	<0,001	<0,001
Anthocoridae			
Anthocoris nemorum *L.*	0,011a	<0,001b	0,006a
Orius laevigatus *Fieber*	0,013a	<0,001c	0,003b
Orius niger Wolff	<0,001	<0,001	<0,001
Aleurodidae			
Bemisia tabaci (Gennadius)	3,21a	8,89b	4,76a
NEUROPTERA			
Chrysopidae			
Chrysoperla sp.	<0,001	<0,001	<0,001
THYSANOPTERA			
Aeolothripidae			
Aeolothrips sp.	0,05a	0,06a	0,04a
Thripidae			
Frankliniella intonsa *(Trybom)*	0,07a	0,12a	0,13a
Frankliniella occidentalis Pergande	0,13a	1,44c	0,35b
Frankliniella tritici (Fitch)	<0,001	<0,001	<0,001
Thrips tabaci Lindeman	0.25a	1.17b	0.44a
COLEOPTERA			
Coccinellidae			
Donia variegata (Goeze)	<0.001	<0.001	<0.001
Coccinella septempunctata L.	0.004	0.002	0.004
Hippodamia undecimnotata (Schn.)	<0.001	<0.001	<0.001
Scymnus sp.	<0.001	<0.001	<0.001
HYMENOPTERA			
Aphelinidae			
Aphelinus sp.	<0.001	-	-
Aphidiidae			
Aphidius colemani Viereck	0.004	0.003	0.003
Lysiphlebus fabarum (Marshall)	0.085a	0.011b	0.050a

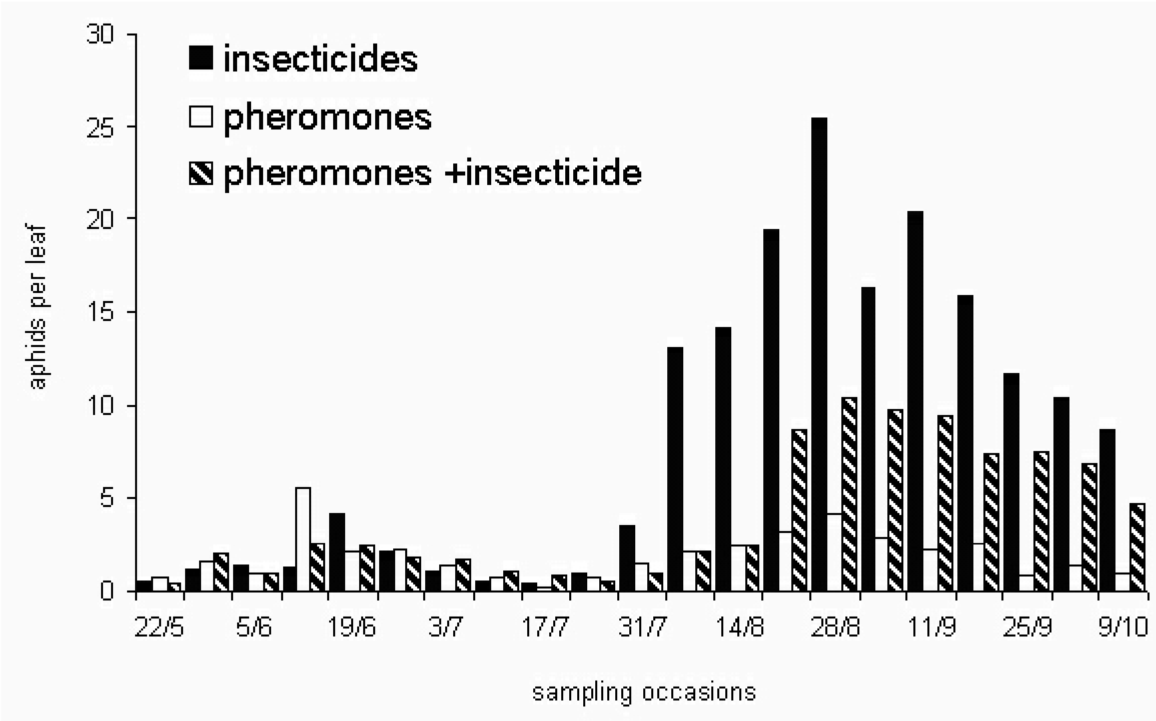

Figure 4. Mean number of *A. gossypii* individuals per leaf, during the sampling period, in the pheromone-treated, insecticide-treated and sprayed pheromone-treated blocks.

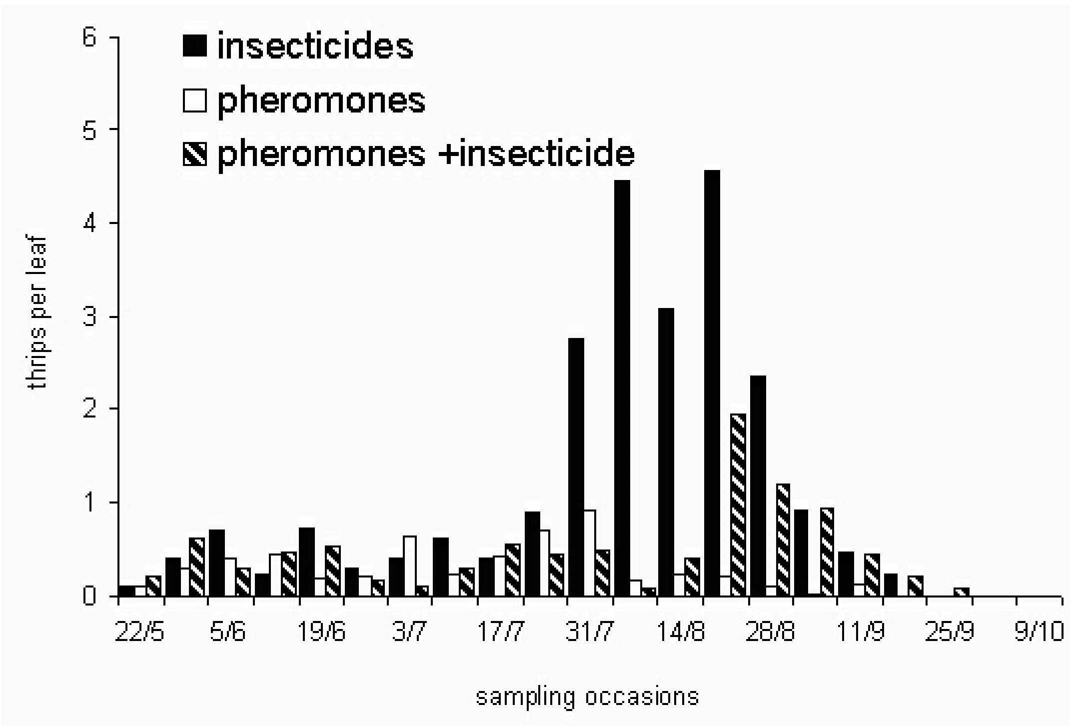

Figure 5. Mean number of *T. tabaci* individuals per leaf, during the sampling period, in the pheromone-treated, insecticide-treated and sprayed pheromone-treated blocks

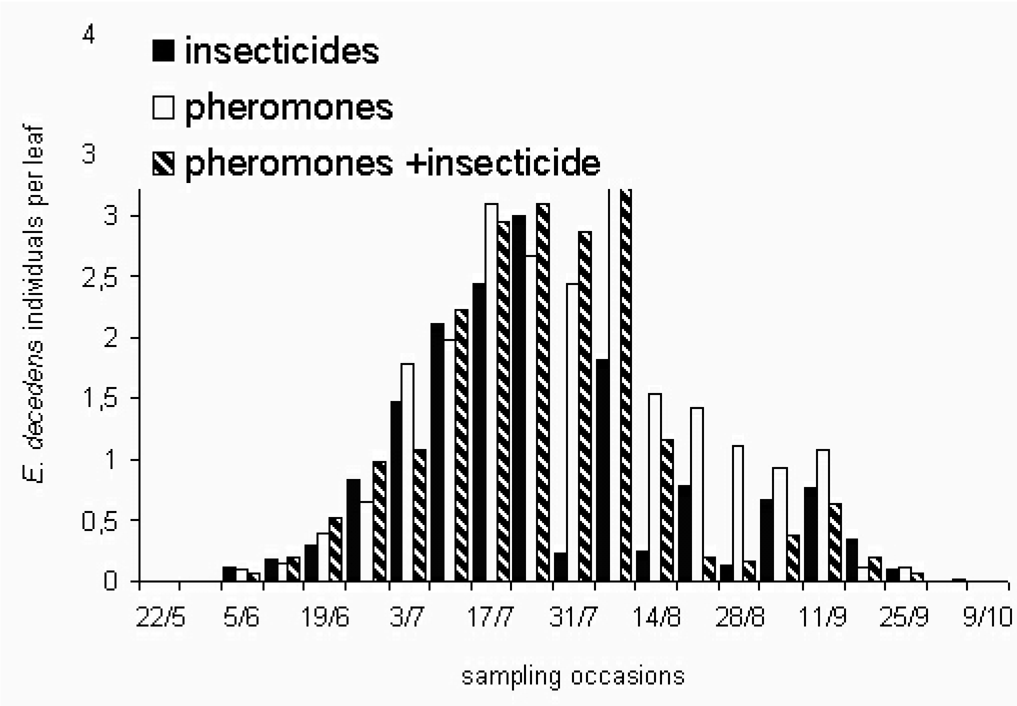

Figure 6. Mean number of *E. decedens* individuals per leaf, during the sampling period, in the pheromone-treated, insecticide-treated and sprayed pheromone-treated blocks.

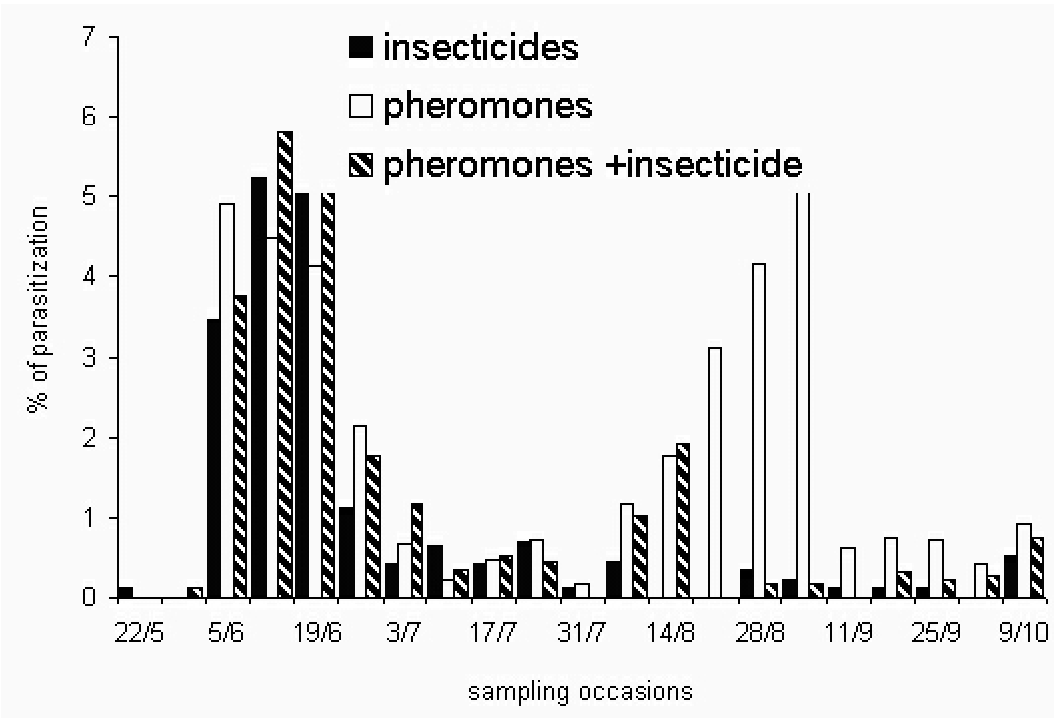

Figure 7. Percentage (%) of *A. gossypii* individuals parasitized by *L. fabarum*, during the sampling period, in the pheromone-treated, insecticide-treated and sprayed pheromone-treated blocks.

Discussion

The nihilism of the captures in the pheromone-treated blocks, was indicative of the reduced rate of mating occurred in this field. Even in cases of non complete suppression of the captures, mating disruption works, provided that the suppression percentage is high, usually more than 95 % (Jones 1998). However, this suppression does not establish zero (or at least reduced) infestation level, because the immigration of mated females from vicinal fields still remains the main drawback of the method (Cardé and Minks 1995, Jones 1998). Even in an insecticide-treated field is well known that numbers of adults in traps between applications are not reliable, and as a result any use of these figures for prediction may be inaccurate (Henneberry and Clayton 1982, Hutchison et al. 1991, Buchelos et al. 1999). On the other hand, the absence of adults in the traps (due to suppression in the case of mating disruption) is only an indication, and does not reflect the infestation level. Hence, for prediction, even when mating disruption is applied, it is necessary to combine trap inspections with frequent samplings in the fruiting bodies (mainly bolls). In our case, infestation level among treatments was similar, but in must be noted that % boll infestation in the insecticide-free blocks tended to increase late in the season, which could justify the need of a late season (late August, early September) insecticidal application. However, the infestation level in the sprayed pheromone-treated blocks, which was similar to that of the other treatments, indicated that there is no warrant for this assumption. Moreover, the infestation level has different meaning when is examined according to sampling occasion, because late bolls usually contribute less in yield. Thus, it is expected that late in the season infestation level, as well as number of larvae per boll, increases (Henneberry and Clayton 1982, Hutchison et al. 1988). The results of the present study indicate that mating disruption can reduce the number of eggs laid in the same boll, and consequently the number of larvae per boll, because in an insecticide-treated field, infestation level is likely to be increased, due to oviposition between applications (Hutchison et al. 1991). However, more larvae are present after harvest in the pheromone-treated filed, because in this case, the reduced release of the disruptant can allow mating and oviposition. On the other hand, a late season insecticidal application is likely to protect non-harvested bolls. Nevertheless, larval survival is influenced by several factors; hence, the presence of larvae late in the season (after harvest) does not constitute a reliable indicator for the upcoming infestation level (Watson 1980, Henneberry 1986).

Our results indicate that the cotton variety is not the “key” factor for the determination of the infestation level by *P. gossypiella* larvae. Chu et al. (1991) also noted that although differences can be observed between varieties other factors and cultivation strategies (including irrigation termination, plant growth regulators and chemical defoliation) are more determinative for the infestation level. The combination of these factors with the appropriate cultivation technique is the best way to utilize the possible natural host-plant resistance (Henneberry 1986, Chu et al. 1991).

Apart from the aforementioned drawbacks, a single insecticidal application late in the season (in order to provide a preventive treatment due to the upcoming reduction in the disruptant's release) in a pheromone-treated field does not provide further protection and thus, is unnecessary. On the other hand, a single application in this case at any rate leads aphid populations to increase rapidly. Same holds for other serious pests, such as thrips and *B. tabaci*, while the only pests found to be controlled by insecticides (at least between applications) were *Empoasca* spp. It must be noted that for these species, no natural enemies were found in Greek cotton so far (Kyriakidou and Drossopoulos 1993, Kyriakidou, personal communication). Apparently, a single application can eliminate the populations of the predators and the parasitoids. In a previous study, Yamvrias and Foundoulakis (1995) also noted that beneficial insects are more numerous in pheromone-treated blocks, but the authors did not estimate pest populations. In the present study, the presence of almost all pests that were found in cotton leaves were low, as compared to the insecticide-treated blocks. This must be seriously taken into account, because the control of population outbursts for certain species (aphids, mites etc.) often following chemical control, is very difficult and often more important than pink bollworm infestation.

In conclusion, mating disruption method is reliable, easy to use and effective. Apart from all factors that were analyzed in this paper and the generally accepted disadvantages for its application (Staten et al. 1987, Cardé and Minks 1995, Jones 1998), this method is the most suitable for area-wide pest management, under the IPM principles. Moreover, it is absolutely essential to examine other factors rendering the requirement of co-operation of groups of farmers and the related social constraints, and hence, further research is required by social scientists (Lyon 1994).

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