Influence of trap type, pheromone quantity and trapping location on capture of the pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae)

Christos G. Athanassiou, Nickolas G. Kavallieratos,* Fotios T. Gravanis,¹
Nickolas A. Koukounitsas¹ and Despoina E. Roussou¹

Laboratory of Agriculture Zoology and Entomology, Agricultural University of Athens, 75 Iera Odos, 11855 Athens, Greece

¹ Technological Educational Institute of Larissa, Department of Plant Production, 41110, Larissa, Greece

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Abstract

Field experiments were conducted in order to evaluate the effect of trap design, pheromone quantity and trapping location on the capture of *Pectinophora gossypiella* in two cotton fields located in Central Greece. In the first field, three commercially available gossyplure-baited trap types were compared: two adhesive, Delta and Pherocon II, and the Funnel trap, on which moths are captured with the addition of a killing agent (DDVP strip). In the second field, Delta traps with 1, 2, 3 or 4 gossyplure lures were compared. Significant differences were noted among trap types. The Funnel traps caught approx. 4.2 and 29.9 times more moths compared to the Delta and the Pherocon II traps, respectively. The correlation of captures among the three trap types was positive and significant only until mid-July. On the other hand, throughout the entire trapping period (June–September), this correlation was significant only between the two adhesive trap types. No significant differences were noted among traps with different pheromone quantity. In addition, the correlation of captures among traps with different lure numbers was positive and significant during the entire trapping period. For both experimental fields, no significant differences were recorded between centrally located and peripheral traps, although a wider range of captures was recorded in the peripheral traps.

Key words: *Pectinophora gossypiella*, trapping, gossyplure, cotton

INTRODUCTION

Pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) is one of the most threatening pests in the major cotton productive regions of the world. It can cause considerable yield loss, and is almost invulnerable to the activity of natural enemies, as well as to insecticides because its entire larval development is completed in the internal part of the infested bolls (Hutchison et al., 1991; Henneberry and Naranjo, 1998; Athanassiou et al., 2002). Furthermore, the internal-feeding behavior of this pest adds an additional implication when developing a sampling protocol in order to assess infestation level, because larval presence is not visible unless the bolls are opened (Hutchison et al., 1988; Henneberry and Naranjo, 1998; Buchelos et al., 1999). Therefore, the pheromone-baited trap is one of the most valuable decision tools for estimating the presence and the seasonal activity of

the pink bollworm in cotton fields. During the last two decades, many researchers have proposed several regression models for prediction of the infestation level on the basis of trap catches (Henneberry and Clayton, 1982; Qureshi et al., 1993; Buchelos et al., 1999). However, the interpretation of trap catches meets with several difficulties, and often higher numbers of captured adults do not always reflect actual levels of population density, because captures are usually influenced by a variety of factors (such as time of sunset, wind speed, temperature etc.) (Beasley and Adams, 1994b; Henneberry and Naranjo, 1998), which do not affect “absolute” sampling (collecting fruiting bodies). The purpose of this study was to assess the significance of some of these factors, such as trap design, quantity of the pheromonic sources and trapping location, on the capture of *P. gossypiella* adults in pheromone-baited traps.

* To whom correspondence should be addressed at: E-mail: nick_kaval@hotmail.com

MATERIALS AND METHODS

The experiment was carried out in the region of Rizomylos (Thessaly, Central Greece), during the 2001 growing season. In this region, cotton is the main cultivation crop, and *P. gossypiella* is the main cotton pest. Two rectangular cotton fields, 4 km apart, approx. 200,000 m² each, were used for experimentation. For both fields, the seeding was carried out on 19 of April 2001 (approx. 15 plants per meter on the row, 1 m between rows), followed by standard cultivation care. The cotton variety used was Midas (Stoneville, USA). Both fields were surrounded by wheat fields; the wheat was harvested in mid June. In the first field, on May 24, three trap types were suspended in four replicates each. These traps were: a) Funnel trap (Agrisence BCS, UK) on which the moths are captured with the addition of a DDVP strip (Agrisence BCS, UK), containing 0.5 g of dichlorvos; b) Delta trap (Agrisence BCS, UK), on which the moths are captured on an adhesive surface; and c) Pherocon II trap (Trécé Inc., USA), which is also an adhesive trap. Each trap was baited with a pheromone lure (Agrisence BCS, UK), containing 1 mg of gossyplure (Z,Z- and Z,E-7,11-hexadecadienyl acetate), the male attractant of *P. gossypiella*. In the second field, four gossyplure-baited Delta traps were placed, in four replicates. For each replicate, each of the four traps bared one, two, three and four gossyplure lures, respectively.

The traps were checked for captured *Pectinophora gossypiella* adults, from May 31 until September 27, at weekly intervals. Thus, a total of 18 trap-checks were carried out. The sex of the captured moths was not checked, given that the majority of adult moths caught in sex pheromone traps are male. For both fields, on each trap check date, traps within the same replicate were rotated clockwise, in order to minimize the influence of trapping location. The distance among traps within replicates was approx. 120 m, while the distance among replicates was approx. 210 m. Each trap was suspended at a height of 0.85 m. No insecticides, chemical defoliators or plant growth regulators were applied during the experimental period. On each trap, the lure was replaced every three weeks. The sticky surfaces of the Delta traps and the Pherocon II traps were replaced on each trap-check date.

Data were submitted to analysis of variance, in

order to evaluate the influence of trap type, pheromone quantity and trapping location, given that some of the traps were centrally located while others were in-field peripheral (approx. 10 m from the fields' edges). Before the analysis, counts were transformed to $\log(x+1)$, in order to homogenize variances and standardize means. Means were compared by the Tukey-Kramer (HSD) test (Sokal and Rohlf, 1995) (at $p=0.05$) using the statistical package JMP (Sall et al., 2001). Finally, in order to evaluate the "synchronization" between pairs of catches among different types of traps on the same date, the correlation coefficients' values were calculated. These values were tested for departure from zero using the two-tailed *t*-test, at $n-2$ df and $p=0.01$ (Snedecor and Cochran, 1989).

RESULTS

Trap type

Significant differences were recorded among trap types (Table 1). The Funnel traps caught approx. 4.2 and 29.9 times more pink bollworm adults compared to the Delta and the Pherocon II traps, respectively (Fig. 1). *P. gossypiella* captures were found to be notably varied during the trapping period (Fig. 2). Thus, more than 80% of the total number of adults was captured during the last ten trap-check dates (from late July and on). The peak for the Funnel traps was noted late in the season (late August), with more than 890 adults per trap (over 9 and 67 times more adults compared to the Delta and the Pherocon II, respectively), while afterwards, captures were extremely high (compared to the other two types) until the end of the trapping period. A second peak for the Funnel traps was also noted in early August, while the peaks for Delta and Pherocon II traps were observed one week earlier. The Funnel traps captured more adults during the entire trapping period, with the exception of three dates (July 19, July 26 and Au-

Table 1. ANOVA statistics for main effects (trap type and trapping location) and interaction (total df=215)

Effects	df	F	p
Trap type	2	23.177	<0.0001
Location	1	0.117	0.7317
Trap type*Location	2	0.102	0.9024

Fig. 1. Total number of captured *P. gossypiella* moths ($\pm$ SE) for each trap type. Different letters indicate significant differences (Tukey-Kramer test at $p=0.05$).

Fig. 2. Mean number of captured *P. gossypiella* moths for each trap type, during the entire trapping period.

gust 23), where more adults were counted in the Delta traps. On the contrary, on each date, the Pherocon II traps captured the fewest adults, and did not exceed 16 moths/trap. Additionally, no adults were found in more than 15% of the total number of Pherocon II traps, while the other trap types captured at least 1 adult (Table 2). On the other hand, more than 50% of the Funnel traps were found to contain >100 adults, while the respective figure for Delta traps was extremely low ($<6\%$) (Table 2). A positive and significant correlation coefficient was established for pairs of captures between Delta and Pherocon II traps (Table 3). This "synchronization" was not significant between the Funnel trap and the other two trap types during the entire experimental period. Nevertheless, it must be noted that when the first 8 dates were examined separately, the cor-

Table 2. Detection sensitivity and capture rates for each trap type

No. of adults captured by each trap	% of traps with each trap type		
	Funnel	Delta	Pherocon II
0	0	0	15.8
1–9	12.5	22.2	84.2
101–200	31.9	5.5	0
>200	19.4	0	0

relation coefficient values among the three trap types were very high, given that more than 90% of the variability could be explained by a linear relationship (Table 3).

Table 3. Correlation coefficient's values for pairs of *P. gossypiella* catches among trap types

	Delta	Pherocon II	Delta (until 19/7)	Pherocon II (until 19/7)
Funnel	0.284	0.205	—	—
Delta	—	0.947*	—	—
Funnel (until 19/7)	—	—	0.918*	0.984*
Delta (until 19/7)	—	—	—	0.924*

* Coefficient's values are significantly different from zero (two tailed *t*-test at $p=0.01$).

Table 4. ANOVA statistics for main effects (pheromone quantity and trapping location) and interaction (total df=287)

Effects	df	<i>F</i>	<i>p</i>
Pheromone quantity	3	0.720	0.5406
Location	1	0.871	0.3514
Quantity*Location	3	1.385	0.2474

Table 5. Detection sensitivity and capture rates for Delta traps with different pheromone quantity

No. of adults captured by each trap	% of traps with each pheromone quantity			
	1 lure	2 lures	3 lures	4 lures
0	0	0	0	0
1–9	27.7	37.5	31.9	23.6
101–200	11.1	5.6	8.3	12.5
>200	0	0	0	0

Pheromone quantity

No significant differences were noted among Delta traps with different quantity of lures (Table 4). Twenty-six point five percent of the total number of captured moths was found in the traps which were baited with 1 lure, followed by traps with 3, 4 and 2 lures which caught 25.7%, 25.6% and 22.2% of the total, respectively. All traps were found to contain at least 1 adult, while none of the traps captured more than 200 adults (Table 5). Captures were relatively high early in the season, with a concomitant decrease later (Fig. 3). The peak was observed in late August (23/8), with more than 130 moths/trap, with the exception of the traps with 1 lure, for which the peak was observed one week later. A second peak was observed approx. one month earlier (26/7) with more than 75 moths/trap, for all treatments. The “synchronization” of captures among traps was notably similar, as indicated

by the high numbers of correlation coefficients' values shown in Table 6.

Trapping location

For both experiments, captures between centrally located and in-field peripheral traps did not differ significantly. Also, no significant interaction was recorded between trapping location and trap type or pheromone quantity (Tables 1 and 4). However, it must be noted that, although central and peripheral traps captured similar numbers of moths (for both experiments, the ratio of captured moths between peripheral and central traps was approx. 1.08 : 1), the range of captures was notably wider in the peripheral traps, as compared to the central ones. For instance, in the case of different pheromone quantities, the mean number of adults ($\pm$ SE) per trap was 40.3 ± 3.7 and 42.2 ± 8.6 for the centrally located and peripheral traps, respectively.

DISCUSSION

The comparison of different pheromone-baited trap types for the capture of *P. gossypiella* adults, according to our results, has two main characteristics. Firstly, considerable differences in capture efficacy were observed, by means of capture rate and detection sensitivity. Thus, some traps capture extremely high numbers of moths, while others fail to capture adults in a high number of trapping locations. Secondly, different trap designs can provide completely different information about the seasonal abundance of the pink bollworm. As a result, the population fluctuation (as defined by captures) is likely to vary significantly depending on the trapping device used, and hence, traps are often poor indicators for estimating pink bollworm population densities (Hutchison et al., 1991; Buchelos et al., 1999). On the other hand, the interpretation of captures of a high capacity trap can be mislead-

Fig. 3. Mean number of captured *P. gossypiella* moths in Delta traps baited with different quantities of gossypure lures, during the entire trapping period.

Table 6. Correlation coefficient's values for pairs of *P. gossypiella* catches among Delta traps with different pheromone quantity

	2 lures	3 lures	4 lures
1 lure	0.878*	0.844*	0.867*
2 lures	—	0.981*	0.965*
3 lures	—	—	0.982*

* Coefficient's values are significantly different from zero (two tailed *t*-test at $p=0.01$).

ing, except for the case of mass trapping (Mafra-Neto and Habib, 1996). In general, the main drawback of the use of adhesive traps is that the sticky surface is often "overloaded" with moths, dust or wing scales, which reduces trapping efficacy (Beasley and Adams, 1994a). In our study, although the replacement of the sticky surfaces was made on each of the trap-check dates, saturation could not be avoided, given that in sticky traps the majority of captured moths is likely to be accumulated in very short intervals (such as one night). This fact renders these traps ineffective when pink bollworm activity levels are high (Beasley and Adams, 1994a).

One of the most interesting findings of this study is the varied fluctuation of pink bollworm males for each trap type. The two types of sticky traps (Delta and Pherocon II) were found to contain relatively high adult numbers (compared to the other trap-check dates) in mid season (July) when all fruiting

bodies exist (squares, flowers and small bolls), while the Funnel traps had extremely high adult numbers later in the season (August) when almost only bolls exist. The moth fluctuation is proportionally similar among traps until mid-July, which is the season of cotton florescence and appearance of the first bolls in Greece, while afterwards only the sticky traps gave similar fluctuations. Apparently, this is attributed to the fact that the sticky traps capture moths by the same mechanism, but their efficiency is influenced by various factors (presence of dust etc.), which do not affect the capture potential of the Funnels. Precedent studies for pink bollworm capture, have also reported a higher capture rate of funnel-type traps over the Delta ones, especially at high moth densities, where saturation reduces the capture capacity of sticky surfaces (Lingren et al., 1980; Beasley and Adams, 1994a; Tamhankar et al., 2001). In general, funnels are considered to have greater capture potential (high load capacity) and efficiency (numbers captured vs numbers attracted), as compared to Delta traps (Lingren et al., 1980); however, there are moth species for which sticky traps are more efficient (Angerilli and McLean, 1984; Lindgren et al., 1984; Ameline and Frérot, 2001). From Fig. 2 it becomes evident that the Funnels presented, at least in some cases, a small (one trap-check date) "delay" in catching adults compared to the Delta traps. This could be attributed to the fact that in the early period of moth emergence Delta traps may capture more adults than Funnel traps, because

Funnels cannot catch as many males in the presence of high numbers of unmated females and fresh sticky surfaces, by reason of competition. On the contrary, in the latter period of moth emergence, Funnels may capture more males (who might survive after copulation) because of the scarcity of virgin females. This dissimilarity presents an additional complication when estimating boll infestation level by *P. gossypiella* larvae based on trap catches. Further experimentation is needed in order to assess and interpret these differences in trap performance, for more than one growing season, as fluctuations are likely to be highly affected by the year-to-year variation (Hutchison et al., 1991; Qureshi et al., 1993; Beasley and Adams, 1994b).

On the other hand, contrary to trap design, pheromone quantity does not affect captures, at least at the rates that lure containment was used in the present study, and thus, *P. gossypiella* males seem to respond equally well to a relatively wide range of pheromone release. Flint et al. (1978) in field tests also recorded that the male mate-seeking behavior of this species was similar to a wide range of gossyplure emission rates. The authors reported that a single female pink bollworm moth is equivalent to a trap baited with one lure of gossyplure. However, this behavior is not desirable when pheromones are used for communication disruption (Flint et al., 1978; Cardé et al., 1998). In our results, the negligible difference of moth fluctuations among traps with different numbers of lures constitutes in an additional indication that a minimum quantity (one lure) is adequate for successful trap performance.

Regardless of trap type and lure quantity, trapping location did not affect capture rate. This could be attributed to the fact that both cotton fields were surrounded by wheat fields, and hence the influence of the borders was similar in all cases. Leggett et al. (1994) have also reported similar results regarding the influence of the in-filed peripheral zones. In addition, evidence that this behavior is manifested in traps placed in non-cotton crops in the vicinity of cotton fields is recorded by Manley (1987). Nevertheless, our results suggest that, when a small number of traps is used for monitoring the pink bollworm's seasonal activity, the peripheral outlines must be avoided because moth captures are likely to be varied, as compared to the more

centrally located traps on which moth counts are more stable.

In conclusion, of all three factors examined in this study, trap design seems to be most decisive in affecting pink bollworm captures. Thus, although several regression models for insecticide timing according to trap catches have been developed thus far, these models can be applied only when the same (initial) trapping device is used, because different trap types are likely to produce different results. In addition, it is essential to assess these factors in relation to the cost of the trapping protocol, which in practice is at least as important as the increased efficiency and the satisfactory prediction levels.

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