Article

Factors Affecting Adult Captures of the Cotton Bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in Pheromone-Baited Traps

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Abstract: The effects of funnel-trap color, trap height and pheromone formulation on the adult captures of the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) were evaluated in traps that were suspended in cotton fields in central Greece. Briefly, in a first trial, the efficacy of funnel traps of three different colors, i.e., green, striped (with black and white stripes) and white, was comparatively evaluated, whereas in a second trial green funnel traps were placed at three heights, i.e., 30, 60 and 90 cm from the ground. Finally, in a third trial we tested the efficiency of green funnel traps with three commercially available pheromone lures. Considering the overall captures, trap color and pheromone formulation affected male captures, whereas trap height had no influence. Captures notably increased in all traps from late August to mid-September. In total, the white funnel trap captured more moths than the green or striped funnel traps. Placement of the traps at different heights did not significantly affect captures, but seasonal differences were observed at individual dates during the trapping period. Barrettine's pheromone lure provided significantly more captures than the other two (Russell, Trécé) in some of the trap-check dates. The results can be further utilized in the monitoring protocols of *H. armigera* in cotton fields.

Keywords: *Helicoverpa armigera*; cotton; pheromone traps; monitoring; funnel traps

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1. Introduction

The cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), is an economically serious pest with a wide host range comprising more than 180 cultivated and wild plant species [1]. Some of the high-value crops that are infested by this species are cotton, maize, tobacco, sunflower, sorghum, soybeans, pulses, rapeseed, safflower and groundnuts [1–6]. The number of generations of this particular insect varies from 1 per year in cold climates up to 11 generations per year in the tropics [1,7]. In northern Greece, *H. armigera* completes two or three generations per year, while for the rest of Greece the available data are inconclusive [8].

The larvae of this species feed on all the reproductive and vegetative parts of cotton, showing a special preference to buds and bolls due to the high concentration of oxygen in these plant parts [1,9]. The larval feeding behavior can either trigger the buds to bloom prematurely, preventing fruiting, or cause the fall of the bolls and the deterioration of the fiber [1]. All of the above lead to significant production losses and to high control costs that exceed \$5 million per year globally [10,11]. Furthermore, this species has developed a considerable level of resistance to many groups of insecticides such as pyrethroids, organophosphate and carbamate [12–15]. Nonetheless, some groups of insecticides such as spinosyns, diamides and growth regulators have shown encouraging results against the cotton bollworm [16–18]. The adult population of *H. armigera* in cotton, but also in other crops, is successfully monitored mainly by pheromone-baited traps and capture

numbers are used to time the insecticidal applications [11,19–21]. The chemical structure of the female sex pheromone of *H. armigera* was identified as a (Z)-11-hexadecenal and (Z)-9-hexadecenal in a 97:3 ratio [22]. This sex pheromone is used in pheromone traps, which can be used both for monitoring the insect population, as well as for mass trapping with good results [23–29].

There is a wide variety of pheromone-baited traps that vary in design, size and other visual stimuli such as the color of the trapping surface, depending on the target insect species [24–26,28,29]. The results of several studies have shown that the trap color significantly affects the capture efficacy of a trap for several moth species of economic importance [23–28]. For example, Athanassiou et al. [26] evaluated the efficacy of four different-colored pheromone traps for the monitoring of adults of the pine processionary moth, *Thaumetopoea pityocampa* (Denis & Schifferrmüller) (Lepidoptera: Thaumetopoeidae), and reported that white- and yellow-colored traps caught significantly more males than the brown- and green-colored traps in high-density pine stands. In another study, Hashemi [30] observed that the highest captures of adults of the potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae), were recorded in green traps compared to the red and yellow ones. Nevertheless, there is still inadequate information on this subject in the case of adult captures of *H. armigera*.

Apart from the characteristics of the traps, other factors that affect the capture rate in pheromone traps are the trap placement, the pheromone source and the trapping location [24,26,27,30]. There are a number of studies on the impact of the height at which the trap is placed on the number of captures of several insect species [27,29–33]. Kavalieratos et al. [27] reported that trap height had no influence on the adult male captures of the olive moth, *Prays oleae* (Bernard) (Lepidoptera: Yponomeutidae), in olive orchards. Witzgall et al. [32] found that the traps that were placed at a height of 3.0 m above the ground level captured the highest number of *H. armigera* adult males in pigeon-pea crops, compared with the traps placed at a height of 1.5 and 2.0 m. Considering the above, it becomes evident that, even if the same trapping device and pheromone lure is used, the way that the traps are suspended may notably differentiate the number of captures, resulting in different decision making in relation to control measures [34].

Another important factor that affects the trap captures is the type of the lure that is used. Apparently, different pheromone attractants have different insect-trapping capacities [25,35,36]. Adams et al. [35] reported significant differences in the capturing efficiency of four commercially available sex pheromone lures for adults of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae). Similarly, differences were observed when testing various commercially available pheromone lures for the corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) [36]. Even in similar quantities of the pheromone, the way that the pheromone is loaded can drastically affect captures, as has been shown in the case of the jasmine moth, *Palpita unionalis* (Hübner) (Lepidoptera: Pyralidae) [25].

Although Greece is the European Union's main cotton producer, accounting for over 80% of the total European production [37], few published studies are available regarding the monitoring of *H. armigera* adults using pheromone-baited traps, although they are the major cotton pests in Greece [8,38,39]. In a study conducted from 2002 to 2005 in 10 areas of the prefecture of Larissa in Thessaly, a negative correlation was found between the number of trapped males of *H. armigera* and the cotton production for each year [39]. Still, the data are scarce in the case of the population fluctuation of this species in the other prefectures of Thessaly, Greece, which is the main cotton-producing area of the country. In this context, the objective of the present study was to investigate the effects of trap color, trap height, and pheromone formulation on the capture of *H. armigera* in the prefecture of Magnesia, Thessaly, in an effort to contribute further towards the use of standardized trapping protocols.

2. Materials and Methods

2.1. Experimental Site

The experiments were carried out in the region of Velestino (Magnesia, Thessaly, Central Greece) during the 2018 growing season. Velestino is located at an altitude of 120 m and its longitude and latitude are 22°44' and 39°24', respectively. The area was chosen due to the presence of large cotton fields. The sowing of cotton was done in mid-April, followed by standard cultivation care, whereas the trapping period was initiated in early June and terminated in late September, 2018. The minimum and maximum temperatures during the experimental period in the area of Velestino were 16.2 and 31.8 °C in June, 18.4 and 37.4 °C in July, 21.3 and 37.2 °C in August and 14.7 and 31.9 °C in September, while rainfall was 113.4, 19.4, 14.2 and 52.0 mm in June, July, August and September, respectively. Table 1 presents the climatic data at time intervals between observations. These data were collected by a local meteorological station.

Table 1. The average temperature (°C), rainfall (mm) and wind speed (km/h) in the area of Velestino at intervals between observations of pheromone traps.

Date	No of Observation	Average Temperature (°C)	Average Rainfall (mm)	Average Wind Speed (km/h)
6 June (installation)–13 June	1	25.6	0.1	7.6
13 June–22 June	2	24.4	1.9	6.9
22 June–18 July	3	25.1	4.0	7.3
18 July–25 July	4	27.8	0.0	8.7
25 July–1 August	5	26.9	6.8	4.3
1 August–8 August	6	27.6	1.7	4.6
8 August–16 August	7	27.1	0.0	4.2
16 August–23 August	8	27.9	0.0	5.9
23 August–29 August	9	26.3	4.1	5.6
29 August–6 September	10	27.3	0.0	4.8
6 September–12 September	11	26.5	0.0	7.5
12 September–21 September	12	23.9	0.1	4.9
21 September–29 September	13	20.6	0.3	5.6

2.2. Trapping Devices and Pheromones

There were three series of field experiments. In the first series, we used funnel traps of three different colors, i.e., green, striped (with black and white stripes) and white (Hellapharm, Attica, Greece). All traps were suspended with their lowest part at 90 cm from the ground level. In the second series, we evaluated the height of the traps, by placing green funnel traps at three heights, i.e., at 30, 60 and 90 cm from the ground. Barrettine's pheromone lure (Barrettine Environmental Health, Bristol, UK) was used in both series of experiments. Finally, in the third series, we used green funnel traps that were placed at 90 cm from the ground, with three commercially available pheromone lures, obtained from Barrettine (Barrettine Environmental Health, Bristol, UK), Russell (Russell IPM, Deeside, UK) and Trécé (Trécé, Inc., Adair, IA, USA). A paper that was saturated with the insecticide transfluthrin (0.4% w/w, VAPONA, Sarantis SA, Athens, Greece) was placed inside each trap and used as a killing agent.

2.3. Trap Set Up

The installation of the traps took place on June 6, 2018. In all cases, there were three replicates for each treatment ($3 \times 3 = 9$ traps/treatment). The traps were set on a cotton plot at a distance of 20 m from each other. The traps were placed in 9 parallel rows, where the first 3 rows corresponded to the factor with a specific color (green, white, striped), the next 3 rows to the factor of trap placement height (30, 60 and 90 cm) and the last 3 to factor different pheromone formulations (Barrettine, Russell, Trécé). The traps were inspected at weekly intervals by recording the number of *H. armigera* adults that were captured. There

were 13 trap-check dates in total. After each inspection, all of the adults were removed and the traps were rotated in order to minimize the influence of the individual trapping location [24]. The pheromone lures were replaced every four weeks.

2.4. Statistical Analysis

Prior to analysis, all data were tested for normalization and homogeneity using either Levene's or O'Brien's test. Then, separately for each test, the data were submitted to a two-way ANOVA for each factor (trap color, trap height or pheromone) and trap-check date. For the comparison of the means, the Tukey–Kramer (HSD) test was used at 0.05 significant level. Moreover, in order to evaluate the 'synchronization' between pairs of catches among different trap items (traps with different characteristics) on the same date, the correlation coefficient values were calculated. These values were tested for their departure from zero by using a two-tailed *t*-test, at *n*–2 df and at 0.01 significant level.

3. Results

3.1. Effect of Trap Color

All of the main effects (trap color and trap-check date) and their associated interactions were significant (Table 2). The white traps caught the highest number of *H. armigera* adults with an average of 17 individuals per trap compared to the green and striped traps with five and four adults per trap, respectively (Table 3). There were no significant differences between the green and striped traps regarding the total number of captures for any of the trap-check dates that were tested (Table 3). In the first measurements in June and July, the number of captures was low and did not exceed an average of two adults per trap (Table 3). In August, the captures were increased and in September they peaked for all of the traps. In the first three trap-check dates of September, significant differences were recorded between the white and the two other trap colors (Table 3).

Table 2. ANOVA parameters for trap color and trap-check dates (total df (degrees of freedom) = 116), F = ratio of two variables.

Effects	df	F	<i>p</i>
Trap color	2	23.4	<0.01
Date	12	17.0	<0.01
Trap color × Date	24	3.2	<0.01

Table 3. Mean number ($\pm$ SE) of *Helicoverpa armigera* adults per trap captured in each trap color and each trap-check date.

Date	Green	White	Striped	F	<i>p</i>
13 June 2018	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.33 $\pm$ 0.33	1.00	0.42
22 June 2018	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	-	-
18 July 2018	0.66 $\pm$ 0.33 a	1.00 $\pm$ 0.00 b	0.00 $\pm$ 0.00 a	7.00	<0.05
25 July 2018	0.00 $\pm$ 0.00	2.33 $\pm$ 1.85	0.66 $\pm$ 0.66	1.11	0.38
1 August 2018	0.66 $\pm$ 0.33	6.66 $\pm$ 5.23	1.00 $\pm$ 1.00	1.19	0.36
8 August 2018	0.66 $\pm$ 0.66	11.00 $\pm$ 10.50	0.66 $\pm$ 0.33	0.96	0.43
16 August 2018	1.00 $\pm$ 0.57	13.66 $\pm$ 13.16	0.66 $\pm$ 0.33	0.94	0.43
23 August 2018	3.66 $\pm$ 1.66	17.33 $\pm$ 13.90	4.00 $\pm$ 3.05	0.88	0.46
29 August 2018	3.33 $\pm$ 1.20	21.33 $\pm$ 16.89	4.33 $\pm$ 1.85	1.05	0.40
6 September 2018	25.66 $\pm$ 6.96 a	61.33 $\pm$ 11.17 b	14.33 $\pm$ 5.69 a	8.77	<0.05
12 September 2018	23.66 $\pm$ 0.33 a	78.00 $\pm$ 11.53 b	20.66 $\pm$ 6.33 a	8.03	<0.05
21 September 2018	1.33 $\pm$ 1.33 a	9.33 $\pm$ 1.20 b	3.33 $\pm$ 0.88 a	13.00	<0.05
29 September 2018	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	-	-
Total average	4.66 $\pm$ 1.47 a	17.07 $\pm$ 4.35 b	3.84 $\pm$ 1.15 a	7.33	<0.05

Within each date, means followed by the same letter were not significantly different (in all cases df = 2, 8). Where no letters exist, no significant differences were noted. For the 1st observation 'Brien test was: F = 1.7, *p* = 0.247 for the 3rd was: F = 1.7, *p* = 0.247, for the 4th was: F = 1.5, *p* = 0.286, for the 5th was: F = 1.7, *p* = 0.259, for the 6th was: F = 1.7, *p* = 0.249, for the 7th was: F = 1.7, *p* = 0.248, for the 8th was: F = 1.6, *p* = 0.265, for the 9th was: F = 1.7, *p* = 0.252. The unreported observations meet the criteria of the Levene's test.

In more than 5% of the total observations, adult captures in the white traps exceeded 50 individuals per trap, in contrast to the other two traps for which captures did not exceed 26 moths per trap at any of the trap-check dates (Table 4). Furthermore, more than 16% of the green and striped traps captured no adults, while the respective figure for white traps was much lower (Table 4). Finally, a positive and significant correlation coefficient was recorded between the white and green and the white and striped traps, but not between the green and striped traps (Table 5).

Table 4. Detection sensitivity and capture rates for each trap color.

Number of Adult Captures	% of Total Observations in Each Trap Color		
	Green	White	Striped
0	16.2	10.3	16.2
1–10	12.0	12.8	12.8
11–50	5.1	5.1	4.2
51–100	0	5.1	0
>100	0	0	0

Table 5. Correlation coefficient values for pairs of *H. armigera* captures between traps with different colors.

Trap Color	R	df	t	p
Green–White	0.78	38	3.754	0.001
Green–Striped	0.86	38	1.121	0.270
White–Striped	0.63	38	3.571	0.001

3.2. Effect of Trap Height

Considering the overall data, trap height was not significant (Table 6). Considering each trap-check date, no significant differences were recorded among the traps that had been placed at different heights, with the exception of August 8, when captures by the traps at 30 cm differed significantly from the respective figures for the other two heights, and of September 21, when the traps at 60 cm differed from the other two heights (Table 7). As in the case of trap color, the highest captures were recorded late in the experimental period (Table 7).

Table 6. ANOVA parameters for trap height and trap-check dates (total df = 116).

Effects	df	F	p
Trap height	2	1.4	0.24
Date	12	7.1	<0.01
Trap height × Date	24	0.5	0.96

Table 7. Mean number ($\pm$ SE) of *Helicoverpa armigera* adults per trap captured in each trap height and each trap-check date.

Date	30 cm	60 cm	90 cm	F	p
13 June 2018	0.33 $\pm$ 0.33	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	1.00	0.42
22 June 2018	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	-	-
18 July 2018	2.33 $\pm$ 1.45	0.66 $\pm$ 0.33	1.66 $\pm$ 0.88	0.70	0.53
25 July 2018	0.33 $\pm$ 0.33	0.66 $\pm$ 0.66	0.00 $\pm$ 0.00	0.60	0.57
1 August 2018	0.00 $\pm$ 0.00	0.33 $\pm$ 0.33	0.00 $\pm$ 0.00	1.00	0.42
8 August 2018	1.66 $\pm$ 0.33 a	0.00 $\pm$ 0.00 b	0.33 $\pm$ 0.33 b	10.50	<0.01
16 August 2018	1.00 $\pm$ 0.0	0.66 $\pm$ 0.33	0.33 $\pm$ 0.33	1.50	0.29
23 August 2018	0.66 $\pm$ 0.33	5.00 $\pm$ 5.00	2.00 $\pm$ 1.15	0.55	0.59
29 August 2018	1.66 $\pm$ 0.33	3.33 $\pm$ 2.84	2.00 $\pm$ 0.57	0.27	0.77

Table 7. Cont.

Date	30 cm	60 cm	90 cm	F	p
6 September 2018	9.00 ± 6.50	21.66 ± 11.31	17.00 ± 6.00	0.59	0.58
12 September 2018	7.00 ± 4.50	16.33 ± 10.72	8.66 ± 2.60	0.52	0.61
21 September 2018	0.00 ± 0.00 a	2.00 ± 0.57 b	0.00 ± 0.00 a	12.00	<0.01
29 September 2018	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	-	-
Total average	1.84 ± 0.68	3.89 ± 1.51	2.46 ± 0.88	0.93	0.39

Within each date, means followed by the same letter were not significantly different (in all cases $df = 2, 8$). Where no letters exist, no significant differences were noted. For the 1st observation 'Brien test was: $F = 1.7, p = 0.247$, for the 4th was: $F = 1.3, p = 0.325$, for the 5th was: $F = 1.7, p = 0.247$, for the 6th was: $F = 0.8, p = 0.459$, for the 7th was: $F = 0.8, p = 0.459$, for the 8th was: $F = 1.6, p = 0.264$, for the 9th was: $F = 1.6, p = 0.263$. The unreported observations meet the criteria of the Levene's test.

Additionally, none of the traps in these series of tests captured over 50 adults/trap, and in general, their detection sensitivity was comparable (Table 8). Finally, correlation coefficients were not significant for any of the trap pairs (Table 9).

Table 8. Detection sensitivity and capture rates for each trap height.

Number of Adult Captures	% of Total Observations in Each Trap Height		
	30 cm	60 cm	90 cm
0	15.3	17.9	20.5
1–10	16.2	11.1	9.4
11–50	1.7	4.2	3.4
51–100	0	0	0
>100	0	0	0

Table 9. Correlation coefficient values for pairs of *H. armigera* catches in traps suspended at different trap heights.

Trap Height	R	df	t	p
30 cm–60 cm	0.65	38	−1.730	0.092
30 cm–90 cm	0.81	38	−1.195	0.240
60 cm–90 cm	0.61	38	1.197	0.239

3.3. Effect of Pheromone Formulations

Both of the main effects (pheromone formulation and trap-check date) and their interactions were significant (Table 10). The Barretine pheromone formulation collected the highest *H. armigera* adult numbers per trap, which was significantly higher than the respective figures for the other two formulations (Table 11). Early in the trapping period, as in the case of the previous tests, the number of captures was low, and comparable for all three formulations (Table 11). The traps that contained the Barretine formulation peaked on 6 September with 25 adults/trap, while for the other two traps the peak was recorded on 23 August, with four and four adults/trap for Russell and Trécé, respectively.

Table 10. ANOVA parameters for pheromone formulation and trap-check dates (total $df = 116$).

Effects	df	F	p
Pheromone formulation	2	17.6	<0.01
Date	12	7.1	<0.01
Pheromone formulation × Date	24	7.1	<0.01

Table 11. Mean number ($\pm$ SE) of *Helicoverpa armigera* adults per trap captured in each pheromone formulation and each trap-check date.

Date	Barrettine	Russell	Trécé	F	p
13 June 2018	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	1.33 $\pm$ 1.33	1.00	0.42
22 June 2018	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.33 $\pm$ 0.33	1.00	0.42
18 July 2018	1.00 $\pm$ 0.57	1.33 $\pm$ 0.88	1.66 $\pm$ 0.88	0.17	0.84
25 July 2018	0.33 $\pm$ 0.33	0.00 $\pm$ 0.00	1.33 $\pm$ 1.33	0.76	0.50
1 August 2018	1.66 $\pm$ 0.88	1.00 $\pm$ 1.00	1.33 $\pm$ 0.66	0.15	0.86
08 August 2018	0.33 $\pm$ 0.33	0.00 $\pm$ 0.00	2.33 $\pm$ 1.45	2.15	0.19
16 August 2018	1.00 $\pm$ 0.57	1.33 $\pm$ 0.33	0.33 $\pm$ 0.33	1.40	0.31
23 August 2018	5.66 $\pm$ 2.18	4.33 $\pm$ 2.18	4.00 $\pm$ 0.00	0.24	0.79
29 August 2018	4.66 $\pm$ 1.66	3.66 $\pm$ 2.02	2.00 $\pm$ 0.57	0.75	0.51
6 September 2018	25.33 $\pm$ 3.66 a	0.66 $\pm$ 0.66 b	0.00 $\pm$ 0.00 b	45.02	<0.01
12 September 2018	16.66 $\pm$ 8.29	1.00 $\pm$ 1.00	0.33 $\pm$ 0.33	3.66	0.09
21 September 2018	3.33 $\pm$ 1.76	0.00 $\pm$ 0.00	2.00 $\pm$ 0.57	2.45	0.16
29 September 2018	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00		
Total average	4.61 $\pm$ 1.35 a	1.02 $\pm$ 0.31 b	1.36 $\pm$ 0.28 b	5.33	<0.01

Within each date, means followed by the same letter were not significantly different (in all cases $df = 2, 8$). Where no letters exist, no significant differences were noted. For the 1st observation O'Brien test was: $F = 1.7, p = 0.247$, for the 2nd observation O'Brien test was: $F = 1.7, p = 0.247$, for the 4th was: $F = 1.6, p = 0.265$, for the 8th was: $F = 0.8, p = 0.459$, for the 10th was: $F = 1.7, p = 0.256$, for the 11th was: $F = 1.7, p = 0.252$, for the 12th was: $F = 1.5, p = 0.279$. The unreported observations meet the criteria of the Levene's test.

The traps that were baited with the Barrettine lures were the only ones that captured 10–50 adults/trap (Table 12). Finally, the correlation coefficients' values were generally lower than those of the previous tests, and were not significant except for Russell and Trécé (Table 13).

Table 12. Detection sensitivity and capture rates for each trap baited pheromone formulation.

Number of Adult Captures	% of total Observations in Each Pheromone Formulation		
	Barrettine	Russell	Trécé
0	14.5	23.0	16.2
1–10	14.5	10.2	17.0
11–50	4.2	0	0
51–100	0	0	0
>100	0	0	0

Table 13. Correlation coefficient values for pairs of *H. armigera* catches among traps baited with different pheromone formulations.

Pheromone Formulation	R	df	t	p
Barrettine–Russell	−0.03	38	2.571	0.014
Barrettine–Trécé	−0.10	38	2.363	0.023
Russell–Trécé	0.21	38	−0.788	0.436

4. Discussion

In a previous work in cotton fields in Makedonia, Northern Greece during the 2005 and 2006 growing period, Mironidis et al. [8] used pheromone-baited funnel traps to monitor the *H. armigera* male activity. They recorded three peaks of male captures for 2005 (late July, late August and mid-September) and two for 2006 (late July and late August), suggesting that there were three or four generations of *H. armigera* per year in this region [8]. Our data showed a more uniform fluctuation in the area of Magnesia, with a longer single-peak period, starting from late August and lasting until mid-September. Similar results, in terms of captures that are concentrated in a relatively short period, have also been found in other surveys in several countries, such as Australia [23,40], Tanzania [41] and India [21,42]. For instance, Baker et al. [40] found that the highest number of captures in New South Wales, Australia, was reached at the end of the summer. In the work of Nyambo [41],

the variation of the population of adults of *H. armigera*, as well as the level of infestation, were characterized by intense seasonality and were also influenced by the location of the experiment.

During the entire experimental period, between 13 June and 29 September, the white traps captured more *H. armigera* adults than the other two trap colors. The above results are consistent with many studies concerning either *H. armigera* [23] or other Lepidopteran species [24–28]. In a study that was conducted in Australia for the evaluation of various traps for the estimation of the *H. armigera* population, Sage and Gregg [23] found that the conical trap Texas with white plastic mesh (Albany International Corp. Needham Heights, Massachusetts) was the one that captured the most adults compared to the modified Texas with the gray plastic screen. Similarly, in an experiment that took place in two regions of Greece, Athanassiou et al. [25] showed that the white funnel traps captured the most adult males of the *P. unionalis*, in relation to brown, green and yellow funnel traps. The preference to the white trap color has been attributed to the fact that the reflective energy of the white color (370–450 nm) is higher than that of the other two trap colors used [25,26]. The high-reflectance energy colors help males to locate the pheromone source, at least during the first interval of their activity when there is some light. This means that, at least at this stage, the pheromonal stimulus coexists with a visual stimulus and males may respond to both cues. Kelber et al. [43] demonstrated that the hawk moths *Deilephila elpenor* (L.), *Hyles lineata* (F.), and *Hyles gallii* (Rottemburg) (Lepidoptera: Sphingidae) use color vision to discriminate between flowers at night. The significant influence of high-reflectance-energy-colored traps on adult male captures has also been reported for *T. pityocampa* [26].

Although no significant differences were recorded among the examined trap heights, seasonal differences were observed at individual dates. These seasonal differences in captures may be either related to the seasonal changes of the growth of the cotton plants and their fruiting organs or to the population fluctuations of the insect. Priyanka et al. [33] found that traps placed at canopy level in pigeon-pea cultivation gathered a higher number of male adults of *H. armigera* than the traps that were placed one and two feet above and below the canopy level. The seasonality of the captures of *H. armigera* at traps placed at different heights has been also reported by Ujjan et al. [29], who observed the highest catches at chickpea crops in traps placed at 6 feet (183 cm) during the crop season and at 4 feet (122 cm) after harvest. Early in the experimental period, when the plants had smaller heights, we noticed that on some of the trap-check dates, relatively higher captures were recorded in traps that were placed at 30 cm than at 60 and 90 cm, while later in the growing season, the traps at this height had lower capture numbers compared to the other heights.

The pheromone agent, in the sense of a commercially available pheromone capsule formulation, has been found to be an important factor in *H. armigera* adult captures. However, our data show that all three formulations provided a similar population fluctuation pattern of *H. armigera*. This is especially important, as the indication of generations is a top priority in the management of this species, especially at the time of the appearance of the cotton bolls. Hence, despite differences in the captures, the “synchronization” of the different trap categories in estimating the time of the increase in *H. armigera* adult numbers is of fundamental importance, in order to accurately time the insecticidal applications. Similar results have been reported in the case of the pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), where different pheromone levels provided a similar estimation of the occurrence of the generations [24].

In conclusion, this study shows that trap color and pheromone formulation are characteristics that strongly affect the response of *H. armigera* males to pheromone-baited traps. Hence, specific trap colors and pheromone lures were found to be more effective than others, while trap height played a less-important role. These findings should be taken into account when developing a monitoring system, which should be standardized and provide results that reliably depict *H. armigera* populations, which is particularly critical in the case of area-wide management protocols.

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