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Effect of planting dates and recommended insecticides application on *Earias insulana* (Boisd.) and its associated predators in cotton field in Egypt

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Research Paper

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Abstract

Cotton crops are an important agricultural product in Egypt. However, the bollworm *Earias insulana* is a significant pest of cotton. Field experiment was carried out during the 2018 and 2019 seasons at Qaha Experimental Station, Qalyoubia governorate to determine the best dates for sowing cotton crops, to minimize *E. insulana* infestation and maintain high populations of the predators of spiny bollworm. The latest sowing date had a significantly lower infestation of squares, flowers and green bolls than the other two sowing dates. After spraying the three planting date plots with profenofos, lambda-cyhalothrin and methomyl insecticides, infestation of cotton bolls by spiny bollworm was significantly reduced in treated compared with untreated plots. A significant positive correlation ($r = 0.829^*$ and 0.827^*) was found between the average temperature and *E. insulana* infestation of squares and flowers, respectively, for the first planting date and ($r = 0.819^*$) in squares for the second planting date of untreated plots of season 2018. The explained variance percentages of multiple regression analysis showed that the effects of mean temperature and relative humidity (RH) on the third sowing date had a significantly lower infestation of squares, flowers and green bolls by spiny bollworm as compared to the first and second sowing dates. The populations of common natural enemies of *E. insulana* on cotton plants, i.e., *Chrysoperla carnea*, *Coccinella undecimpunctata* and spiders were counted during the two seasons. The correlation between the RH percentage and populations of the three predators was insignificantly positive during the 2018 season, while it was negatively or positively insignificant during the 2019 season. The correlation between the mean temperature and the populations of the three predators was insignificantly negative for *C. carnea* and positive for spiders during the 2018 season, whereas a positive correlation was found between temperature and *C. carnea* and spiders and a negative correlation between temperature and *C. undecimpunctata* during the 2019 season.

Introduction

Cotton, commonly known as White Gold, is considered to be the most important fibre crop in Egypt as well as in other countries. In all of the areas in which it is cultivated, the planting dates are determined according to the suitability of the environmental conditions. Many authors have indicated that early cotton planting reduces infestation by late season insect pests, increases lint yield and facilitates earlier harvest. This occurs when soil temperature reaches at least 18°C (Bibro and Ray, 1973; Davidonis *et al.*, 2004; Ali *et al.*, 2009; Adams *et al.*, 2013; Moustafa *et al.*, 2015; Emara *et al.*, 2018).

It has been reported that accumulated heat units (degree-days, DD^s) help in predicting pest occurrence and monitoring the activity of *Earias insulana* (Kandil, 2013; Moursy *et al.*, 2014). Yones *et al.* (2012) stated that the occurrence of many insect pests can be predicted by DD^s, as in the case of *Pectinophora gossypiella*. Therefore, DD^s can be used to optimize the scheduling of pesticide sprays.

Spiny bollworm *E. insulana* (Boisd.) is a major pest of cotton (*Gossypium barbadense* L.) and other crops in Egypt (Nada *et al.*, 2010). The larvae cause damage to the terminal shoots, squares, flowers and bolls of cotton plants. The larvae penetrate the bolls and move from one plant to another leaving holes covered with faeces. Infestation of the mature bolls injures the developing filaments, and introduces bacteria and fungi. A heavy attack may destroy the entire crop, resulting in a reduction in the quality and quantity of cotton yield (Ahmad, 1980; Khan *et al.*, 2007). Chemical control is the major tool for bollworm management. The success of the control of *E. insulana* depends on spraying the insects at the appropriate stage of development, so it is important to identify the fluctuations in the insect populations, this knowledge may be helpful for insecticidal application when the target stage of the insect appears.

The objective of the present study was to determine the best date at which to sow cotton to minimize *E. insulana* infestation, maintain high populations of its associated predators and thus increase crop quality and quantity during two successive seasons (2018 and 2019).

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Materials and methods

Field experiment

Field experiment was carried out at Qaha Experimental Station, Qalyoubia governorate during the 2018 and 2019 seasons, to determine the best sowing dates for cotton crops. The experimental area was a randomized complete block design with three treatments and replicates. Each treatment area was divided into six plots: three for treatment and the other as a control. Giza 86 cotton seeds were obtained from Cotton Research Institute, Agriculture Research Center, Giza, Egypt and sown at 20 cm distance between hills on three different dates: 14 March, 13 March and 15 April during the 2018 cotton season and 26 February, 13 March and 3 April during the 2019 cotton season. Recommended agronomic practices were carried out in all experimental and control plots. The cotton plants were treated with three recommended insecticides; (profenofos) Cord 72% EC at a rate of 750 cm^3/Feddan, (lambda-cyhalothrin) Aksone 5% EC at a rate of 375 cm^3/Feddan and (methomyl) Geto 90% SP at a rate of 300 g/Feddan. Insecticide treatments were done when the infestation percentage of *E. insulana* reached 3%. Spraying of these recommended insecticides was carried out on 2 July for pofenofos, 18 July for lambda-cyhalothrin and 1 August for methomyl in the 2018 cotton season. In 2019, the insecticides were applied on 1 July for pofenofos, 15 Julyfor lambda-cyhalothrin and 29 July for methomyl.

Spiny bollworm infestation

The extents of infestation of spiny bollworm in squares, flowers and green bolls were determined in each season. Twenty-five squares, 25 flowers and 50 bolls from each plot from each of the three planting dates were randomly sampled at weekly intervals until harvest. The level of infestation was recorded at weekly intervals based on the presence of injury symptoms. Collected bolls were carefully dissected and larval infestation in green bolls was determined according to Henderson and Tilton (1955).

Associated predators

The mean number of associated predators in cotton was determined in the two successive seasons (2018 and 2019). The predators monitored were: *Chrysoperla carnea* (family Chrysopidae), *Coccinella undecimpunctata* (family Coccinellidae) and spiders; *Thanatus albini* from the family Philodromidae, *Thomisus sp.* (family Thomisidae) and *Vloborus walckenaerius* (family Uloboridae). To estimate the populations of natural enemies, 50 plants were randomly selected from the three planting dates from 3 May until 13 August in the 2018 season and from 3 April until 28 August in the 2019 season. The numbers of the predators on the selected plants were recorded weekly.

Statistical analysis

Data were subjected to one-way analysis of variance (ANOVA) followed by Duncan Multiple Range Test (Duncan, 1955) at 0.05 probability level using the SAS (2008) software. In order to determine the effect of planting dates on the incidence of spiny bollworm and associated predators, correlation and multiple regression values between the mean temperature and relative humidity (RH) and the infestation of spiny bollworm were calculated. Daily temperature and RH were provided by the Metrological Department (Agriculture Research Center), Dokki, Giza for the 2018 and 2019 seasons.

The degree-days (DD^s) were calculated according to Arnold (1960) as follows:

(Maximum temperature + Minimum temperature/2) – Threshold (base) temperature where the zero development (*t*0) was 8.97°C for *E. insulana* as described by Moursy *et al.* (2014).

Results

Temperature, % RH and accumulated heat units (DD^s) during the 2018 and 2019 seasons

The inspection dates, related mean temperature, % RH and accumulated heat units (DD^s) are shown in table 1. The first samples of squares, flowers and bolls were collected from plots of the first and second planting dates on 25 June in the 2018 season and 24 June in the 2019 season. The corresponding temperature, RH and accumulated heat units (DD^s) were recorded as 29°C, 52.4% and 2444.78 DD^S in the 2018 season and 30.5°C, 49.69% and 2363.25 DD, respectively, for the third planting date in the 2019 season, it started lately on 11 and 3 July at the two seasons with mean temperatures of 29.5 and 31°C, mean RH of 57.5 and 48.8% and DD^s of 2794.26 and 2564.52, respectively (table 1).

Spiny bollworm infestation

The correlation between E. insulana infestation and insecticides application

The infestation of cotton squares, flowers and bolls by the spiny bollworm *E. insulana* from three planting dates in the 2018 and 2019 seasons is shown in tables 2 and 3. The tabulated data reveal that both insecticide treatment and planting date affected the spiny bollworm infestation.

Squares infestation by E. insulana

With respect to the infestation of squares in untreated plots, the plots sown on the first and second dates were more heavily infested than those sown on the late sowing date. The highest percentages of infested squares of the three untreated plots were recorded on 1 August (44%), 25 July (42%) and 15 August (24%) of the 2018 season with related mean temperature, % RH and DD^s of 32°C, 56.5% and 3243.89; 33.5°C, 42.5% and 2444.78; and 30°C, 56.1 and 3550.81%, respectively (table 1). While the highest percentages of infested squares in treated plots reached 10%, in the plots from the first and third sowing dates 11 July of the 2018 season with the mean temperature, % RH and DD^s as recorded for the untreated plots however, it was 14% in the plots sown on the second date (2 July). The average means of temperature and % RH were approximately equal in the two seasons, while the DD^s value was higher in the 2018 season (2773.94) than in the 2019 season (2631.00).

After spraying with profenofos, lambda-cyhalothrin and methomyl insecticides, spiny bollworm infestation on cotton squares was lower in insecticide-treated plots than in untreated plots. In 2018, infestation at the third sowing date was insignificantly reduced (4.0%) from the two earlier dates being 4.0% as opposed to 6.7%. Differences in average infestation were not significantly different, at 5.0, 6.7 and 4.0% in the three sowing dates of the 2019 season, respectively. Insecticide treatment therefore caused a significant reduction in infestation of the squares. The infestations in the treated plots were lower than those in the untreated

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Table 1. The local meteorological conditions during the experimental period at the two successive seasons of 2018 and 2019

Season 2018				Season 2019			
Date of cultivates, inspection and insecticide sprays	Mean Temp.	Mean % RH	DD^S	Date of cultivates, inspection and insecticide sprays	Mean temp.	Mean % RH	DD^S
14/3/2018	27.00	36.00	528.39	26/2/2019	17.00	46.50	619.21
31/3/2018	19.00	55.00	881.2	13/3/2019	19.00	54.00	738.16
15/4/2018	26.50	34.00	1087.65	3/4/2019	20.00	46.70	945.29
25/6/2018	29.00	52.40	2444.78	24/6/2019	30.50	49.69	2363.25
2/7/2018	28.50	52.50	2597.49	1/7/2019	31.00	55.50	2519.96
11/7/2018	29.50	57.50	2794.26	3/7/2019	31.00	48.80	2564.52
18/7/2018	31.50	57.10	2933.97	8/7/2019	30.50	57.50	2670.17
25/7/2018	33.50	42.50	3090.68	10/7/2019	31.00	52.29	2714.73
1/8/2018	32.00	56.50	3243.89	15/7/2019	30.00	52.27	2826.38
8/8/2018	31.00	58.70	3397.60	17/7/2019	35.00	54.60	2857.94
13/8/2018	31.00	57.10	3508.75	22/7/2019	30.00	55.00	2980.59
15/8/2018	30.00	56.10	3550.81	24/7/2019	30.50	52.50	3024.65
22/8/2018	30.50	60.40	3701.52	29/7/2019	30.50	52.00	3129.80
29/8/2018	29.60	55.60	3848.73	31/7/2019	31.00	58.50	3173.86
5/9/2018	30.70	57.30	3999.44	7/8/2019	29.50	54.00	3326.07
				14/8/2019	32.00	44.00	3481.28
				21/8/2019	30.00	57.00	3636.49
				28/8/2019	30.50	53.50	3785.70

plots by 72.25, 75.33 and 79.96% in 2018 and 75.80, 83.14 and 78.94% in the 2019 season, respectively.

The correlation between the infestation of cotton squares by spiny bollworm, mean temperature and % RH is shown in tables 4 and 5. During the 2018 cotton season, the percentage of squares infested in the first and second plantation dates of the untreated plots was significantly positively correlated with mean temperature ($r = 0.829^*$ and 0.819^*). In the 2019 season, at the untreated plots, a positive correlation with the mean temperature existed for the first date ($r = 0.512$). Positive relationships were found for treated plots of the three dates ($r = 0.482$, 0.033 and 0.591, respectively) (tables 4 and 5).

Flowers infestation by E. insulana

During the 2018 season, infestation of flowers started on 25 June with a low percentage of 2.0% in the first and second planting dates of the untreated plots and 4.0 and 2.0% at the treated plots. However, infestation started on 11 July in the third sowing date with 6.0% of infestation in treated and untreated plots. Infestation percentage increased gradually to reach maxima of 64.0 and 56.0% in the first and second sown dates on 1 August in untreated plots with a mean temperature of 32°C, 56.5% RH and 3243.89 DD^s. In the third sown date, the maximum infestation reached 30% on 15 August with a mean temperature of 30°C, 56.1% RH and 3550.81 DD^s. In the treated plots, infestation averaged 3.7% in the third sown date as opposed to 11.34 and 7.0% in the first and second sowing dates, respectively. In addition, insecticide treatment greatly affected the spiny bollworm infestation as infestation was lower in the treated than in the untreated plots by 85.70, 76.14 and 75.03% in the three planting dates of the 2018 season and by 91.00, 86.23 and 81.44%, in the 2019 season, respectively (tables 2 and 3).

During the 2018 cotton season, there was a significant positive correlation between mean temperature and flower infestation ($r = 0.827^*$). Whereas, positive correlations were only observed in the second sowing date ($r = 0.168$) of treated plots. During the 2019 cotton season, an insignificant negative correlation was found between temperature and spiny bollworm infestation of cotton flowers in both untreated and treated plots, whereas an insignificant positive correlation with % RH was obtained in the first sown dates ($r = 0.344$ and 0.181) of both untreated and treated plots (tables 4 and 5).

Bolls infestation by E. insulana

The reduction in infestation percentages of green cotton bolls by *E. insulana* is shown in table 2. Infestation started at an average of 4.0–10.0% in all experiment plots and increased to its maximum of 98.0% on 29 August in the first and second sowing dates and 88.0% in the third date of untreated plots with a temperature of 29.6°C and 55.6% RH. Generally, the majority of bolls in untreated plots were infested at the end of the two seasons. The differences in the means of infestation average were significant; 67.4, 68.4 and 55.8% in untreated plots of the three sowing dates as opposed to 18.6, 16.4 and 8.44% after insecticide treatment in the 2018 season. Accordingly, a high reduction in the infestation of green bolls reached 83.44, 76.02 and 84.87%, respectively, in the first, second and third sown dates after treatment with profenofos, lambda-cyhalothrin and methomyl insecticides, during the 2018 season. Data tabulated in table 3 show the infestation averaged 40.6, 60.4 and 44.88% at untreated

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Table 2. Infestation by *E. insulana* under recommended insecticide programme at three cotton planting dates (2018 cotton season)

	Infestation percentage					
	Control plots			Insecticide-treated plots		
Inspections date	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date
Squares						
25/6	2.00	4.00	0.00	2.00	4.00	0.00
2/7	14.00	18.00	0.00	8.00	14.00	0.00
11/7	20.00	30.00	8.00	10.00	2.00	10.00
18/7	30.00	36.00	12.00	4.00	8.00	2.00
25/7	34.00	42.00	8.00	6.00	2.00	2.00
1/8	44.00	32.00	10.00	10.00	10.00	2.00
8/8	0.00	0.00	14.00	0.00	0.00	4.00
15/8	0.00	0.00	24.00	0.00	0.00	0.00
Mean ± SE	$24^{a} \pm 0.58$	$27^{a} \pm 4.04$	$12.7^{b} \pm 1.73$	$6.7^{a} \pm 1.70$	$6.7^{a} \pm 0.61$	$4.0^{a} \pm 1.15$
Reduction of infestation (%)				72.25	75.33	79.96
T-value between control and treatment of each planting date				150.76**	14.19**	70.45**
F^2, *x*-value	71.99***			3.56^{ns}		
Pr > *F*	≤0.0001			0.096		
LSD	3.18			2.83		
Flowers						
25/6	2.00	2.00	0.00	4.00	2.00	0.00
2/7	24.00	22.00	0.00	14.00	16.00	0.00
11/7	40.00	28.00	6.00	26.00	4.00	6.00
18/7	50.00	30.00	2.00	10.00	10.00	2.00
25/7	58.00	38.00	12.00	6.00	4.00	4.00
1/8	64.00	56.00	18.00	8.00	6.00	2.00
8/8	0.00	0.00	20.00	0.00	0.00	4.00
15/8	0.00	0.00	30.00	0.00	0.00	4.00
Mean ± SE	$39.7^{a} \pm 0.79$	$29.3^{b} \pm 0.35$	$14.7^{c} \pm 0.63$	$11.34^{a} \pm 1.60$	$7.0^{b} \pm 0.87$	$3.7^{b} \pm 0.38$
Reduction of infestation (%)				85.70	76.14	75.03
T-value between control and treatment of each planting date				10.77**	12.87**	4.76**
F^2, *x*-value	118.29***			12.74**		
Pr > *F*	≤0.0001			0.0069		
LSD	3.99			3.88		
Bolls						
25/6	6.00	8.00	0.00	10.00	8.00	0.00
2/7	30.00	28.00	0.00	14.00	14.00	0.00
11/7	40.00	52.00	4.00	28.00	10.00	4.00
18/7	74.00	70.00	4.00	14.00	14.00	2.00
25/7	78.00	80.00	36.00	12.00	8.00	6.00
1/8	80.00	82.00	38.00	30.00	16.00	2.00
8/8	88.00	86.00	78.00	12.00	18.00	24.00
15/8	88.00	90.00	80.00	18.00	20.00	8.00
22/8	92.00	90.00	84.00	22.00	26.00	10.00

(*Continued*)

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Table 2. (*Continued.*)

	Infestation percentage					
	Control plots			Insecticide-treated plots		
Inspections date	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date
29/8	98.00	98.00	88.00	26.00	30.00	8.00
5/9	0.00	0.00	90.00	0.00	0.00	12.00
Mean ± SE	$67.4^{a} \pm 0.90$	$68.4^{a} \pm 0.99$	$55.8^{b} \pm 0.44$	$18.6^{a} \pm 0.59$	$16.4^{a} \pm 0.46$	$8.44^{b} \pm 0.45$
Reduction of infestation (%)				83.44	76.02	84.87
T-value between control and treatment of each planting date				13.31**	15.01**	16.41**
F^2, *x*-value	17.99**			9.52**		
Pr > *F*	0.0029			0.0137		
LSD	5.65			5.99		

***Highly significant (≤0.0001); **highly significant (≤0.001); *significant (≤0.05); NS, not significant.
In a vertical column means followed with the same small letter(s) are not significantly different ($P = 0.05$).

plots as opposed to 12, 14 and 7.34% in treated plots, respectively, in the first, second and third sown dates. While, the infestation reduction percentages of *E. insulana* were 85.29, 85.43 and 89.10%, respectively, in the first, second and third sowing dates after insecticide application.

Comparisons of *E. insulana* infestation of cotton squares, flowers and bolls in three planting dates for the 2018 and 2019 seasons using *T*-sample test are shown in tables 2 and 3. There were significant differences between the means of treatments and control in most of the means treatment or control inspection plots.

The correlation between spiny bollworm cotton bolls infestation, mean temperature and % RH is shown in tables 4 and 5. During the 2018 cotton season, an insignificant positive correlation with mean temperature ($r = 0.623$, 0.626 and 0.603), respectively, was observed in the first, second and third sown dates of untreated plots. During the 2019 cotton season, an insignificant positive correlation was found between temperature and spiny bollworm infestation of cotton bolls in the first sown date of untreated plot ($r = 0.019$), whereas an insignificant positive correlation with humidity was found in the second and third sown dates of untreated plots ($r = 0.045$ and 0.180).

Multiple regression

Multiple regression was used to check the impact of weather factors (mean temperature and % RH) on *E. insulana* infestation (table 6). The effects of these factors were insignificant during the 2 years of the study in both treated and control plots. The percentages of explained variance of the two factors were high reaching 83.88% in *E. insulana* infestations and were affected by mean temperature and RH in control plots in the first sown date during the 2018 cotton growing season; reaching 83.60% in the treated plots of squares infested by *E. insulana* in the third sown date during 2019, during the first sown date of the 2019 season.

Associated predators

The common natural enemies of *E. insulana* are found on cotton plants, i.e., *C. carnea*, *C. undecimpunctata* and spiders; *T. albini* (family: Philodromidae), *Thomisus sp.* (family: Thomisidae) and *V. walckenaerius* (family: Uloboridae). The populations of these predators were counted during the two seasons of 2018 and 2019 (tables 7 and 8). The survey was performed in both treated and untreated plots. The treated area had approximately the same numbers of predators and the natural enemies were not affected by the application of insecticides. The survey of predators per 50 plants started on 3 May and continued until 13 August in the 2018 season. While the survey started one month earlier in 2019 and continue for two weeks (from 3 April until 28 August) in the 2019 season.

In the 2018 season, the maximum number of *C. carnea* reached 113 individuals in the first sown plots, and 118 in the second sown plots, on 25 June with a mean temperature of 29° C and 52.5% RH. It reached 89 individuals on 30 May with 27.5°C and 55.5% RH in the third sown date. The recorded mean number of *C. carnea* decreased gradually with increasing the mean temperature, moreover zero numbers of *C. carnea* were recorded on 13 August with a mean temperature of 31°C in the earlier two dates (first and second dates). There are no records of *C. carnea* in the third sown date (on 25 July) when the mean temperature reached 33.5°C. During the 2019 season, the highest numbers of *C. carnea* (77, 51 and 64 individuals) were counted on 21 May at the two earlier dates and on 11 June at the third planting date. Also, the number of predators decreased gradually until it disappeared on 24 July and 14 August with mean temperatures of 30.5 and 32°C and RH of 53.5 and 44%, respectively. Insignificantly, a positive correlation was observed ($r = 0.381$, 0.120 and 0.106) at the first, second and third sown dates. There was a significant positive correlation between the *C. carnea* and *E. insulana* populations at the three planting dates during the 2019 season.

Data in tables 7 and 8 show that the numbers of *C. undecimpunctata* were less than those recorded for *C. carnea*. The highest numbers of *C. undecimpunctata* in 2018 (42, 43 and 51 individuals) were recorded on 25 June for the first and third sown dates and on 18 July for the second sown date. The corresponding mean temperatures were 29 and 31.5°C and the RH were 52.4 and 57.1%. This predator was not observed on 18 July and 1 August on the aforementioned sowing dates with mean temperatures of 31.5 and 32°C and RH of 57.1 and 56.5%. In the 2019 season, the highest numbers of *C. undecimpunctata* (40, 37 and 55

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Table 3. Infestation by *E. insulana* under recommended insecticide programme at three cotton planting dates (2019 cotton season)

	Infestation percentage					
	Control plots			Insecticide-treated plots		
Inspection date	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date
Squares						
24/6	6.00	4.00	0.00	6.00	6.00	0.00
1/7	12.00	16.00	4.00	6.00	10.00	6.00
8/7	20.00	20.00	6.00	4.00	4.00	6.00
15/7	24.00	30.00	10.00	6.00	6.00	2.00
24/7	28.00	40.00	14.00	2.00	10.00	4.00
29/7	34.00	48.00	16.00	6.00	4.00	2.00
7/8	0.00	0.00	26.00	0.00	0.00	4.00
Mean ± SE	$20.66^{a} \pm 1.40$	$26.34^{a} \pm 1.22$	$12.66^{b} \pm 1.35$	$5.0^{b} \pm 0.76$	$6.7^{a} \pm 0.62$	$4.0^{b} \pm 2.03$
Reduction of infestation (%)				75.80	83.14	78.94
T-value between control and treatment of each planting date				5.30*	33.60**	3.65^{ns}
F^2, *x*-value	16.26**			1.46^{ns}		
Pr > *F*	0.00.38			0.304		
Flowers						
24/6	2.00	4.00	0.00	6.00	8.00	0.00
1/7	10.00	10.00	6.00	8.00	10.00	6.00
8/7	32.00	16.00	8.00	4.00	2.00	4.00
15/7	34.00	30.00	18.00	12.00	8.00	2.00
22/7	34.00	45.00	22.00	4.00	10.00	4.00
29/7	36.00	54.00	22.00	6.00	6.00	4.00
7/8	0.00	0.00	24.00	0.00	0.00	2.00
14/8	0.00	0.00	30.00	0.00	0.00	2.00
Mean ± SE	$24.66^{a} \pm 1.04$	$26.66^{a} \pm 1.17$	$18.0^{b} \pm 0.81$	$6.66^{a} \pm 0.39$	$7.34^{a} \pm 0.55$	$3.34^{b} \pm 1.27$
Reduction of infestation (%)				91.00	86.23	81.44
T-value between control and treatment of each planting date				30.25**	14.72*	5.60*
F^2, *x*-value	7.42*			7.01*		
Pr > *F*	0.024			0.027		
Bolls						
24/6	2.00	4.00	0.00	8.00	6.00	0.00
1/7	20.00	30.00	4.00	10.00	8.00	6.00
8/7	26.00	52.00	6.00	2.00	2.00	4.00
15/7	34.00	56.00	30.00	10.00	19.00	2.00
24/7	38.00	60.00	46.00	12.00	12.00	14.00
29/7	42.00	68.00	50.00	16.00	22.00	10.00
7/8	50.00	76.00	56.00	14.00	10.00	8.00
14/8	60.00	78.00	64.00	12.00	16.00	8.00
21/8	64.00	86.00	72.00	18.00	22.00	4.00
28/8	70.00	94.00	76.00	18.00	24.00	10.00
Mean ± SE	$40.8^{c} \pm 0.64$	$60.4^{a} \pm 0.69$	$44.88^{b} \pm 1.01$	$12.0^{a} \pm 1.15$	$14.0^{a} \pm 2.31$	$7.34^{b} \pm 0.54$
Reduction of infestation (%)				85.29	85.43	89.10

(*Continued*)

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Table 3. (*Continued.*)

	Infestation percentage					
	Control plots			Insecticide-treated plots		
Inspection date	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date
T-value between control and treatment of each planting date				16.13**	26.56**	10.72**
F^2, *x*-value	14.92**			9.38*		
Pr > *F*	0.0047			0.014		

**Highly significant (≤0.001); *significant (≤0.05); NS, not significant.
In a vertical column means followed with the same small letter(s) are not significantly different (*P* = 0.05).

Table 4. Correlation coefficient (*R*) between *E. insulana* infestation in cotton sowing at three different dates and mean temperature and relative humidity (% RH) through 2018 seasons

	Correlation coefficient (*R*)					
	Insecticide-treated plots			Untreated plots		
Parameters	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date
Squares						
Mean temp.	0.829*	0.819*	−0.438^{ns}	0.038^{ns}	−0.288^{ns}	−0.757^{ns}
% RH	−0.021^{ns}	−0.083^{ns}	0.324^{ns}	0.257^{ns}	0.314^{ns}	0.346^{ns}
Flowers						
Mean temp.	0.827*	0.671^{ns}	−0.153^{ns}	−0.412^{ns}	−0.476^{ns}	−0.512^{ns}
% RH	−0.031^{ns}	0.009^{ns}	0.091^{ns}	−0.048^{ns}	0.168^{ns}	−0.051^{ns}
Bolls						
Mean temp.	0.623^{ns}	0.626^{ns}	0.603^{ns}	−0.042^{ns}	−0.140^{ns}	−0.140^{ns}
% RH	0.251^{ns}	0.237^{ns}	0.361^{ns}	0.442^{ns}	0.540^{ns}	−0.610^{ns}

Table 5. Correlation coefficient (*R*) between *E. insulana* infestation in cotton sowing at three different dates and mean temperature and relative humidity (% RH) through 2019 seasons

	Correlation coefficient (*R*)					
	Untreated plots			Insecticide-treated plots		
Parameters	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date
Squares						
Mean temp.	0.512^{ns}	−0.449^{ns}	−0.381^{ns}	0.482^{ns}	0.033^{ns}	0.591^{ns}
% RH	0.154^{ns}	0.970^{ns}	−0.071^{ns}	−0.551^{ns}	0.212^{ns}	−0.572^{ns}
Flowers						
Mean temp.	−0.602^{ns}	−0.523^{ns}	−0.573^{ns}	−0.122^{ns}	−0.059^{ns}	0.220^{ns}
% RH	0.344^{ns}	−0.023^{ns}	0.087^{ns}	0.181^{ns}	−0.312^{ns}	−0.638^{ns}
Bolls						
Mean temp.	0.019^{ns}	−0.029^{ns}	−0.292^{ns}	−0.161^{ns}	−0.022^{ns}	−0.433^{ns}
% RH	−0.322^{ns}	0.045^{ns}	0.180^{ns}	−0.059^{ns}	−0.160^{ns}	−0.051^{ns}

individuals) were recorded on 21 May in the first and second sown dates and on 8 May in the third date. The related means of temperature were 30.5 and 21.5°C while the RH were 44.5 and 53.5%, respectively. The mean numbers of *C. undecimpunctata* were 23.43 and 21.89 individuals during the 2018 season, whereas 24.12 and 25.86 individuals during the 2019 season.

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Table 6. Multiple regressions between *E. insulana* infestation in cotton sowing at three different dates and weather factors (mean temperature and relative humidity %) through 2018 and 2019 seasons

Infestation weather factors				2018 season			2019 season		
				Partial regression	Explained variance %	*P*	Partial regression	Explained variance %	*P*
1st Date	Squares	T	Tem.	0.33^{ns}	10.50	0.847^{ns}	−0.34^{ns}	55.20	0.300^{ns}
			RH	0.21^{ns}			2.38^{ns}		
		C	Tem.	7.84*	83.88	0.065^{ns}	0.88^{ns}	30.20	0.583^{ns}
			RH	1.15^{ns}			−14.30^{ns}		
	Flowers	T	Tem.	−0.94^{ns}	27.30	0.620^{ns}	−0.24^{ns}	6.30	0.907^{ns}
			RH	0.53^{ns}			−0.76^{ns}		
		C	Tem.	8.18*	65.50	0.204^{ns}	2.46^{ns}	57.40	0.278^{ns}
			RH	1.39^{ns}			−25.37^{ns}		
	Bolls	T	Tem.	0.69^{ns}	20.77	0.443^{ns}	−0.59^{ns}	0.70	0.976^{ns}
			RH	0.53^{ns}			−1.74^{ns}		
		C	Tem.	14.72*	50.55	0.085^{ns}	−0.41^{ns}	8.70	0.727^{ns}
			RH	3.17^{ns}			−2.76^{ns}		
2nd Date	Squares	T	Tem.	−0.45*	12.55	0.818^{ns}	0.20^{ns}	4.30	0.936^{ns}
			RH	0.20^{ns}			0.32^{ns}		
		C	Tem.	6.45^{ns}	71.20	0.154^{ns}	0.97^{ns}	23.20	0.673^{ns}
			RH	0.056^{ns}			−20.25^{ns}		
	Flowers	T	Tem.	0.71^{ns}	8.89	0.869^{ns}	0.33^{ns}	9.30	0.863^{ns}
			RH	0.05^{ns}			−0.23^{ns}		
		C	Tem.	8.18^{ns}	65.30	0.204^{ns}	0.28^{ns}	26.30	0.632^{ns}
			RH	1.39^{ns}			−27.39^{ns}		
	Bolls	T	Tem.	0.17^{ns}	29.77	0.289^{ns}	−0.56^{ns}	0.85	0.971^{ns}
			RH	0.82^{ns}			−2.53^{ns}		
		C	Tem.	14.17*	50.40	0.086^{ns}	−0.22^{ns}	4.90	0.840^{ns}
			RH	3.03^{ns}			−4.37^{ns}		
3rd Date	Squares	T	Tem.	−3.59*	79.50	0.025	−2.12^{ns}	83.60	0.067^{ns}
			RH	0.43*			1.51^{ns}		
		C	Tem.	1.54*	60.10	0.399^{ns}	−0.34*	53.10	0.321^{ns}
			RH	0.48^{ns}			−0.44*		
	Flowers	T	Tem.	−1.35^{ns}	72.50	0.144^{ns}	−0.10^{ns}	77.80	1.104^{ns}
			RH	−0.26^{ns}			−0.44*		
		C	Tem.	−1.64^{ns}	3.00	0.955^{ns}	−1.62^{ns}	55.60	0.297^{ns}
			RH	−0.15^{ns}			2.11^{ns}		
	Bolls	T	Tem.	0.34^{ns}	6.40	0.820^{ns}	−0.10^{ns}	10.70	0.431^{ns}
			RH	0.38^{ns}			−1.16^{ns}		
		C	Tem.	−7.63^{ns}	9.10	0.751^{ns}	0.88^{ns}	24.50	0.711^{ns}
			RH	0.27^{ns}			−4.56^{ns}		

On the other hand, there was a positive correlation between *C. undecimpunctata* population and % RH through the first, second and third planted dates of season 2018 ($r = 0.093$, 0.555 and 0.031, respectively).

As for the spiders, they were observed on 12 May and 17 April of the 2018 and 2019 seasons, respectively. The predator populations started with low numbers at the three sowing dates and increased gradually over the following months and reaching 29,

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Table 7. Predators' population on cotton plants sowing at three different dates in relation to mean temperature and relative humidity (% RH) through 2018 season

			Chrysoperla carnea			*Coccinella undecimpunctata*			Spiders		
Date	Mean temperature	% RH	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date
3/5	31.5	39.5	0	1	4	19	6	22	0	0	0
12/5	24.5	56.5	6	4	27	15	13	26	7	5	6
21/5	33	30	31	48	56	23	18	37	7	7	6
30/5	27.5	55.5	50	47	89	31	21	40	9	8	6
13/6	29.5	68.5	77	98	81	33	27	43	7	6	5
25/6	29	52.4	113	118	10	42	29	51	7	8	6
11/7	29.5	57.5	100	87	5	1	38	2	12	11	8
18/7	31.5	57.1	51	48	1	0	43	0	16	16	11
25/7	33.5	42.5	37	26	0	0	2	0	19	16	16
1/8	32	56.5	17	11	0	0	0	0	24	19	20
8/8	31	58.7	5	5	0	0	0	0	28	21	26
13/8	31	57.1	0	0	0	0	0	0	29	23	33
Total	363.5	631.8	487	493	273	164	197	221	165	145	143
Mean	30.29	52.65	48.7^{a}	44.82^{a}	34.12^{b}	23.43^{b}	21.89^{b}	31.57^{a}	15^{a}	12.08^{a}	13^{a}
Correlation (*r*) with mean temperature			-0.076^{ns}	-0.119^{ns}	-0.166^{ns}	0.033^{ns}	-0.128^{ns}	0.004^{ns}	0.505^{ns}	0.593^{ns}	0.478^{ns}
Correlation (*r*) with % relative humidity			0.188^{ns}	0.277^{ns}	0.162^{ns}	0.093^{ns}	0.555^{ns}	0.031^{ns}	0.153^{ns}	0.115^{ns}	0.123^{ns}
Correlation (*r*) with *E. insulana* infestation (control)			−0.782*	−0.829*	-0.696^{ns}	-0.716^{ns}	-0.598^{ns}	-0.520^{ns}	0.737^{ns}	0.717^{ns}	0.991***

Table 8. Predators' population on cotton plants sowing at three different dates in relation to mean temperature and relative humidity (% RH) through 2019 season.

			Chrysoperla carnea			*Coccinella undecimpunctata*			Spiders		
Date	Mean temperature	% RH	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date	1st Date	2nd Date	3rd Date
3/4	19.5	36	2	4	0	18	25	0	0	0	0
17/4	19	55	25	17	24	19	31	44	7	5	3
8/5	21.5	53.5	38	27	31	37	34	55	15	12	5
21/5	30.5	44.5	77	51	53	40	37	53	16	12	8
11/6	32	49	70	46	64	38	31	39	16	16	13
26/6	30.5	45	44	11	16	27	14	16	20	20	14
10/7	31	52.29	27	5	11	11	9	5	28	25	16
17/7	35	54.6	12	1	7	3	0	1	37	25	19
24/7	30.5	52.5	0	0	5	0	0	0	39	33	23
7/8	29.5	54	0	0	2	0	0	0	41	37	26
14/8	32	44	0	0	0	0	0	0	43	40	28
28/8	30.5	53.5	0	0	0	0	0	0	47	44	31
Mean	28.46	49.49	36.87^{a}	20.25^{b}	23.67^{b}	24.12^{b}	25.86^{b}	30.43^{a}	28.09^{a}	24.45^{b}	16.91^{c}
Correlation (*r*) with mean temperature			0.381^{ns}	0.120^{ns}	0.106^{ns}	-0.120^{ns}	-0.330^{ns}	-0.635^{ns}	0.600^{ns}	0.560^{ns}	0.625*
Correlation (*r*) with % relative humidity			0.0005^{ns}	-0.042^{ns}	-0.529^{ns}	-0.189^{ns}	0.049^{ns}	-0.166^{ns}	0.108^{ns}	0.0009^{ns}	-0.005^{ns}
Correlation (*r*) with *E. insulana* infestation			−0.950*	−0.972*	−0.978*	-0.544^{ns}	-0.544^{ns}	-0.770^{ns}	0.882**	0.887**	0.911*

23 and 33 individuals on 13 August at the first, second and third planted dates at the end of the 2018 season and 47, 44 and 31 individuals on 28 August at the end of season 2019. They differed significantly between each other (28.09, 24.45 and 16.91 individuals) in season 2019. In addition, there was an insignificant positive correlation between the spider population and the mean temperature and % RH ($r = 0.505$, 0.593 and 0.478; $r = 0.153$, 0.115 and 0.123) of all experiment plots at the three planting dates of the two seasons and a high positive correlation between the spider population and the *E. insulana* population ($r = 0.991^{***}$) in the third planted date during the 2018 season. During the 2019 season, there was an insignificant positive correlation between spiders and % RH at the first and second planting dates ($r = 0.108$ and 0.0009). In addition, there was a positive significant correlation between the spider population and the *E. insulana* population at the three planting dates.

Discussion

The effect of recommended insecticides application against the spiny bollworm in this study was similar to that observed by Ansari and Kumar (1988), Saad *et al.* (2015) and Ismail (2019). The use of chlorpyrifos and lambda-cyhalothrin insecticides resulted in a high reduction in the *E. insulana* population. In our present study, we observed lower levels of infestation of spiny bollworm after the application of insecticides.

In all experimental plots of cotton bolls infested with spiny bollworm, the third sowing date had significantly lower infestation than the two earlier dates during both seasons of study. This different result for the third sowing may be due to the different times of plantation as the climatic factors varied slightly. Similar results were obtained by Terry *et al.* (1991) who stated that planting dates indicated a little effect on early season infestations of pink bollworm. Moreover, Yogesh and Preeti (2020) reported that climatic factors play an important role in the fluctuations of spiny bollworm population. They found that mild rainfall with mild to high temperature (26–34°C) and high humidity (>60%) was congenial for the multiplication of the pest population. Patel (2020) found that the multiple coefficient value between the pink bollworm population and the variables indicated that 89.90% of the changes in the pink bollworm population were affected by the temperature and RH.

In both seasons, a significant positive correlation ($r = 0.829^{*}$ and 0.827^{*}), respectively, was found between the extent of *E. insulana* infestation and the average temperature in the case of squares and flowers in the first planting of untreated plots in the 2018 season. On the contrary, an insignificant correlation between infestation and temperature or % RH was observed in all the remaining experimental plots in the two seasons (tables 4 and 5). Many authors have produced different results, including Dhaka and Pareek (2008) and Dubey (2010) who recorded a significant negative correlation between temperature and spiny bollworm population. However, Nadaf and Goud (2007) found insignificant and significant positive relationships. These results also agreed with those of Hassanein *et al.* (1995), El-Zanan and Watson (1998) and Somaa (2016). Moreover, Bhatti *et al.* (2007) found that maximum infestation of *E insulana* on green bolls (16.76%) at 28.61°C, and 48.17% RH the populations were affected by the slight increase in temperature and humidity during the period of insect activity.

The present results revealed that *C. carnea* and *C. undecimpunctata* were present in high numbers during June and July and were not observed in cotton at the end of the season. On the contrary, the true spider population was found in low number during June and July and increased as the season progressed. Similar results were found by Burleigh *et al.* (1973) who mentioned that as the season progressed, the level of beneficial organisms declined and their efficacy decreased during the hot months. Also, Abdelrahman and Sanaa (2010) found that natural predators at the end of the cotton season were not observed in the cotton fields, and that the population of associated predators during the period of spiny bollworm activity was considerably influenced by the changes in the mean temperature. However, the present results disagree with those reported by Nadeem *et al.* (2011) who suggested that the overall numbers of *C. carnea* eggs, larvae and pupae were relatively high in the months of August and September, and lowest in the months of June and July.

The present results revealed that there was a significant negative correlation between the *C. carnea* and *E. insulana* population in the first and second planting dates ($r = -0.0782^{*}$ and -0.829^{*}), respectively, and a significant positive correlation between spiders and *E. insulana* population in the third planting date ($r = 0.991^{***}$) during season 2018. While there was a significant negative correlation between *C. carnea* and *E. insulana* population in the three planting dates and a highly significant positive correlation between spiders and *E. insulana* population in the three planting dates during season 2019. In this respect, similar results were obtained by Somaa (2016) and Mesbah *et al.* (2008) who found significant correlation between predators and spiny bollworm population. Also, Gosalwad *et al.* (2009) found a positive correlation between the decrease in spotted bollworm population and those of predators.

Conclusion

The results of explained variance of multiple regression analysis indicated that the effects of mean temperature and RH on the third sown dates had the least infestation of squares, flowers and green bolls by spiny bollworm compared to the first and second sown plots, although the effects were not significant. After spraying the plants in the three plantation dates with profenofos, lambda-cyhalothrin and methomyl insecticides, infestation of cotton bolls by spiny bollworm was more insignificantly reduced in treated than in untreated plots. The results of predators' population revealed that *C. carnea* and *C. undecimpunctata* were present in high numbers during June and July but were not observed at the end of the season. On the contrary, the true spider population was found in low number during June and July and increased in number when the season progressed.

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