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Influence of some insecticide sequences on the injurious insect- pests of cotton plants

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Abstract

Background: Cotton growers in Egypt have experienced severe economic loss from cotton bollworms, especially the pink bollworm, *Pectinophora gossypiella* (Saund.), and spiny bollworm, *Earias insulana* (Boisd.), so a field experiment was carried out to determine efficiency of eight insecticides in their seven sequence programs to evaluate the best solution for cotton bollworms problems, during two successive seasons.

Results: The highest reduction percentages are effective sequences 7 and 5 (gave about 90% infestation reduction) were started and mediated with new insecticides, and when started and mediated with spinosad, or with cypermethrin, sequences 2 and 3 (gave about 86%) respectively, also, the repetition of the same insecticide twice in a regimen might increase, might decrease, or has no effect on the insecticide efficiency against cotton bollworms. The tested sequence programs showed high protection for green bolls with protection percentages ranged from 66.1 and 67.2% (sequence 1) to 92.6 and 94.1% (sequence 7) during two seasons respectively. On the other hand, the superiority in yield loss reduction can arrange in the following descending order: sequences 7, 5, 2, 3, 6, 4, and 1 respectively.

Conclusions: From this study, it can be concluded that the importance of sequence insecticide programs included new groups of insecticides to directing tactics to fight against resistance development and used this sequence programs to restore susceptibility for conventional insecticides. This study devoted to obtaining the optimum regimen of insecticides that give low reduction of cotton bollworms' infestation and high cotton yield.

Keywords: Cotton bollworms, *Pectinophora gossypiella*, *Earias insulana*, Pesticide sequence programs

Background

Cotton growers in Egypt have experienced severe economic loss from cotton bollworms, especially the pink bollworm, *Pectinophora gossypiella* (Saund.), and spiny bollworm, *Earias insulana* (Boisd.), which spend most of their life cycles inside the bolls and are considered to be a great menace because they can destroy the plants in a few days. Bollworms mainly feed on fruiting parts of cotton, resulting in considerable losses both in quality and quantity and 20–60% damage to and a decrease in the market value of fiber. The larvae of *E. insulana* attack soft and growing tissues, especially terminal bud of the main stem, flower buds, and bolls, which ultimately shed. Therefore, plant protection has now become a necessity of the most important components of a profitable farming system to overcome the losses, keep the level of the infestation under the economic threshold, and to obtain the good yield (Amin and Gergis 2006). Control of these pests have depended exclusively on conventional insecticides which have an important role in management programs to control cotton bollworms; as a result, occurred high level of resistance to these insecticides in cotton bollworms and other pests of cotton (Ramsubramanian 2004) have resulted in renewed interest in the farmers for using new group of insecticides available in the Egyptian markets (Gunning and Devonshire 2002). In order for the cotton bollworms control program to be successful, it has to rely on the use of insecticides belonging to different groups in certain sequences, application time, and spraying interval (Abd El-Mageed et al. 2007).

Newer chemistries of pesticides have raised the hopes for better management of destructive pest in many areas. Therefore, an attempt was made to study the evaluation

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of programs consisting of seven different insecticide sequences, including new groups of insecticides for the control of cotton bollworms (pink and spiny bollworms) in cotton crop, and the aim of our study was concentrated on obtaining the optimum regimen of insecticides which gives a reduction of the infestation with cotton bollworms, and an increase of the cotton yield.

Materials and methods

Chemicals

The evaluated insecticides, common names, and rates are introduced in Table 1.

Field trials

The experiments were conducted during the cotton growing seasons 2017 and 2018 in El-Beheira Governorate at Kafr El-Dawar district. The tested insecticides are listed in Table 1. The evaluated insecticides were used in seven sequences as follows: sequence no. (1) of profenofos, profenofos, cypermethrin, and cypermethrin; sequence no. (2) spinosad, profenofos, spinosad, and carbosulfan; sequence no. (3) of cypermethrin, profenofos, cypermethrin, and carbosulfan; sequence no. (4) carbosulfan, carbosulfan, cypermethrin, and cypermethrin; sequence no. (5) acetamiprid, cypermethrin, chlorfenapyr, and profenofos; sequence no. (6) of profenofos, spinosad, cypermethrin, and carbosulfan; and sequence no. (7) of cypermethrin, emmamectin benzoate, indoxacarb, and profenofos. The fields were cultivated with cotton variety "Giza 70"; the average percent infestation in all experimental field plots was monitored till that reached 7% at zero time of application. The experimental area was 2.5 feddans, and it was divided into plots of 2 Kirrats each, and the treatments were arranged in complete random plots with four replicates which were sprayed four times (every 2 weeks) using a ground motor sprayer at the rate of 400 liter per feddan.

Table 1 Recommended and used doses of the tested insecticides

Pesticides	Group	Rate of application (feddan)
Acetamiprid 20% SP (Acetamor®)	Neonicotinoids	100 g
Chlorfenapyr 24% EC (Pyricide®)	Halogenated pyrroles	300 cm^3
Spinosad 24% SC (Spintor®)	Bio-insecticides	50 cm^3
Emmamectin benzoate 0.5% EC (Radicl®)	Avermectains	800 cm^3
Indoxacarb 30% WG (Abizo®)	Oxadiazine	125 cm^3
Carbosulfan 24.7% SC (Marshal®)	Carbamate	600 g
Cypermethrin 20% EC (Cyparko®)	Pyrethroids	300 cm^3
Profenofos 48% EC (Dora®)	O.P.	1 liter

Laboratory examination

For each treatment, we took samples of 100 green bolls per treatment (25 bolls per each replicate) before spraying time and weekly after insecticide application. Percentage of infestation by pink bollworm, *P. gossypiella*, and that of spiny bollworm, *E. insulana*, was determined in the laboratory by dissection of bolls and checking the bolls externally and internally. The percent reduction of pink bollworm or spiny bollworm infestation was calculated according to Henderson and Tilton (1955).

Estimation of cotton yield loss

Randomly, one hundred cotton plants were chosen from each treatment to study the cotton yield loss caused by bollworms. The following method, according to Hassan (2007), was used to estimate the cotton yield losses. The complete opened bolls (*A*), the 2/3 opened bolls (*B*), the 1/3 opened bolls, the dry bolls (*D*), and the unopened green bolls (*E*) were counted; then, the expected open bolls (*F*) were calculated as follows: $F = A + B + C + D + E$

$$\text{The true opened bolls } (G) = A + (B \times 2/3) + (C \times 1/3)$$

$$\text{The number of unopened bolls } (H) = F - G$$

$$\text{The loss\%}(I) = (H/F) \times 100 \, or \, I\% = (1 - G/F) \times 100$$

Statistical analysis

All biological aspects were analyzed using one-way ANOVA by SPSS 13.0 (SPSS, 2004). Tukey's honestly significant difference (HSD) studentized range test was used to determine the probability level to compare the differences among some parameter means ($P < 0.05$).

Results

Efficacy of tested sequences of insecticides against *Pectinophora gossypiella* during two seasons

The elucidated data in Table 2 show the variation between the weekly calculated reduction percentages of the pink bollworm, *P. gossypiella*, during the application of seven suggested sequences of certain compounds. The percentages of infestation reduction of all tested compounds were more in the first week after treatment than that in the second week throughout the four sprays. In general, all the tested sequences resulted in an appreciable reduction in *P. gossypiella* infestation; as compared with control, the infestation reduction percentages were more than 72% during the two seasons. Regarding the second spray, the application of profenofos after cypermethrin caused 88.7 and 86.3%, while after spinosad caused 90.5 and 89.7% reduction of infestation for both seasons 2017 and 2018, respectively. The statistical

Table 2 Infestation reduction percentage of *Pectinophora gossypiella* during two seasons

Treatments	Percentage of infestation reduction												
	First spray			Second spray			Third spray			Fourth spray			General mean
	1st week	2nd week	Mean	1st week	2nd week	Mean	1st week	2nd week	Mean	1st week	2nd week	Mean	
Season 2017													
Sequence 1	Profenofos			Profenofos			Cypermethrin			Cypermethrin			
	78.3	75.0	76.7b	80.0	79.0	79.5b	72.4	70.9	71.7b	70.6	68.5	69.6c	74.4b
Sequence 2	Spinosad			Profenofos			Spinosad			Carbosulfan			
	90.4	85.0	87.7a	92.0	89.0	90.5a	82.9	80.0	81.5a	85.8	83.0	84.4a	86.0a
Sequence 3	Cypermethrin			Profenofos			Cypermethrin			Carbosulfan			
	84.0	81.0	82.5a	91.4	86.0	88.7a	83.6	80.2	81.9a	82.6	78.0	80.3a	83.4a
Sequence 4	Carbosulfan			Carbosulfan			Cypermethrin			Cypermethrin			
	82.9	77.1	80.0a	70.3	66.3	68.3c	77.4	71.0	74.2b	81.0	76.2	78.6b	75.3b
Sequence 5	Acetamiprid			Cypermethrin			Chlorfenapyr			Profenofos			
	93.2	92.0	92.6a	82.6	80.4	81.5a	90.2	87.0	88.6a	93.3	89.0	91.2a	88.5a
Sequence 6	Profenofos			Spinosad			Cypermethrin			Carbosulfan			
	88.1	84.4	86.3a	84.3	82.6	83.5a	81.5	79.1	80.3a	76.7	75.7	76.2b	81.6a
Sequence 7	Cypermethrin			Emmamectin benzoate			Indoxacarb			Profenofos			
	93.0	89.7	91.4a	96.4	95.0	95.7a	94.5	93.2	93.9a	93.7	91.2	92.5a	93.4a
Season 2018													
Sequence 1	Profenofos			Profenofos			Cypermethrin			Cypermethrin			
	81.8	79.2	80.5a	77.7	68.3	73.0b	71.5	68.5	70.0b	67.1	64.8	66.0c	72.4b
Sequence 2	Spinosad			Profenofos			Spinosad			Carbosulfan			
	93.0	90.7	91.9a	90.9	88.5	89.7a	81.6	79.0	80.3a	87.7	84.3	86.0a	87.0a
Sequence 3	Cypermethrin			Profenofos			Cypermethrin			Carbosulfan			
	91.8	77.9	84.9a	88.5	84.0	86.3a	78.3	71.1	74.7b	80.7	77.0	78.9b	81.2a
Sequence 4	Carbosulfan			Carbosulfan			Cypermethrin			Cypermethrin			
	80.1	78.0	79.1b	65.5	61.0	63.3c	78.0	72.0	75.0b	78.2	75.2	76.7b	73.5b
Sequence 5	Acetamiprid			Cypermethrin			Chlorfenapyr			Profenofos			
	94.0	92.6	93.3a	85.1	81.0	82.1a	91.0	88.3	89.7a	94.4	90.2	92.3a	89.4a
Sequence 6	Profenofos			Spinosad			Cypermethrin			Carbosulfan			
	86.9	82.1	84.5a	81.5	79.1	80.3a	75.8	73.9	74.9b	81.6	78.4	80.0a	80.8a
Sequence 7	Cypermethrin			Emmamectin benzoate			Indoxacarb			Profenofos			
	93.9	90.0	92.0a	97.6	95.4	96.5a	95.9	93.6	94.8a	94.2	92.0	93.1a	94.1a

Means in the same column followed by the same letter are not significant at $P < 0.05$

analysis indicated that the sequence 7 achieved the highest reduction percentages during the 2nd, 3rd, and 4th spray applications, which gave the following reduction percentages of 95.7 and 96.5, 93.9 and 94.8, and 92.5 and 93.1 during the two seasons 2017 and 2018, respectively; in contrast, the sequence 4 achieved low efficacy in the 2nd spray application. Also, the statistical analysis revealed that there were significant differences among tested sequences. Sequence 7 was the best and showed a significant reduction in boll infestation during both seasons 2017 and 2018, followed by sequence 5. The lowest efficacy was obtained from sequence one followed by sequence four during the two seasons.

Efficacy of tested sequences of insecticides against *Earias insulana* during two seasons

The exhibited data in Table 3 show the variation between the weekly calculated reductions of the infestation percentages by the spiny bollworm, *Earias insulana*, when different sequences of compounds were used. Concerning the first spray application during both seasons 2017 and 2018, the sequence 7 (cypermethrin,

Table 3 Infestation reduction percentage of *Earias insulana* during two seasons

Treatments	Percentage of infestation reduction												
	First spray			Second spray			Third spray			Fourth spray			General mean
	1st week	2nd week	Mean	1st week	2nd week	Mean	1st week	2nd week	Mean	1st week	2nd week	Mean	
Season 2017													
Sequence 1	Profenofos			Profenofos			Cypermethrin			Cypermethrin			
	70.2	67.2	68.7c	84.5	79.2	81.9a	78.1	74.4	76.3b	80.7	77.3	79.0b	76.5d
Sequence 2	Spinosad			Profenofos			Spinosad			Carbosulfan			
	87.4	85.1	86.3ab	92.8	88.0	90.4ab	83.3	79.3	81.3a	85.4	82.5	84.0a	85.5b
Sequence 3	Cypermethrin			Profenofos			Cypermethrin			Carbosulfan			
	93.4	88.8	91.1ab	95.9	91.4	93.7ab	86.0	85.0	85.5a	90.0	88.0	89.0a	89.8a
Sequence 4	Carbosulfan			Carbosulfan			Cypermethrin			Cypermethrin			
	82.2	79.6	80.9a	76.9	74.3	75.6c	79.0	77.0	78.0b	77.9	75.8	76.9b	77.9b
Sequence 5	Acetamiprid			Cypermethrin			Chlorfenapyr			Profenofos			
	94.6	92.5	93.6ab	95.0	91.4	93.2ab	91.3	89.2	90.8ab	89.0	85.0	87.0a	91.2ab
Sequence 6	Profenofos			Spinosad			Cypermethrin			Carbosulfan			
	90.2	88.4	89.3a	85.2	83.2	84.2a	83.7	82.3	83.0a	81.1	77.8	79.5b	84.0a
Sequence 7	Cypermethrin			Emmamectin benzoate			Indoxacarb			Profenofos			
	96.0	95.9	96.0ab	96.3	93.0	94.7ab	94.4	92.5	93.5ab	92.8	90.3	91.6ab	94.0ab
Season 2018													
Sequence 1	Profenofos			Profenofos			Cypermethrin			Cypermethrin			
	73.6	68.1	71.4d	84.0	81.4	82.7c	75.8	72.2	74.0d	85.9	82.0	84.0c	78.0d
Sequence 2	Spinosad			Profenofos			Spinosad			Carbosulfan			
	94.7	92.8	93.8a	90.0	86.0	88.0b	84.3	80.2	82.3c	88.9	85.1	87.0 a	87.8b
Sequence 3	Cypermethrin			Profenofos			Cypermethrin			Carbosulfan			
	94.0	90.0	92.4a	91.8	89.3	90.6a	91.7	88.3	90.0a	93.0	90.0	91.5a	91.1a
Sequence 4	Carbosulfan			Carbosulfan			Cypermethrin			Cypermethrin			
	84.6	81.4	83.0a	74.6	72.4	73.5d	86.5	83.4	85.0c	79.2	76.1	77.7d	79.8d
Sequence 5	Acetamiprid			Cypermethrin			Chlorfenapyr			Profenofos			
	96.9	95.0	96.0a	95.5	92.4	94.0a	93.3	92.0	92.7a	91.0	88.6	89.8ab	93.1a
Sequence 6	Profenofos			Spinosad			Cypermethrin			Carbosulfan			
	97.7	95.6	96.7a	82.7	80.8	81.8a	94.9	91.7	93.3a	83.1	81.0	82.1a	88.5b
Sequence 7	Cypermethrin			Emmamectin benzoate			Indoxacarb			Profenofos			
	96.9	95.7	96.3a	96.5	95.2	95.9a	96.0	95.4	95.7a	95.0	93.4	94.2a	95.5a

Means in the same column followed by the same letter are not significant at $P < 0.05$

emmamectin benzoate, indoxacarb, and profenofos) achieved superior efficacy during the 1st, 2nd, 3rd, and 4th spray applications, where it resulted in 96.0, 94.7, 93.5, and 91.6 and 96.3, 95.9, 95.7, and 94.2 throughout the seasons 2017 and 2018, respectively. The results indicated that the repetition of the same insecticide twice in a sequence did not show a clear effect could be increased or decreased, or no effect on the insecticide efficiency. Therefore, the application of profenofos in the 2nd spray after the same treatment in the 1st spray within sequence 1 improved the insecticide efficiency against the *E. insulana*, where the infestation reduction increased from 68.7 to 81.9% during the season 2017 and from 71.4 to 82.7% during the season 2018, respectively. While the repetition of carbosulfan within sequence 4 for 1st and 2nd spray application depress the insecticide efficiency, the infestation reduction decreased from 80.9 to 75.6% and from 83.0 to 73.5% during the two seasons 2017 and 2018, respectively. Moreover, almost no effect of infestation reduction was recorded by cypermethrin repetition of application. According to the statistical analysis of the general mean reduction percentages, the (cypermethrin, emmamectin benzoate, indoxacarb, and profenofos) sequence 7 came first (94.0 and 95.5%) during seasons 2017 and 2018 respectively. No significant difference was recorded between sequence 2 (spinosad, profenofos, spinosad, and carbosulfan) and sequence 6 (profenofos, spinosad, cypermethrin, and carbosulfan); both sequences (2 and 6) came 85.5 and 84.0% and 87.8 and 88.5% during the two seasons 2017 and 2018, respectively.

Efficacy of tested sequences of insecticides against cotton bollworms

To know the effect of different sequences on both bollworms *P. gossypiella* and *E. insulana* together, the infestation reduction of bollworms was calculated and their values are presented in Table 4. The repetition application of profenofos, in the 2nd spray, increased the infestation reduction while the repetition of carbosulfan sequence 4 decreased the infestation reduction during the two seasons. Regarding the general mean, all tested sequences caused the infestation reduction percentages more than 75% throughout the two seasons. However, both sequences 7 and 5 were significantly higher in infestation reduction than that of other sequences. Consequently, the statistical analysis indicated that the sequence 1 had the lowest efficacy. The average of infestation reduction percentages of bollworms was also estimated (Table 5) for the two seasons. The data indicated that the sequence 7 showed a superior reduction in *P. gossypiella* (94.3% infestation reduction) followed by sequence 5 (90.6%). On the other hand, sequences 1 and 4 were the least effective, tested pesticide sequences in this respect. The average of infestation reduction for both *P. gossypiella* and *E. insulana* and the average values for the two seasons 2017 and 2018 are summarized in Table 5 as an infestation reduction of cotton bollworms. Using statistical analysis, the tested different compounds sequences could be grouped in two groups as follows: the first group, which included the sequences that gave more than 83% reduction namely sequences 7,

Table 4 Infestation reduction percentage of cotton bollworms during two seasons

Treatments	Infestation reduction % of four sprays				General mean
	1	2	3	4	
Season 2017					
Sequence 1	Profenofos 72.7b	Profenofos 80.7b	Cypermethrin 74.0b	Cypermethrin 74.3b	75.7c
Sequence 2	Spinosad 87.0a	Profenofos 90.5a	Spinosad 81.4b	Carbosulfan 84.2a	85.8a
Sequence 3	Cypermethrin 86.8a	Profenofos 91.2a	Cypermethrin 83.7a	Carbosulfan 84.7a	86.6a
Sequence 4	Carbosulfan 80.5a	Carbosulfan 72.0c	Cypermethrin 80.0a	Cypermethrin 77.2c	76.7c
Sequence 5	Acetamiprid 93.1a	Cypermethrin 87.4a	Chlorfenapyr 89.7a	Profenofos 89.1a	89.8a
Sequence 6	Profenofos 87.8a	Spinosad 83.9a	Cypermethrin 81.7a	Carbosulfan 77.9c	82.8a
Sequence 7	Cypermethrin 93.7a	Emmamectin benzoate 95.2a	Indoxacarb 93.7a	Profenofos 92.1a	93.7a
Season 2018					
Sequence 1	Profenofos 76.0b	Profenofos 77.9b	Cypermethrin 72.0c	Cypermethrin 75.0c	75.2c
Sequence 2	Spinosad 92.9a	Profenofos 88.9a	Spinosad 81.3ab	Carbosulfan 86.5a	87.4a
Sequence 3	Cypermethrin 88.7a	Profenofos 88.5a	Cypermethrin 82.4ab	Carbosulfan 85.2a	86.2a
Sequence 4	Carbosulfan 81.1ab	Carbosulfan 68.4c	Cypermethrin 80.0a	Cypermethrin 77.2c	76.7c
Sequence 5	Acetamiprid 94.7a	Cypermethrin 88.1a	Chlorfenapyr 91.2a	Profenofos 91.1a	91.3a
Sequence 6	Profenofos 90.6a	Spinosad 81.1ab	Cypermethrin 84.1a	Carbosulfan 81.1ab	84.2a
Sequence 7	Cypermethrin 94.2a	Emmamectin benzoate 96.2a	Indoxacarb 95.3a	Profenofos 93.7a	94.9a

Means in the same column followed by the same letter are not significant at $P < 0.05$

Table 5 Average of infestation reduction percentage for bollworms in two cotton seasons

Treatments	*Pectinophora gossypiella*	*Earias insulana*	Cotton bollworms
Sequences 1	73.7d	78.0b	75.9b
Sequences 2	86.5b	86.7ab	86.6a
Sequences 3	82.3c	90.5a	86.4a
Sequences 4	74.4d	79.0b	76.7b
Sequences 5	89.0a	92.2a	90.6a
Sequences 6	81.2c	86.3ab	83.8b
Sequences 7	93.8a	94.8a	94.3a

Means in the same column followed by the same letter are not significant at $P < 0.05$

5, 2, 6, and 3, and the second group, which included sequence 1 and sequence 4 which gave 75.9 and 76.7% reduction.

Efficiency of tested sequences on cotton yield loss

The presented data in Table 6 show the percentages of protected bolls as a result of compound sequences spray. The highest percent of boll protection was 92.6 and 94.1%; it was obtained by sequence 7 for the two seasons 2017 and 2018, respectively, and the lowest boll protection percent was 66.1 and 67.2 % due to sequence 1 for the two seasons 2017 and 2018, respectively. On the other hand, all the tested sequences could be categorized into the following descending order: sequences 7, 5, 2, 3, 6, 4, and 1.

The results in Tables 7 and 8 show the effect of the applied sequences on the loss of cotton yield. These data pointed to a highly significant difference between the untreated plots and the treated plots, and also, there was a significant difference between some of the applied sequences. In comparison to the untreated plots (loss percent = 44.6 and 42.9%), the lowest estimated percent of yield loss was found with sequence 7 (loss percent = 7.0 and 6.4%), whereas the highest loss percentage was detected for sequence 5 (loss percent = 21.9 and 20.4%). The superiority in yield loss reduction can arrange in the following order: sequences 1, 2, 3, 4, 5, 6, and 7, respectively.

Table 6 Percentages of protected bolls in sequential treatments post-spray in two cotton seasons

Sequences	Total infestation number		General protected bolls %	
	Season 2017	Season 2018	Season 2017	Season 2018
Sequences 1	63	62	66.1	67.2
Sequences 2	31	27	83.6	85.5
Sequences 3	37	35	80.4	81.2
Sequences 4	41	40	78.0	78.8
Sequences 5	26	21	86.2	88.7
Sequences 6	35	32	81.5	82.1
Sequences 7	14	11	92.6	94.1
Control	189	186	–	–

Table 7 Assessment of loss due to bollworms in different sequence treatments during season 2017

Sequences	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I* %
Sequences 1	60.1	4.7	1.4	0.24	2.7	69.1	61.0	8.1	11.7d
Sequences 2	59.7	4.8	3.1	0.28	4.1	72.0	61.1	10.9	15.1c
Sequences 3	62.0	4.3	1.6	0.22	2.6	70.7	64.1	6.6	9.3e
Sequences 4	56.5	9.0	4.4	0.66	8.2	78.8	65.9	12.9	16.4c
Sequences 5	50.8	13.4	7.4	0.70	8.4	80.7	63.0	17.7	21.9b
Sequences 6	59.0	5.7	3.3	0.44	6.6	75.0	63.6	11.4	15.2c
Sequences 7	63.2	4.1	1.7	0.18	2.2	71.4	66.4	5.0	7.0e
Control	29.1	5.2	10.3	15.3	7.3	67.2	37.2	30.0	44.6a

Discussion

In general, the aforementioned results, either in the pink bollworm or in the spiny bollworm, demonstrate that similar effect was obtained when such sequences were applied, according to the average of infestation reduction of both bollworms *P. gossypiella* and *E. insulana* for the two seasons 2017 and 2018. The tested different compounds' sequences could be grouped in two groups as follows: the first group, which included the sequences that gave more than 83% reduction namely sequences 7, 5, 2, 6, and 3, and the second group, which included sequence 1 and sequence 4, which gave 75.9 and 76.7% reduction. According to significant differences, the data clearly show that starting and mediating the sequence with new insecticides emmamectin benzoate, indoxacarb acetamiprid, and chlorfenapyr (sequence 7 and 5) gave high infestation reduction percentages compared to other tested sequences. In similar, starting and mediating the sequence with bio-insecticide, spinosad (sequence 2), induced the efficiency of that sequence against *P. gossypiella* and *E. insulana*. Accordingly, this

Table 8 Assessment of loss due to bollworms in different sequence treatments during season 2018

Sequences	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I* %
Sequences 1	60.8	4.8	2.0	0.20	3.1	71.0	63.6	7.4	10.4d
Sequences 2	60.1	5.7	2.8	0.26	3.7	72.6	63.0	9.6	13.2c
Sequences 3	61.9	4.4	1.7	0.18	2.7	70.9	65.9	5.0	7.1e
Sequences 4	57.5	7.0	3.7	0.33	4.5	73.0	62.0	11.0	15.0c
Sequences 5	52.9	11.1	5.3	0.50	6.0	75.8	60.3	15.5	20.4b
Sequences 6	59.3	6.2	3.0	0.29	4.0	72.8	62.4	10.4	14.3c
Sequences 7	61.6	4.3	1.9	0.17	2.6	70.6	66.1	4.5	6.4e
Control	27.0	4.8	10.5	14.0	6.7	63.0	36.0	27.0	42.9a

result revealed to be used to control the cotton bollworms, where a new chemical group of pests has novel modes of action, which proved their efficacy against cotton bollworms with the highest seed cotton yield. Similar results were elucidated by Allen et al. (1997) who found that large- and medium-sized bollworm larvae were significantly less numerous in cyfluthrin- and spinosad-treated plots than in control plots. Tadros (2003) reported that Achook, as a botanical insecticide, resembles the efficiency of the used synthetic insecticides showing a promising way in the control program of both cotton bollworms. Shashikant (2007) noticed the efficacy of spinosad and indoxacarb against bollworm and higher seed cotton. Starting and mediating the sequence with cypermethrin (sequence 3) gave high infestation reduction percentages and seed cotton yield compared to other tested sequences with profenofos and carbosulfan (sequence 4 and 1). This finding is following that reported by El-Gogary (1987), who said that starting the program with organophosphate followed by pyrethroids gave less satisfactory results. El-Feel et al. (1991) reported that starting the controlling program with synthetic pyrethroids induced the highest reduction of the bollworms infestation. Abd El-Mageed et al. (2007) revealed that obtained data for the tested programs reduced the rate of pink bollworm and spiny bollworm larvae during the three sprays. Imran et al. (2017) reported that Bt cotton was associated with decreases in the number of insecticide sprays which caused the reduction of the risk of resistance of pink bollworm. Also, Awad et al. (2014) reported that the synthetic pyrethroids induced the most significant reduction in bollworms infestation that was associated with the highest amount of seed cotton yield more compared to the organophosphorous. In contrast, El-Feel et al. (1993) mentioned that pyrethroids could not be able to reduce the building-up of the bollworm population at the early season, while at the late season this aim is not considered.

Conclusions

As a conclusion, it can be asserted that this study points out to minimize repetition of insecticide application in the same season; furthermore, the importance of sequence insecticide programs included new groups of insecticides to directing tactics to fight against resistance development for this conventional insecticide where acetamiprid, chlorfenapyr, indoxacarb, emmamectin benzoate, and spinosad could be used in sequence programs to restore cypermethrin, profenofos, and carbosulfan susceptibility.

These findings may have considerable practical implications for *Pectinophora gossypiella* and *Earias insulana* resistance management, and this leads to obtaining the optimum regimen of insecticides, which gives the reduction of cotton bollworms infestation and high cotton yield.

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The author declares that he/she has no competing interests.

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