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The Single and Combined Effects of Two Active Ingredients Against the Cotton Leafworm, *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae) and Its Predators in Soybean (*Glycine max* L.) in Al Qalyubia Governorate

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ABSTRACT

Soybean plants are subjected to invasion by many insect pests. The cotton leafworm, *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae), is one of the most important pests that infect soybean plants causing a large loss in yield. The extensive use of conventional insecticides caused adverse impacts on the environment and natural enemies, besides the formation of resistance against these compounds. The present study aimed to evaluate the insecticidal activity of the efficacy of chemically mixed compound and its comparison with its active ingredients alone against the larvae of *S. littoralis*, and its predators in two growing seasons, 2020 and 2021. The field application revealed that the commercial mixture Folliam Felixi® (Thiamethoxam + Chlorantraniliprole) significantly reduced the larval population of *S. littoralis* compared to Niloxam® (Thiamethoxam), Coragen® (Chlorantraniliprole), and the untreated area, through both growing seasons. The tested compounds showed no significant toxicity against the individuals of ladybird, *Coccinella sp.*, and lacewing, *Chrysoperla carnea*, through both growing seasons. All tested compounds can be used successfully as a component of integrated pest management of cotton leafworm in Egypt.

INTRODUCTION

Soybean crop (*Glycine max* L.) is a very important economic crop, through-out considered one of the high potential protein sources. Soybean is infested with many insect pests at different growing stages. The cotton leafworm, *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae) caused severe damage to the foliage parts of the soybean (El-Sisi *et al*., 2013; Triboni *et al*., 2019). Many attempts are developed in order to find an effective and safe control method. Among these methods, was the employment of synthetic chemical insecticides (Forgash, 1984). The vigorous application of these chemicals gave rise to many disadvantages; such as high resistance to many chemical pesticides, resurgence, and residues of chemical pesticides in the environment (Forgash, 1984; Hawkins *et al*., 2019). Consequently, many efforts have been carried out to find more convenient alternatives for these chemicals. Using the mixtures of pesticides is one of the effective ways to postpone the development of insecticide resistance or to struggle with current resistance in a pest

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species. This method is generally used, in the field, to increase the spectrum of control when multiple pests are aggressive simultaneously or against a single pest (Ishaaya *et al*., 1987; Talleh *et al*., 2020). These mixtures can grant noteworthy progress for Insect Pest Management programs (IPMs), including the potential impact of lowering the quantities of each agent used (Abd El-Kareem *et al*., 2022). The combination of insecticides with various modes of action could either be synergistic, additive, or antagonistic against an insect species. If the mixtures would be synergistic, the costs of excessive use of insecticides might effectively be reduced (Wolfenbarger & Cantu, 1975; Talleh *et al*., 2020). In this context, the present study aims to evaluate the insecticidal activity against the cotton leaf worm *S. littoralis*, in the two growing seasons, 2020 and 2021, the efficacy of chemically mixed compound and its comparison with its active ingredients alone. These pesticides follow a new chemical group in integrated pest management (IPM) as they work efficiently on insects that have acquired resistance against other pesticides.

MATERIALS AND METHODS

1.Tested Compounds:

Three commercial products belonging to different groups of insecticides, one chemically mixed compound and its comparison with its active ingredients alone were used.

a. Common name: Thiamethoxam 20% + chlorantraniliprole 20% with the trade name Folliam Felixi® 40 % WG, was obtained from Syngenta Agro - Egypt. The application rate is 80 g/feddan.
b. Common name: Thiamethoxam 25% with the trade name Niloxam® 25% WDG, was obtained from Wadi El Nil Co. For Agricultural Development. The application rate is 80 g/feddan.
c. Common name: Chlorantrianliprole 20% with the trade name Coragen®, was obtained from FMC Corporation. The application rate is 60 ml/feddan.

2.Field Application:

The field study was conducted on a soybean plant (*Glycine max* L.) infected with cotton leafworm *S. littoralis* during the two successive planting seasons 2020 and 2021. The two field trials with the same treatments were carried out each year. Field experiments were carried out at Al-Hasanya village, Toukh Center, Al Qalyubia Governorate. The Soybean variety (Giza 111) was used in all the experiments and was cultivated by the middle of May during the two seasons. The field area consisted of 262.5 m^2 (1/16 feddan) in randomized complete block design (RCBD). Four plots were assigned for each treatment and for the untreated area as well, two rows of plants were left untreated between plots. Applications were performed by using a knapsack motor sprayer (80 liters in capacity). All tested compounds were applied at the recommended concentrations according to the recommendation of the Agricultural Pesticide Committee (APC), Ministry of Agriculture and Land Reclamation, Egypt. While control plots were sprayed with water only. Examinations of 10 plants /plot /treatment were carried out just before the first application and after 1, 3, 5, 7, and 10 days after application of all compounds The efficiency of tested treatments was measured as a percentage of reduction in infestation density of S. *littoralis* larvae using Henderson and Tilton (1955) as follows:

$$Reduction\ \% = 1 - \left[\frac{no.\ C\ before\ treatment \times no.T\ after\ treatment}{no.C\ after\ treatment \times no.T\ before\ treatment}\right] \times 100$$

Reduction percentage of predators resulted from treatments: Numbers of *Chrysoperla carnea* (larvae), and *Coccinella sp*. (larvae and adults) were counted per 10 soybean plants just before treatments, and then 1, 3, 5, 7, and 10 days after treatments. Also, the reduction in predators was calculated with the same equation above-mentioned.

RESULTS AND DISCUSSION

1.Effect on *S. littoralis* Larvae:

The toxicity of tested compounds against *S. littoralis* larvae in a field a of Soybean crop (*Glycine max L*.) during two sequential seasons, 2020, 2021 is presented in Tables (1) and (2). The number of larvae of cotton leafworm was recorded before and after treatments and the reduction % was calculated. Results showed that treatment with the recommended concentrations of the tested compounds reduced the larval population of *S. littoralis* through 10-days post-treatment in the 2020 growing season. Results showed that the highest reduction rate was obtained when Coragen® was applied followed by Folliam Felixi® and Niloxam®. During the 2nd growing season, the reduction rate was less than the 1st growing season, although there was a reduction in the population of *S. littoralis* larvae. In addition, results showed that Folliam Felixi® exhibited the highest reduction rate compared to the rest tested compounds. Mixtures of insecticides were employed to control a wide spectrum of insect pests and to reduce insecticide resistance (Mavroeidi & Shaw, 2006; Jones *et al*., 2012). Insecticide compounds may be sold as premixed commercial products or may be prepared by applicators (Ahmad, 2004; Talleh *et al*., 2020; Ahmed *et al*., 2022). In comparison to the separate application of insecticides, the mixed insecticides may cause higher mortality (Warnock & Cloyd, 2005), lessen application number (Cloyd, 2009), and inhibit the inception of resistance development in pest populations (Bielza *et al*., 2009). However, the insect response may differ from one population to another, according to insect strain, physiology, and resistance mechanism observed in a population (Ahmad, 2004; Bielza *et al*., 2009). Chlorantraniliprole showed high toxicity when mixed with any pyrethroid as applied to the fruit moth, *Grapholita molesta* (Busck) in apple and peaches orchards (Jones *et al*., 2012). In addition, the mortality rate of *S. littoralis* was increased when used methoxyfenozide/ spinetoram mixture was against the larval stage, compared to the solitary application of each active ingredient (Ahmed *et al*., 2022). Furthermore, the application of premixed insecticides showed the same response even though the insecticidal groups differ from the tested compounds (Jones *et al*., 2012; Talleh *et al*., 2020; Abd El-Kareem *et al*., 2022; Ahmed *et al*., 2022).

Table 1: The mean number and reduction percentage of *S. littoralis* larvae in soybeans field before and after treatment with the tested insecticides during the 2020 growing season

Treatments	Before treatment	Mean and reduction percentage after treatment				
		1 DAY Mean ±SD	3 DAYS Mean ±SD	5 DAYS Mean ±SD	7 DAYS Mean ±SED	10 DAYS Mean ±SD
Folliam Felixi®	14.25 ± 0.1 a	10.75 ± 1.5 b (28.4) *	8.25 ± 0.5 b (47.98) *	6.75 ± 0.5 b (59.21) *	6.75 ± 0.9 b (61.36) *	3.25 ± 0.5 b (82.32) *
Niloxam®	14.75 ± 0.5 a	10.75 ± 1 b (30.48) *	9 ± 0.8 b (45.17) *	6.75 ± 0.5 b (60.59) *	6.5 ± 0.6 b (64.05) *	5 ± 2.4 b (74.05) *
Coragen®	14.5 ± 1.2 a	10.5 ± 1 b (30.93) *	8.25 ± 0.5 b (48.88) *	7 ± 0.8 b (58.43) *	4.75 ± 0.5 c (73.28) *	3.25 ± 0.9 b (82.84) *
Untreated area	15.5 ± 0.6 a	16.25 ± 0.5 a	17.25 ± 0.5 a	18 ± 0.8 a	19 ± 0.8 a	20.25 ± 1.2 a

Means followed by the same small letter in a column are not significantly different at the 5% level of probability (Duncan's Multiple Range Test)

*The numbers in parentheses indicate the percentage of reduction.

Table 2: The mean number and reduction percentage of S. littoralis larvae in soybeans field before and after treatment with the tested insecticides during the 2021 growing season

Treatments	Before treatment	Mean and reduction percentage after treatment				
		1 DAY Mean ±SD	3 DAYS Mean ±SD	5 DAYS Mean ±SD	7 DAYS Mean ±SD	10 DAYS Mean ±SD
Folliam Felixi®	**12.5 ± 06 [a]**	**9 ± 0.9 [b] (37.76) ***	**9 ± 0.8 [b] (38.80) ***	**7.5 ± 0.6 [b] (54.33) ***	**6 ± 0.8 [b] (66.00) ***	**5.5 ± 0.6 [b] (70.08) ***
Niloxam®	**12 ± 0.8 [a]**	**9.25 ± 0.5 [b] (33.37) ***	**9.25 ± 1.5 [b] (34.48) ***	**8.25 ± 1 [b] (47.67) ***	**7.25 ± 1 [b] (57.20) ***	**6.5 ± 0.6 [b] (63.17) ***
Coragen®	**12.25 ± 0.5 [a]**	**8.75 ± 1 [b] (38.26) ***	**8.5 ± 0.6 [b] (41.02) ***	**7.75 ± 0.5 [b] (51.84) ***	**7.5 ± 0.6 [b] (56.63) ***	**6.25 ±1 [b] (65.31) ***
Untreated area	**12.75 ± 1 [a]**	**14.75 ± 1 [a]**	**15 ± 0.8 [a]**	**16.75 ± 0.5 [a]**	**18 ± 0.8 [a]**	**18.75 ± 1 [a]**

Means followed by the same small letter in a column are not significantly different at the 5% level of probability (Duncan's Multiple Range Test)

*The numbers in parentheses indicate the percentage of reduction.

2.Effect on *S. littoralis* Larvae:

The toxicity of tested compounds against the predators found in the field of Soybean during two consecutive growing seasons, 2020, and 2021 is presented in Tables (3, 4, 5, and 6). Two predators were found at the same time of application. They were lacewing, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) and ladybird, *Coccinella sp.* L. (Coleoptera: Coccinellidae). The obtained results showed that the tested compounds were not significantly toxic against the individuals of both predators through 10-days post-treatment in both growing seasons. Beneficial insects; predators and parasitoids, can be found in field crops and they are subjected to insecticide applications by being directly sprayed, by contacting residues on foliage or in stubble or soil, feeding on treated pests or seeds, or by imbibing nectar or guttation water (Kunkel *et al*., 2001; Larson *et al*., 2014). Both selected insecticidal groups; thiamethoxam, Chlorantrianliprole, and their mixture showed no apparent inverse effects on any of the found predators. These results agreed with earlier findings in different fields (Larson *et al*., 2014; Moscardini *et al*., 2015; Rugno *et al*., 2019).

Table 3: The mean number and reduction percentage of predator (Coccinella sp) in soybean fields before and after treatment with the tested insecticides during the 2020 season

Treatments	Before treatment	Mean and reduction percentage after treatment				
		1 DAY Mean ±SD	3 DAYS Mean ±SD	5 DAYS Mean ±SD	7 DAYS Mean ±SD	10 DAYS Mean ±SD
Folliam Felixi®	**9.25 ± 1 [a]**	**7.75 ± 0.5 [b] (6.36) ***	**6.75 ± 0.5 [b] (15.79) ***	**6.5 ± 0.6 [b] (13.86) ***	**6 ± 0.8 [b] (17.84) ***	**5.5± 0.6 [c] (19.31) ***
Niloxam®	**8.25 ± 0.5 [ab]**	**7.25 ± 0.5 [b] (1.78) ***	**6.25 ±0.5 [b] (12.76) ***	**6 ± 0.8 [b] (10.85) ***	**5.5 ±0.6 [c] (15.56) ***	**5.25 ± 0.5 [c] (13.64) ***
Coragen®	**7.5 ± 0.6 [b]**	**6.5 ± 0.6 [c] (3.14) ***	**6.25 ± 0.5 [c] (4.04) ***	**5.5 ± 0.6 [c] (10.11) ***	**5.25 ± 0.5 [c] (11.33) ***	**4.75 ±0.5 [c] (14.05) ***
Untreated area	**9.5 ± 0.6 [a]**	**8.5 ±0.6 [a]**	**8.25 ± 0.5 [a]**	**7.75 ± 0.5 [a]**	**7.5 ± 1 [a]**	**7 ± 0.8 [a]**

Means followed by the same small letter in a column are not significantly different at the 5% level of probability (Duncan's Multiple Range Test)

*The numbers in parentheses indicate the percentage of reduction.

Table 4: The mean number and reduction percentage of predator (Coccinella sp) in soybean fields before and after treatment with the tested insecticides during the 2021 season.

Treatments	Before treatment	Mean and reduction percentage after treatment				
		1 DAY Mean ±SD	3 DAYS Mean ±SD	5 DAYS Mean ±SD	7 DAYS Mean ±SD	10 DAYS Mean ±SD
Folliam Felixi®	10.25 ± 0.5 ^{a}	9.5 ± 0.6 ^{a} (2.68) *	9 ± 0.8 ^{a} (2.95) *	7.5 ± 0.6 ^{c} (16.94) *	6.75 ± 1 ^{d} (23.17) *	6.5 ± 0.6 ^{c} (23.90) *
Niloxam®	9.5 ± 0.6 ^{ab}	8.75 ± 0.5 ^{c} (3.29) *	8.25 ± 1.5 ^{ab} (4.02) *	8 ± 0.8 ^{b} (4.41) *	7.75 ± 1 ^{c} (4.82) *	6.5 ± 0.6 ^{c} (17.89) *
Coragen®	10 ± 0.8 ^{a}	9 ± 0.8 ^{ab} (5.50) *	8.5 ± 0.6 ^{ab} (6.05) *	8 ± 0.8 ^{b} (9.19) *	7.5 ± 0.6 ^{c} (12.5) *	6 ± 0.8 ^{d} (28.00) *
Untreated area	10.5 ± 0.6 ^{a}	10 ± 0.8 ^{a}	9.5 ± 0.6 ^{a}	9.25 ± 0.5 ^{a}	9 ± 0.8 ^{a}	8.75 ± 0.5 ^{a}

Means followed by the same small letter in a column are not significantly different at the 5% level of probability (Duncan's Multiple Range Test)

*The numbers in parentheses indicate the percentage of reduction.

Table 5: The mean number and reduction percentage of predator (*Chrysoperla carnea*) in soybean fields before and after treatment with the tested insecticides during 2020 season

Treatments	Before treatment	Mean and reduction percentage after treatment				
		1 DAY Mean ±SD	3 DAYS Mean ±SD	5 DAYS Mean ±SD	7 DAYS Mean ±SD	10 DAYS Mean ±SD
Folliam Felixi®	9 ± 0.8 ^{a}	8.5 ± 0.6 ^{a} (0.16) *	8.25 ± 1.2 ^{a} (0.25) *	7.75 ± 1 ^{b} (3.45) *	6.75 ± 1 ^{c} (13.28) *	5.5 ± 0.6 ^{c} (22.03) *
Niloxam®	8.75 ± 0.5 ^{a}	8.25 ± 0.5 ^{a} (0.33) *	8 ± 0.8 ^{b} (0.50) *	7.5 ± 0.6 ^{b} (3.90) *	7.25 ± 1 ^{b} (4.20) *	6.5 ± 0.6 ^{c} (5.22) *
Coragen®	8.5 ± 0.6 ^{a}	7.75 ± 1 ^{b} (3.61) *	7.5 ± 0.6 ^{b} (3.98) *	7 ± 0.8 ^{b} (7.66) *	6 ± 0.8 ^{c} (18.38) *	5.25 ±1 ^{c} (21.2) *
Untreated area	9.25 ± 1 ^{a}	8.75 ± 1 ^{a}	8.5 ± 0.6 ^{a}	8.25 ± 1.3 ^{a}	8 ± 0.8 ^{a}	7.25 ± 0.5 ^{a}

Means followed by the same small letter in a column are not significantly different at the 5% level of probability (Duncan's Multiple Range Test)

*The numbers in parentheses indicate the percentage of reduction.

Table 6: The mean number and reduction percentage of predator (*Chrysoperla carnea*) in soybean fields before and after treatment with the tested insecticides during 2021 season.

Treatments	Before treatment	Mean and reduction percentage after treatment				
		1 DAY Mean ±SD	3 DAYS Mean ±SD	5 DAYS Mean ±SD	7 DAYS Mean ±SD	10 DAYS Mean ±SD
Folliam Felixi®	8.25 ± 0.5 ^{a}	7.75 ± 1 ^{b} (3.38) *	7.25 ± 1 ^{b} (4.13) *	6.5 ± 0.6 ^{b} (8.5) *	6.25 ± 0.5 ^{b} (9.09) *	6 ± 1.2 ^{c} (9.72) *
Niloxam®	8.75 ± 1 ^{a}	8.25 ± 0.5 ^{a} (3.02) *	8 ± 0.8 ^{a} (0.26) *	7.25 ± 1 ^{a} (3.78) *	6.25 ± 1 ^{b} (14.29) *	5.75 ± 1.5 ^{c} (18.42) *
Coragen®	8.5 ± 1.3 ^{a}	8 ± 0.8 ^{b} (3.19) *	7.75 ± 1 ^{b} (0.53) *	6.75 ± 1.5 ^{b} (7.78) *	6.5 ± 0.6 ^{b} (8.24) *	6.25 ±1 ^{c} (8.72) *
Untreated area	9 ± 1.2 ^{a}	8.75 ± 1 ^{a}	8.25 ± 0.5 ^{a}	7.75 ± 1 ^{a}	7.5 ± 0.8 ^{a}	7.25 ± 1 ^{a}

Means followed by the same small letter in a column are not significantly different at the 5% level of probability (Duncan's Multiple Range Test)

*The numbers in parentheses indicate the percentage of reduction.

Conclusion:

From all obtained results, we can conclude that the tested compounds either applied singly or in a mixture showed high efficiency against *S. littoralis* population in the soybean field under field conditions. The premixed compound increased the reduction rate of the insect population, which may be useful in lowering the number of applications. Furthermore, the application of the tested compounds as they were applied solely or in premixed compounds displayed no obvious toxicity against the predatory insects in the soybean field. These were observed not as initial effects only but also as residues. This suggests the effectiveness and safe of the tested compounds against beneficial insects

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