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Research Article

Joint Toxic Action of Spinosad with Fenpropathrin and Chlorpyrifos and its Latent Effect on Different Egyptian Field Populations of *Spodoptera littoralis*

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Abstract

Background and Objective: Resistance to pesticides is probably the biggest challenge facing pesticides researches today. The objective of this study was to test some of their combination against *Spodoptera littoralis* (Boisduval) to help developing control program in the future and increase their efficiency on *S. littoralis* that could inhibit or delay the emergence of resistant strains. **Materials and Methods:** Three methods of the substances determined the effect of joint action against *S. littoralis* larvae and the impact of these combinations on some biological characters and fecundity were studied. **Results:** Beni-suef strain showed tolerance ratios of 129.57 and 58.67 to chlorpyrifos and fenpropathrin, respectively. On the other hand, the El-monofia strain showed tolerance ratios of 89.86 and 44.08 to the same insecticides, respectively. The two F-strains show slight tolerance rates to spinosad. The combination of spinosad and fenpropathrin results in a synergistic effect, while chlorpyrifos results in additive or antagonistic effect. **Conclusion:** All the tested combinations showed significantly reduce mean larval and pupal weight, pupation (%), adult emergence (%), fecundity and fertility compared with the control. While, prolonged larval duration and some of the mixtures showed sterility effect.

Key words: *Spodoptera littoralis*, joint action, biological aspects, latent effect

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The biggest challenge that researchers are facing today that pests have grown resistance to pesticides. Consequently, insecticides from different chemical groups with a different mode of action and also some of their combination should be tested against *Spodoptera littoralis* (Boisduval) to help developing control program in the future and increase their efficiency on *S. littoralis* that could inhibit or delay the emergence of resistant strains[1,2]. The development of multiple insecticide resistance in field strains of the *S. littoralis* which is lepidopteran model and is one of the key pests that cause considerable damage to cotton plants as well as other plants in Egypt, larval instars, which are the most destructive stages of this pest can feed on ≈90 economically important plant species belonging to 40 families, however, the larval stages have become extremely tolerance to the action of insecticides because the frequent use extensively of traditional pesticides usually leads to the development of resistance in the target pests. More considerations need evaluation of the insecticides efficiency for controlling the insects in different areas became urgent, this will give the chance to replace the failed managing agents by effective alternatives[3-5]. Therefore, the mixture of insecticides which are from different chemical groups with various mode of actions can result in more potent use of insecticides that could inhibit or delay the emergence of resistant strains. On the other hand, study the situation of conventional pesticides to monitor the development of *S. littoralis* resistance to the insecticides applied, to make the right decision at the right time, in addition to the continuous monitoring of resistance is fundamentally essential to every resistance management programs to preservation of both insecticides efficacy.

In Egypt, no reports on monitoring of resistance to insecticides in the *S. littoralis* have been done yet. Annual evaluation of resistance monitoring data on field population is needed to provide an adequate database that would allow more flexibility in choosing an appropriate insecticide for control of pests. Thus, the present study was conducted to investigate the variation in susceptibility of *S. littoralis* collected from Beni-suef and El-monofia governorates representing upper and lower Egypt to OP-insecticide, pyrethroid-insecticide and bio-insecticide compared to the laboratory strain. The present study was conducted to find out joint action effects of mixing tested insecticides and the latent effect of the candidate mixtures was also studied.

MATERIALS AND METHODS

Test insects

Laboratory strain: Laboratory strain (L-strain) of *S. littoralis* was obtained from the central lab of pesticides, Agricultural Research Center (ARC), Cairo, Egypt and reared on castor oil leaves under laboratory conditions (27 ± 2°C and RH 65%$\pm$5) for several years, according to Eldefrawi *et al.*[6].

Field strains: Field strains (F-strains) of *S. littoralis* were obtained from the cotton fields at El-Fashn and Quesna districts, Governorate Beni-suef and El-monofia, respectively representing upper and lower Egypt during the season 2019. Samples were brought to the laboratory as egg masses the hatched larvae were reared on castor oil leaves under the same conditions.

Test insecticides: The pyrethroid-insecticide, fenpropathrin (Meothrin®, 20% EC), organophosphorus-insecticide, chlorpyrifos (Dursban® 48% EC) and bio-insecticide, spinosad (Tracer® 48% SC) were produced by Sumitomo Chem., Co., Dow Chem., Co. and Dow AgroSciences Co., respectively.

Bioassay

Toxicity test: Bioassays were performed on 4th instars larvae of both L-strain and two F-strains to assess the activity of the five-mentioned insecticides, a series of aqueous concentrations for each insecticide were prepared using the commercial formulations. The leaf dipping technique was used to determine the median lethal concentration (LC_{50}) values, fresh castor oil leaves were cut into discs (2 cm^2), each disc was dipped for 30 sec in one of the prepared concentrations. The treated leaves had dried under laboratory conditions before being an offer to *S. littoralis* larvae. Ten larvae (40-50 mg/larvae) in three replicated were used for each concentration. Larvae were fed on leaves immersed in only water as a control. Newly moulted 4th larval instars were fed on the treated leaves in a glass jar covered with muslin for 24 h for the tested insecticides. Another untreated one replaced the treated leaves. Mortality percentages were recorded after 24 h of treatment for chlorpyrifos and fenpropathrin and after 72 h for spinosad. The corrected mortality was calculated by using Abbott[7] formula data were subjected to probit analysis as described by Finney[8]. Resistance Ratio (RR) as F/L was calculated by dividing the LC_{50} value of the F-strain by the LC_{50} value of the L-strain.

Joint toxic action of spinosad with tested insecticides against *S. littoralis* larvae: Joint toxic action of the spinosad with the synthetic insecticides (fenpropathrin and chlorpyrifos) against 4th instar larvae was investigated. Larvae were treated with spinosad at LC_{50}, while synthetic insecticides at LC_{25}. Larvae were treated with synthetic insecticides in three different ways, spontaneously with spinosad, 24 h before spinosad and 24 h after spinosad treatments. Three control groups were subjected to calculate the expected mortalities. Co-toxicity factors which were estimated according to the equation given by Mansour *et al.*[9].

Latest effects of tested insecticides against *S. littoralis*: Castor oil leaves were soaked in the previously determined LC_{50} and LC_{25} equivalent concentrations for tested insecticides. About 400 4th instar larvae (2.3±0.1 mg/larva) in 4 replicates were used for each treatment and provided with treated leaves. After 24 h, surviving larvae were transferred the jar containing fresh untreated leaves and observed daily for pupation. Pupa was sexed and weighed 24 h after formation. Larval, pupal and adult durations and survivorship were determined, as well as, larval and pupal weights and the percentages of adult emergence. Resulted adults were placed in plastic cups provided with a folded sheet paper as an oviposition site. Two adult males were kept with one adult female to maximize the probability of successful mating. The sub-lethal effects of various insecticides on fecundity (total number of eggs/female) and fertility (hatchability percentage of eggs) were determined. Mating of untreated adults of both sexes were used as control. Initially, 12 mating were planned for each insecticide treatment as well as control. The mating cups were checked daily and egg masses were removed until female death. The total number of eggs/female for each mating and hatched eggs percentages were evaluated, sterility percentages were calculated[10].

Statistical analysis: All biological aspects were analyzed by 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 AND DISCUSSION

Toxicity of tested insecticides against *S. littoralis* larvae: Susceptibility of two F-strains of *S. littoralis* compared to L-strain for chlorpyrifos, fenpropathrin and spinosad is given in Table 1. Generally, Beni-suef strain exerts tolerance ratios higher than El-monofia strain to the tested conventional insecticides. *Sodoptera littoralis* showed the tolerance to the OP-insecticide (chlorpyrifos) more than tolerance to pyrethroid-insecticide (fenpropathrin). Beni-suef strain showed tolerance ratios of 129.57 and 58.67 to chlorpyrifos and fenpropathrin, respectively. On the other hand, the El-monofia strain showed tolerance ratios of 89.86 and 44.08 to the same insecticides, respectively. The two F-strains showed tolerance ratios slightly to spinosad compared to the L-strain. According to the laboratory bioassay, Beni-suef strain exerts tolerance ratios higher than El-monofia strain to the tested conventional insecticides. The two F-strains showed tolerance ratios slightly to spinosad compared to the L-strain. The present results emphasized that during many years of selection pressure in the field, the resistance and/or tolerance levels to OP-insecticides and pyrethroids-insecticides had increased due to the intensive application of such insecticides for controlling *S. littoralis* in cotton fields. *Sodoptera littoralis* larvae collected from a cotton field that was heavily sprayed with conventional insecticides showed strong resistance to OPs and pyrethroids whereas, the LC_{50} values of the F-strains were 120 and 102 times more resistant than the L-strain to chlorpyrifos and cypermethrin, respectively[11-13]. Despite the

Table 1: Toxicity of tested insecticides against 4th larval instar of *S. littoralis*

				Confidence limits			
Strains	Insecticides	LC_{25} (ppm)	LC_{50} (ppm)	Lower	Upper	Slope values±SE	TR
Laboratory	Fenpropathrin	0.178	0.863	0.650	1.300	0.98±0.43	--------
	Chlorpyrifos	0.312	1.21	0.119	0.532	1.14±0.19	--------
	Spinosad	0.097	0.356	0.215	0.495	1.55±0.17	--------
El-monofia	Fenpropathrin	5.479	38.04	14.200	148.760	0.80±0.21	44.08
	Chlorpyrifos	7.990	77.55	4.034	56.740	0.68±0.22	89.86
	Spinosad	0.323	1.28	0.124	0.551	1.13±0.19	3.6
Beni-suef	Fenpropathrin	7.750	70.99	19.170	298.700	0.70±0.22	58.67
	Chlorpyrifos	12.090	156.78	32.080	496.450	0.61±0.22	129.57
	Spinosad	0.470	2.37	0.171	0.803	0.96±0.18	6.66

TR: Tolerance ratio (LC_{50} of the F-strain/LC_{50} of L-strain)

Table 2: Joint action effects of different pesticides combinations against 4th instar *S. littoralis* larvae

Strains	Combinations (F+S)	Expected M (%)	Observed M (%)	CTF	Type of interaction
Laboratory	Spontaneously	61	90	47.54	Potentiation
	Pre-treated	66	88	35.38	Potentiation
	Post-treated	67	86	29.85	Potentiation
El-monofia	Spontaneously	55	74	34.55	Potentiation
	Pre-treated	59	75	27.12	Potentiation
	Post-treated	67	82	22.39	Potentiation
Beni-suef	Spontaneously	51	67	31.37	Potentiation
	Pre-treated	52	65	25.00	Potentiation
	Post-treated	42	51	21.43	Potentiation

CTF: Co-toxicity factor, F+S: Fenpropthrin+Spinosad

Table 3: Joint action effects of different pesticides combinations against 4th instar *S. littoralis* larvae

Strains	Combinations (F+S)	Expected M (%)	Observed M (%)	CTF	Type of interaction
Laboratory	Spontaneously	55	61	10.91	Additive
	Pre-treated	55	68	19.12	Additive
	Post-treated	61	52	-14.75	Antagonism
El-monofia	Spontaneously	63	69	9.52	Additive
	Pre-treated	69	80	15.94	Additive
	Post-treated	55	50	-9.09	Antagonism
Beni-suef	Spontaneously	53	56	5.66	Additive
	Pre-treated	59	67	13.56	Additive
	Post-treated	47	45	-4.26	Antagonism

high mobility of the cotton leafworm, the resistance level of the strain collected from Beni-suef (129.57 and 89.86 folds to chlorpyrifos and fenpropathrin, respectively) was higher than those of the strain collected from El-monofia (58.67 and 44.08 folds, respectively). Mascarenhas *et al.*[12] found that several F-strains of *Spodoptera exigua* exhibited reduced susceptibility to chlorpyrifos and thiodicarb. Also, Robertson *et al.*[13] reported that the significant variations in LC_{50s} among F-strains probably reflect the natural variation. In another study showed low levels of tolerance to spinosad, these results are in variance with Temerak[14], who reported that the F-strain of the *S. littoralis* larvae proved to be more susceptible to spinosad. These results all indicated that the potential for insect pests to develop resistance to chlorpyrifos, fenpropathrin and spinosad exists. However, the extent and the degree of resistance depend on the insects and selection pressure. Further studies are needed to show the mechanisms of this tolerance.

Joint toxic action of spinosad with tested insecticides against *S. littoralis* larvae: The joint toxic action of spinosad with other synthetic insecticides is presented in Table 2 and 3. When the 4th instar *S. littoralis* larvae treated with spinosad at LC_{50} and fenpropathrin at LC_{25}, co-toxicity factors are +47.54, +34.55 and +31.37 for L-strain and two F-strains (El-monofia and Beni-suef, respectively). According to Mansour *et al.*[9], these values indicated that the combination between spinosad and fenpropathrin at the same time resulting in a good potentiation. The same trend was observed (potentiation effect) when larvae were pre and post-treated with fenpropathrin. When larvae pre-treated with LC_{25} of chlorpyrifos, co-toxicity factors are +19.12, +15.94 and +13.56 for L-strain and two F-strains, respectively produced an additive effect. The lowest additive effect was recorded when larvae spontaneously with chlorpyrifos, but it produced an antagonism effect at post-treated with chlorpyrifos. In respect with the joint toxic action, it could be concluded that all tested combinations positive effect except in the case of post-treated spinosad/chlorpyrifos mixtures, these potentiation or additive effects depending upon their different chemical groups with modes of action for these insecticides are mixed on the assumption that they would complement the action of each other for killing the target pest and to act influenced on *S. littoralis*. In contrast, the results revealed that their synergistic effects were reduced antagonism effect of post-treated spinosad/chlorpyrifos mixtures. This was attributed to the fact that the generalized levels of tolerance in the F-strains towards various compounds may have influenced the several defence mechanisms to act against the synergistic action of the chemical mixtures. Also, these mixtures are potentiating, it is a useful tool in enhancing control efficacy and combating insecticide resistance, in this case, there may be potential for reducing the application rate of one or both components of the mixture, spinosad and abamectin in combination with profenofos resulting in antagonistic effect[15,16].

Table 4: Latent effects of different pesticides combinations on larval weight, larval duration and pupation percentage of *S. littoralis*

		Mean weight (mg/larval)±SE		Larval duration (days)±SE		Pupation (%)	
Strains	Combinations	F+S	C+S	F+S	C+S	F+S	C+S
Laboratory	Spontaneously	160.9 ± 1.9^{d}	179.0 ± 3.8^{d}	23.5 ± 0.4^{b}	19.5 ± 0.2^{b}	60.4 ± 1.6^{d}	83.6 ± 4.0^{b}
	Pre-treated	166.3 ± 4.2^{d}	173.2 ± 4.5^{e}	20.0 ± 0.5^{b}	22.0 ± 0.4^{b}	69.1 ± 1.5^{c}	76.2 ± 2.4^{b}
	Post-treated	170.9 ± 3.6^{d}	241.6 ± 4.7^{ab}	18.5 ± 0.3^{c}	13.5 ± 0.2^{a}	73.6 ± 4.1^{c}	98.3 ± 2.0^{a}
El-monofia	Spontaneously	174.6 ± 3.2^{d}	186.6 ± 2.4^{c}	21.0 ± 0.6^{b}	17.0 ± 0.8^{c}	68.9 ± 1.6^{c}	88.2 ± 3.2^{ab}
	Pre-treated	180.1 ± 3.2^{c}	182.8 ± 4.2^{d}	18.0 ± 0.4^{c}	19.0 ± 0.5^{c}	75.7 ± 2.8^{b}	82.8 ± 2.4^{b}
	Post-treated	187.7 ± 3.5^{b}	243.0 ± 4.5^{ab}	16.5 ± 0.4^{d}	14.0 ± 0.2^{a}	77.9 ± 2.2^{b}	98.7 ± 2.6^{a}
Beni-suef	Spontaneously	179.1 ± 2.1^{c}	198.9 ± 2.5^{c}	19.0 ± 0.5^{c}	16.0 ± 0.3^{c}	76.1 ± 1.6^{b}	96.5 ± 3.6^{a}
	Pre-treated	186.2 ± 2.4^{b}	192.2 ± 2.3^{c}	16.5 ± 0.1^{d}	17.0 ± 0.6^{c}	80.0 ± 2.1^{b}	92.8 ± 1.4^{a}
	Post-treated	190.0 ± 3.0^{b}	248.1 ± 3.4^{ab}	15.0 ± 0.5^{d}	14.0 ± 0.5^{a}	84.4 ± 1.7^{b}	99.0 ± 4.4^{a}
Control	---------------	240.0 ± 3.2^{a}		14.5 ± 0.2^{a}		98.2 ± 2.4^{a}	

Means in the same column followed by the same letter are not significantly at $p<0.05$, F+S: Fenpropathrin+Spinosad, C+S: Chlorpyrifos+Spinosad

Table 5: Latent effects of different pesticides combinations on the pupal weight, pupal duration, adult emergence and longevity of *S. littoralis*

		Pupal mean weight (mg/pupa)±SE		Pupal duration (days)±SE		Adult emergence (%) ±SE		Adult longevity (days)±SE	
Strains	Combinations	F+S	C+S	F+S	C+S	F+S	C+S	F+S	C+S
Laboratory	Spontaneously	181.9 ± 1.4^{d}	229.8 ± 3.6^{d}	8.0 ± 0.1^{b}	10.0 ± 0.4^{b}	65.4 ± 2.8^{c}	75.7 ± 2.2^{b}	6.0 ± 0.6^{d}	8.7 ± 0.5^{b}
	Pre-treated	200.6 ± 5.9^{cd}	211.1 ± 2.5^{d}	9.0 ± 0.3^{b}	9.0 ± 0.2^{b}	71.3 ± 2.5^{c}	68.9 ± 2.4^{c}	6.8 ± 0.4^{c}	8.0 ± 0.2^{c}
	Post-treated	238.8 ± 2.8^{b}	266.2 ± 2.0^{a}	10.0 ± 0.1^{a}	14.0 ± 0.2^{c}	73.0 ± 3.0^{c}	97.7 ± 2.4^{a}	7.2 ± 0.4^{c}	10.9 ± 0.4^{a}
El-monofia	Spontaneously	214.6 ± 5.5^{cd}	254.8 ± 2.4^{b}	8.5 ± 0.2^{b}	10.5 ± 0.3^{b}	67.8 ± 3.7^{c}	81.1 ± 3.0^{b}	6.6 ± 0.5^{c}	9.3 ± 0.3^{b}
	Pre-treated	231.6 ± 1.0^{c}	240.0 ± 4.5^{c}	9.5 ± 0.4^{a}	9.5 ± 0.3^{b}	78.6 ± 1.0^{b}	72.5 ± 1.9^{c}	7.5 ± 0.2^{b}	8.7 ± 0.1^{b}
	Post-treated	242.9 ± 2.6^{b}	267.5 ± 1.8^{a}	10.5 ± 0.4^{a}	16.5 ± 0.2^{c}	80.7 ± 1.2^{b}	98.0 ± 1.1^{a}	7.9 ± 0.1^{b}	11.0 ± 0.3^{a}
Beni-suef	Spontaneously	225.8 ± 2.3^{c}	260.4 ± 2.8^{ab}	9.0 ± 0.2^{b}	11.5 ± 0.3^{a}	79.1 ± 3.6^{b}	87.8 ± 2.1^{a}	7.3 ± 0.2^{c}	9.8 ± 0.4^{b}
	Pre-treated	240.0 ± 1.2^{b}	249.7 ± 4.1^{bc}	10.5 ± 0.3^{a}	11.0 ± 0.1^{a}	82.7 ± 2.3^{b}	83.6 ± 2.7^{b}	8.0 ± 0.2^{b}	9.2 ± 0.2^{b}
	Post-treated	244.5 ± 5.6^{b}	269.1 ± 3.8^{a}	11.0 ± 0.4^{a}	19.0 ± 0.1^{c}	84.4 ± 2.7^{b}	99.0 ± 2.8^{a}	8.5 ± 0.3^{b}	11.5 ± 0.2^{a}
Control	--------------	264.8 ± 4.4^{a}		12.0 ± 0.2^{a}		97.4 ± 2.8^{a}		10.7 ± 0.2^{a}	

Means in the same column followed by the same letter are not significantly at $p<0.05$, F+S: Fenpropathrin+Spinosad, C+S: Chlorpyrifos+Spinosad

Table 6: Latent effects of different pesticides combinations on eggs stage and its sterility effect of *S. littoralis*

		Fecundity (No. of eggs laid/female)±SE		Hatchability (%) ±SE		Sterility (%)±SE	
Strains	Combinations	F+S	C+S	F+S	C+S	F+S	C+S
Laboratory	Spontaneously	328.1 ± 1.2^{c}	244.3 ± 5.8^{c}	56.2 ± 1.2^{d}	64.1 ± 5.8^{c}	48.8 ± 3.3^{d}	63.6 ± 0.4^{c}
	Pre-treated	340.8 ± 1.4^{c}	230.8 ± 4.1^{c}	77.1 ± 1.4^{b}	41.6 ± 4.1^{d}	29.6 ± 1.2^{c}	73.6 ± 4.5^{c}
	Post-treated	444.0 ± 1.3^{b}	544.3 ± 3.7^{a}	80.4 ± 1.3^{b}	91.1 ± 3.7^{a}	23.6 ± 4.9^{b}	17.1 ± 5.7^{b}
El-monofia	Spontaneously	347.6 ± 2.1^{c}	251.1 ± 3.4^{b}	63.5 ± 2.1^{c}	70.9 ± 3.4^{b}	37.5 ± 4.1^{d}	89.2 ± 0.2^{e}
	Pre-treated	351.1 ± 1.4^{bc}	247.5 ± 4.9^{c}	83.6 ± 1.4^{b}	55.9 ± 4.9^{c}	25.5 ± 3.7^{c}	78.8 ± 3.3^{d}
	Post-treated	476.2 ± 0.7^{ab}	547.6 ± 6.2^{a}	88.8 ± 0.7^{a}	92.5 ± 6.2^{a}	20.2 ± 5.3^{b}	10.0 ± 5.0^{a}
Beni-suef	Spontaneously	357.7 ± 5.3^{bc}	272.2 ± 3.1^{b}	72.6 ± 5.3^{c}	76.2 ± 3.1^{b}	31.1 ± 4.4^{c}	91.5 ± 1.8^{e}
	Pre-treated	367.5 ± 1.5^{bc}	265.6 ± 2.7^{b}	87.2 ± 1.5^{a}	60.6 ± 2.7^{c}	11.0 ± 5.0^{a}	82.2 ± 2.6^{d}
	Post-treated	497.6 ± 2.4^{ab}	553.4 ± 1.7^{a}	90.1 ± 2.4^{a}	93.3 ± 1.7^{a}	12.6 ± 5.1^{a}	3.4 ± 4.1^{a}
Control	--------------	542.2 ± 3.4^{a}		98.0 ± 5.1^{a}		0.0 ± 0.0	

Means in the same column followed by the same letter are not significantly at $p<0.05$, F+S: Fenpropathrin+Spinosad, C+S: Chlorpyrifos+Spinosad

Latent effects of spinosad with tested insecticides on some biological aspects of *S. littoralis*: The latest effects were studied on the L-strain and two F-strains of *S. littoralis* the results were presented in Table 4, 5 and 6. Data in Table 4 represented the average weight of treated larvae was decreased significantly compared to control during the observation period. All mixture of spinosad with fenpropathrin was significantly the highest in effect in reducing the larval weight, the same trend was observed when larvae were spontaneously or pre-treated with chlorpyrifos, while when mixture of spinosad post-treated with chlorpyrifos increased the larval weight, where the average larval weight were 241.6, 243 and 248.1 mg/larva for L-strain and two F-strains (El-monofia and Beni-suef, respectively). Also, the results presented in Table 4 showed that the all combinations of tested insecticide significantly increased the larval duration, while when the mixture of spinosad post-treated with chlorpyrifos did not differ significantly compared to larvae given control treatment which recorded 13.5, 14 and 14 days for L-strain and two F-strains, respectively. The tested combinations had a considerable effect on pupation, while when a mixture of spinosad post-treated with chlorpyrifos given 98.3, 98.7 and 99% for L-strain and two F-strains, respectively without significant differences among them. The data presented in Table 5 showed that the combination of treatments exhibited various effects to pupal and adult stages. The average pupal weight for all different combinations of insecticides was significant except the spinosad post-treated with chlorpyrifos. The mixtures significantly decreased the average pupal weight, on the other hand, the mix of spinosad post-treated with chlorpyrifos increased the pupal weight, where the average pupal weight were 266.2, 267.5 and 269.1 mg/pupa for L-strain and two F-strains (El-monofia and Beni-suef, respectively). On the other hand, the all tested combinations highest reduction significantly the pupal duration and adult longevity, while in case of mixture spinosad post-treated with chlorpyrifos prolonged the pupal duration and adult longevity with compared the control. Reduction percentage in the adult emergence rates significantly occurred in all tested combinations, while treatment spinosad post-treated with chlorpyrifos caused the increased in the adult emergence, where the adult emergence percentage was 97.7, 98 and 99% for L-strain and two F-strains, respectively without significant differences among them. The data in Table 6 elucidated the latent effects of different insecticide combinations on the egg stage. The mixture of spinosad with either fenpropathrin or chlorpyrifos decreased the number of laid per female in three different ways. In contrast, the mix of spinosad post-treated with chlorpyrifos increased the number of eggs per laid the obtained values were 544.3, 547.6 and 553.4 for L-strain and two F-strains respectively. The percentage of hatchability was highly data significant affected by all the tested combinations except the spinosad post-treated with chlorpyrifos, which appeared 91.1, 92.5 and 93.3% of hatchability. The efficiency of the different combinations as chemosterilants can be descendingly arranged as follow; spontaneously, pre-treated and post-treated spinosad with fenpropathrin. In contrast, mixtures of spinosad with chlorpyrifos arranged as follow: pre-treated and spontaneously, while it can be concluded that it is not preferred to mix spinosad post-treated with chlorpyrifos which can lead to reducing the efficacy for controlling *S. littoralis*. Also, these tested mixtures negatively affect some biological aspects of *S. littoralis*, these effects are significant from a practical point of view, because offspring can then be reduced and the insect population can be negatively affected. These results agreed with those obtained by using spinosad, *B. thuringiensis* and cypermethrin against the cotton *S. littoralis* larvae were significantly reduced the female longevity, fecundity and fertility compared to control[17,18]. In addition, all binary mixtures of profenofos, emamectin benzoate, spinosad and chlorfluazuron on some biological parameters against *S. littoralis* were negatively effects[19,20].

CONCLUSION

Taken overall, the present study supports the importance of joint toxic action in directing tactics to fight against resistance development for these conventional insecticides where spinosad could be used in mixtures to restore fenpropathrin and chlorpyrifos susceptibility. These findings may have considerable practical implications for *S. littoralis* resistance management.

SIGNIFICANCE STATEMENT

This study discovers the possible synergistic effect of spinosad with fenpropathrin and chlorpyrifos combination that can be beneficial for fighting against resistance development for these conventional insecticides and thus, can be restored its susceptibility against *S. littoralis.*

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