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Efficacy of Common Synthetic Insecticides for Management of Fall Armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Egypt

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ABSTRACT

Being the most invasive and destructive pests in maize fields, the promising insect; is the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). The first onset of fall armyworm in Egypt started in 2019 in the south of Egypt among maize plants in Aswan Governorate. Heading north, the pest spread quickly to Luxor, Qena, Sohag and Assuit governorates in the south. Many synthetic insecticides were recommended to control this insect pest. For this purpose, this research was to evaluate the potential effectiveness and toxicity of the following insecticides, Methomyl (Lannate® 90%), Chlorpyrifos (Dofos 48%) and Spinosad (Tracer 24%) on the biological aspects of *S. frugiperda* in the laboratory. Bioassays were conducted on the newly molted 4th instar of *S. frugiperda* larvae under 25 ± 2 °C room temperature, 70 ± 10% relative humidity. The LC_{50} values were 105.5, 470, and 2.5 ppm for the compounds methomyl, chlorphyrifos, and spinosad, respectively. Distilled water was served to the control group. Accumulative larval mortality percentages were 42, 55 and 44 for methomyl, chlorpyrifos, and spinosad, respectively. A significant increase in the total duration of the consecutive larval instars and pupae was recorded post-treatment at the 4th instar larvae with the LC_{50} concentrations of tested insecticides. Accordingly, the differences were significant in the toxicity to *S. frugiperda*; hence, the variation in LC_{50} is a reference to the varying actions of the tested insecticides. These data indicate that these recommended synthetic insecticides are effective in controlling fall armyworm instars.

INTRODUCTION

In early 2016, the fall armyworm *Spodoptera frugiperda* recorded the first outbreak in West and Central Africa (Goergen *et al.*, 2016). Whilst in Egypt, particulate in Upper Egypt; the Agricultural Pesticide Committee (APC) of the Ministry of Agriculture announced the first case of *S. frugiperda* in May 2019 among a maize yield in Kom Ombo City located in Aswan Governorate (FAO 2019; Dahi *et al.*, 2020). As well, on the 6th of

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August of 2021, fall armyworm began to invade the maize crop in Assuit Governorate, Upper Egypt; where the damage was more severe on sorghum plants (Mohamed *et al.,* 2022).

As a result of the significant damaging influence of *Spodoptera frugiperda* in Africa, 300 million people could be threatened by hunger. *S. frugiperda* has a very broad host extent, and 353 plant species from 76 different plant families, including significant hosts from the Poacaea, Asteraceae, and Fabaceae, have been identified as larval hosts (Casmuz Augusto *et al.,* 2010; CABI 2018; Montezano *et al.,* 2018). This insect can significantly harm crops by decreasing productivity yield and resulting in considerable financial losses (Idrees *et al.,* 2022).

Under optimal conditions, in a single life cycle, a female *S. frugiperda* lays 1500 eggs that overlap on the adaxial face of a corn leaf. Four days after oviposition, the first instar larvae emerge and scrape the leaf, whereas subsequent instars completely consume the leaf, causing severe damage and plant death. The last larval instar is typically found within a leaf sheath (Cruz 1995; Galo *et al.,* 2002; Capinera 2008; Valicente & Tuelher 2009) where it is protected from insecticide applications (Gassen, 1996).

Chemical insecticides have been most commonly used to control pests in plants since they are the most effective, easy to use, and provide satisfactory results. Even with some disadvantages, chemical inputs are vital to the maintenance of high yields in modern agriculture (EPA, 2021).

Neurotoxic insecticides for example chlorfenapyr and methomyl (Viana & Costa 1998) are often applied to control *S. frugiperda* larvae. Nevertheless, these insecticides also can be used for eggs (Travares *et al.*, 2011) and the mature stage of *S. frugiperda* (Pratissoli et al., 2004). Application of insecticides to the larvae of *S. frugiperda* consequently is widen control efficiency.

Methomyl, an oxime carbamate, was the first insecticide has been synthesized in 1968 for the management of many insect classes at the broad range, involving Hemiptera, Lepidoptera, Diptera, Homoptera, and Coleoptera. Similar to various carbamates, Methomyl is able to suppress the acetylcholine (AChE) activity, accompanied by nerve and/or tissue insufficiency and probably death occur. Owing to significant toxicity to varying stages of insects as larva and adult, methomyl is assumed to be highly degraded metabolically via mixed-function oxidase (Van Scoy *et al.,* 2013). Despite of own acute toxicity, rare incidents rise from labeled usage of methomyl, perhaps because of its weak stability, low bioaccumulative activity, and more reversible with speedy dispersal from almost environmental matrices (Mortensen and Serex, 2014).

Furthermore, chlorpyrifos is an insecticide of wide spectrum use that can destroy insects by means of disruption of the nervous system via block of the breakdown of a neurotransmitter AChE (Smegal, 2000). Chlorpyrifos inhibit the breakdown of ACh through binding to the active site of the cholinesterase (ChE) in the synaptic cleft. As a result, excess ACh accumulates in synaptic clefts, which results in neurotoxicity and eventual death for the neurons (Karanth *et al.,* 2000).

Ultimately, spinosad is an insecticide obtained naturally from an actinomycete bacterium species, *Saccharopolyspora spinosa* (Mertz and Yao 1990) that confer the efficiency of a synthetic insecticide. It is composed of spinosyn A and D which are designated the two most active metabolites. Both spinosyns are readily degraded in moist aerobic soil, and field dissipation, which is quite rapid (half-life, 0.3-0.5 d) can be attributed to photolysis or a combination of metabolism and photolysis. Spinosad induces neurologic impacts in insects that are appropriate to the general stimulation of nicotinic acetylcholine receptors but by a novel mechanism among familiar insecticide compounds. Spinosad is considered more efficient for lepidopteran larvae, in addition to some Diptera, Thysanoptera, Coleoptera, and Hymenoptera, however, it exhibits limited toxicity to other insects and reveals less activity to mammals and wildlife.

Wherefore, the aim of this work was to estimate the efficiency of the known used synthetic insecticides methomyl, chlorpyrifos and spinosad against new invasive pests in Egypt and study their biological effects on the pest like larval mortality percentage, larval duration, pupation percentage, pupal weights of both sexes, pupal duration of male and female, pupal mortality percentage, adult emergence, sex ratio, male and female longevity, fecundity and fertility % for developing an emergency-based approach by novel insecticides for reducing crop wastes by repressing this notorious pest in Egypt and other influenced countries.

MATERIALS AND METHODS

The current design was established for studying the effect of methomyl, chlorpyrifos and spinosad insecticides toward newly moulted 4th of *S. frugiperda* larvae.

Test Insect:

The culture of FAW was initiated with larvae gathered from maize cultivation at Qena province existed in Upper Egypt. Where they were kept at the laboratory for several generations and reared in laboratory environments under controlled 25 ± 2 °C, 70 ± 10 % RH), and fed on castor leaves according to Dahi (1997). Larvae have daily provided and fed on castor bean leaves. The resultant pupae were placed in clean moist sawdust jars to supply the pupation site. But adults were supplied 10 % sugar solution.

Insecticides:

Commercial formulations of the most applied insecticides belonging to various chemical groups were used. The insecticide concentrations assigned in this study were Methomyl (Lannate® 90), Chlorpyrifos (Dofos 48%), and Spinosad (Tracer 24%) (Table 1). The concentrations used for each insecticide were 180, 90, 45 and 22.5 ppm for methomyl, 1000 ppm, 600 ppm, 500 ppm, 250 ppm, 200 ppm and 125 ppm for chlorpyrifos and 5 ppm, 3 ppm, 2 ppm, 1 ppm, 1.5 ppm, and 0.5 ppm for spinosad.

Bioassay of Tested Compounds on *S. frugiperda* (Smith):

The larvicidal efficiency of the studied compounds was estimated on newly moulted 4th of *S. frugiperda* larvae. Each of the prepared concentrations of tested compounds was immersed in fresh castor oil leaves; then allowed to dry at room temperature prior to being offered to the 4th instar larvae preserved in ice cube packs. Larvae were awarded contaminant leaves for a period of 24 hours. Each handling involved 50 larvae which were replicated five times. The control comprised similar numbers of larvae, and given castor oil leaves immersed in distilled water. The mortality percent of the larvae was calculated post-exposure by 24 h. and corrected according to Abbott's formula (1925). The obtained results were expressive graphically and LC_{50} values were calculated using computerizing LDP line plots.

Table 1. Insecticide formulations tested against *S. frugiperda* larvae including active ingredients, formulation type, manufacturer, chemical group and respective mode of action.

Common name	Trade name	Manufacturer	Chemical group	Mode of action
Methomyl	Lannate 90% S P	DuPont de Nemours, USA	Carbamate	Acetylcholinesterase (AChE) inhibitors
Chlorpyrifos	Dofos 48% EC	chema_industries -Elisra_Industries	Organophospourus	Acetylcholinesterase (AChE) inhibitors
Spinosad	Tracer 24% SC	UK Dow Agrosciences	5, Spinosyns	Nicotinic acetylcholine receptor (nachr) allosteric modulators - site i

Biological Studies:

Fresh castor oil leaves were immersed in the LC_{50} for each insecticide and then left to dry at room temperature before being offered contaminated leaves as before for each compound. 50 larvae were comprised in each treatment enclosed by five times replication (10 larvae/ice cube packs). The same number of larvae were considered a control; these larvae were offered castor oil leaves immersed in distilled water. The following parameters were recorded: larval mortality percentage, larval duration, pupation percentage, pupal weight, male pupal weight, female pupal weight, pupal duration, male pupal duration, female pupal duration, pupal mortality percentage, adult emergence, sex ratio, male and female longevity, fecundity (Number of eggs laid per female) and fertility percentage (Egg hatchability).

Statistical Analysis:

The current data were subjected to analysis of variance (ANOVA) using the software package SPSS Statistics version 25 (New York, USA). The significance of variable treatments was determined by Duncan test ($p<0.05$). Lethal concentrations at LC_{50}, 95% confidence limits (CLs) and slope were calculated using the Ldp Line software according to Finney (1971).

RESULTS

Effect of Toxicity by Insecticides on 4th Instars Larvae of *S. frugiperda*:

As represented in Table 2, the toxicity by methomyl, chlorphyrifos, and spinosad on the 4th larval instar of *S. frugiperda* varied according to their concentrations and chemical structure. Overall, the high concentration attended by a rise in mortality rate, and conversely.

The LC_{50} values were 105.5, 470 and 2.5 ppm for methomyl, chlorphyrifos, and spinosad, respectively. Correspondingly, the most effective chemical was spinosad, followed by methomyl, then chlorphyrifos. The results proved the toxicity effect on *S. frugiperda* was different. Moreover, variations in LC_{50} values perhaps reflected the different modes of action of insecticides.

Table 2. The toxicity of the insecticides on the 4th larval instar of fall armyworm, *S. frugiperda*.

Insecticide	Concentrations (ppm)	Mortality %	Corrected mortality %	LC_{50} (ppm)	Slope
Methomyl	180	74	73.45	105.5	2.816
	90	44	42.86		
	45	18	16.33		
	22.5	4	2.04		
	Control	2			
Chlorpyrifos	1000	92	92	470	3.87
	600	66	66		
	500	50	46		
	250	14	14		
	200	8	8		
	125	2	2		
	Control	0.0			
Spinosad	5	80	80	2.5	1.938
	3	46	46		
	2	44	44		
	1	40	40		
	1.5	22	22		
	0.5	10	10		
	Control	0.0			

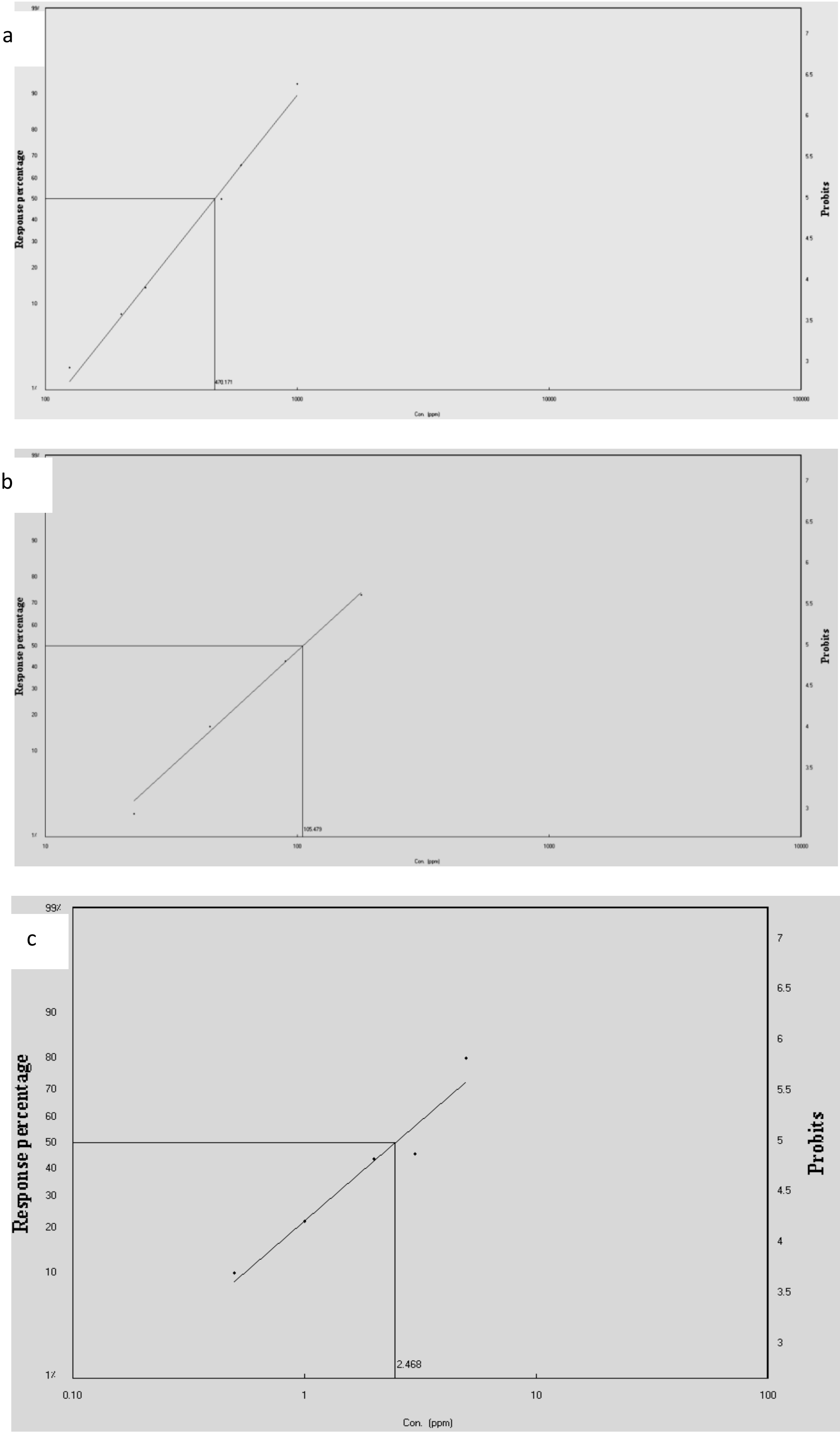

Fig. 1. The toxicity LDP line of the insecticides used on the 4th larval instar of fall armyworm, *S. frugiperda*, a) Chlorpyrifos b) Methomyl c) Spinosad

1- Latent Effect of LC_{50} of Methomyl on Some Biological Aspects of 4th Instars *S. frugiperda* Larvae:

1.1-Effect on the Larvae Development:

Under conditions of the present work, the duration of the initially treated instar (i.e., newly ecdysed 4th instar larvae) with LC_{50} of methomyl, plus the subsequent 5th and 6th larval instars and up to pupation, was a total of 12.93±0.21 days. Meanwhile, control data expressed that the development of untreated larvae from the start of the 4th instar up to the initiation of the pupal stage was 11.09±0.28 days. This shows that as a result of the treatment the larval stage was extended by 1.84 days compared to the equivalent control (Table 3).

The accumulative larval mortality percentage was 42 % for the 4th instar larvae exposed to LC_{50} methomyl at the termination of the larval stage and prior to pupation. This percentage was 3% in untreated larvae (Table 3).

1.2- Effect of LC_{50} Methomyl on *S. frugiperda* Pupae Treated As 4th Instar Larvae:

As illustrated in Table 3, the percentage of pupation was 58% among the recently produced 4th instar larvae following subjected to LC_{50} methomyl. The percentage of pupation was 97% in untreated larvae.

The mean weight of a pupa in the control was 0.1824±0.01 g; a female pupa weighed slightly less than a male pupa, 0.1737±0.004 g and 0.1923±0.004 g, respectively. The mean weight of pupa following its treatment as 4th instar larvae with LC_{50} of methomyl was 0.1998 g, which was not significantly different from their control. As depicted in Table 4, the weight of the female and the male pupae were comparable, being 0.1927±0.004 g and 0.2152±0.006 g, respectively. The pupal mortality reached 6% in treatment as well as in the control.

The mean duration of the pupal stage in the control group averaged 11.29±0.47 days, this period was 11.28±0.54 days when larvae were treated as 4th instar. It is noteworthy that the duration of the pupal stage, whether male or female, in treated 4th instar larvae, didn't significantly change from that in the untreated insects (Table 4).

1.3- Effect on Adult Emergence and Reproductive Potential of Moths from Treated 4th Instar *S. frugiperda* Larvae with LC_{50} Methomyl.

Adult emergence was impaired following treatment of *S. frugiperda* larvae with LC_{50} of methomyl. This effect was 94 %, as it was in their control (Table 4).

As seen in Table 5, normally, the sex ratio of emerging moths is 1:1 (male: female); however, in moths protruding from 4th larvae dealing with LC_{50} of methomyl, the sex ratio was 1:1.4 (male: female). The average life span of adult females for the control moth was 11.25 days, represented by a mean of 3.0±0.71, 6.0±0.41 and 1.0±71 days for pre-oviposition, oviposition and post oviposition period, respectively. The life span of the emerged moths from 4th instar larvae treated with the LC_{50} methomyl was 10.5±0.29 days. Whereas, the pre-oviposition, oviposition, and post-oviposition periods were 3.0±0.41, 6.75±0.63 and 0.0 days, respectively. The reproduction potential of moths emerging from treated larvae was also highly significantly reduced (Table 5). The totality of eggs deposited per female was 1991.25±45.0 eggs per female with 90 percent egg hatchability. In comparison, females in their respective control group deposited 2202±105.17 eggs/ female with 98 % egg viability. The incubation periods for the second generation eggs were 2.75± 0.25and 2.75± 0.25 days for (treated and control) *S. frugiperda* eggs when treated as 4th instar larvae treated with LC_{50} of methomyl, as shown in Table (6).

2- Effect of LC_{50} of Chlorpyrifos on Some Biological Aspects of 4th Instar *S. frugiperda* Larvae:

2.1-Effect on the Development of Treated Larvae:

Following treatment of the 4th instar with LC_{50} of chlorpyrifos, the mean development period of the subsequent larval instars was significantly extended. As seen in Table 3, larval development took 13.89±0.07 days following the initial treatment (4th instar) up to pupation, as compared to 11.09±0.28 days in their respective control group. The accumulative mortality of the larvae was 55% at the end of the larval stage for 4th instar. Of the surviving larvae; 45% were successfully pupated in the respective treated instar, as compared to 97% of the untreated larvae (Table 3).

2.2- Effect of LC_{50} Chlorpyrifos on *S. frugiperda* Pupae Treated as 4th Instar Larvae.

Data presented in Table 4 mean weight of pupa developing from 4th instar larvae treated with LC_{50} chlorpyrifos was 0.2292±0.01 g, respectively, which significantly exceeded the weight of control pupa. This was obvious in both female and male pupae.

It is noteworthy, that the duration of the pupal stage, whether male or female developed from treated 4th instar larvae was comparable and insignificantly similar to untreated insects (Table 4). Furthermore, the mortality of pupae was relatively low reaching 7 % in pupae treated as 4th instar, compared to 6% in the respective control. The percent of malformed pupae was 6.0 % as compared to zero % in the control.

2.3- Effect on Adult Emergence and Reproductive Potential of Moths from Treated 4th Instar *S. frugiperda* Larvae with LC_{50} Chlorpyrifos.

Table 4 exhibited that percentage of adult eclosion was relatively unaffected as a result of the treatment of 4th *S. frugiperda* larvae by LC_{50} chlorpyrifos. In this respective mentioned instar, adult emergence was at a high of 94%, which was only slightly decreased from their control by 1 %. The sex ratio in emerged moths from untreated larvae was equal to 1:1 (male: female) however, this ratio was slightly in favor of an increase in female moths (1: 1.3) emerging from 4th instar larvae treated with LC_{50} chlorpyrifos.

Under the laboratory conditions of the current work, the life span of female *S. frugiperda* treated with LC_{50} chlorpyrifos averaged 11.83±2.48days, giving a pre-oviposition, oviposition, and post-oviposition period of 2.25±0.25, 7.5±0.29 and 0.75±0.48 days, respectively Table 5. A female moth deposited 2166±105.53 eggs with 85% hatchability Table 6.

3-Effect of LC_{50} of Spinosad on Some Biological Aspects of 4th instar *S. frugiperda* larvae

3.1-Effect on the Development of Treated Larvae:

As exhibited in Table 3, 4th instar *S. frugiperda* larvae when treated with LC_{50} of spinosad caused a significant extension of 2.62 days in the duration of the larval stage, i.e., 13.71±0.1 days versus 11.09±0.28 days in the control.

Larval mortality percentages were 44 % and 3 % at the termination of the larval stage in treated and untreated larvae, respectively, giving a respective pupation percentage of 56% and 97 % (Table 3).

3.2- Effect of LC_{50} Spinosad on *S. frugiperda* Pupae Treated as 4th Instar Larvae.

As seen in Table 4, the mean weight of a newly formed pupa was 0.2261 g, following their treatment as 4thinstar larvae with LC_{50} of spinosad was significantly more than the control. This was evident in both female and male pupae.

The duration of the pupal stage, being male or female in treated 4th instar larvae was a non-significant difference from that in untreated insects (Table 4).

The percent of malformed pupae was 6.0 % as compared to zero % in the control.

3.3- Effect on Adult Emergence and Reproductive Potential of Moths from Treated 4th Instar *S. frugiperda* Larvae with LC_{50} Spinosad.

As observed in Table 4, in the treatment of 4th instar *S. frugiperda* larvae with LC_{50} spinosad, the percentage of adult eclosion was slightly reduced to 79% as compared to 94 % in the control. The Percentages of malformed moths were much higher in moths developed from treated 4th instar larvae (7.0%). The sex ratio in moths that emerged from the treated 4th instar was 1:1.7 (male: female) Table 5.

Under the conditions of the present work, the life span of a female moth in control averaged 11.0 days, giving 3.0±0.71, 6.0±0.41and 1.0±0.71 days for the pre-oviposition, oviposition and post oviposition periods, respectively. The average of deposited eggs was 2202.5 eggs per female, with 98% egg viability.

Emerged moths from 4th instar larvae treated with LC_{50} spinosad had a life span of 11.0 days. In the treated larval instar, the periods for pre-oviposition, oviposition and the post oviposition stages were not affected. The reproductive potential of these moths was significantly reduced. The mean number of deposited eggs was 2006.75 eggs per female in emerged moths from the treated 4th instar larvae, with respective egg viability of 90%.

Table 3: Effects of LC_{50} concentrations of the tested insecticides on the larval stage of *S. frugiperda*

Biological aspects	Control	Methomyl	Chlorpyrifos	Spinosad
Larval duration (days)	11.09 ± 0.28 C	12.93 ± 0.21 b	13.89 ± 0.07 a	13.71 ± 0.1 a
Pupation %	97	58.0	45.0	56.0
Larval mortality %	3	42.0	55.0	44.0
Normal larvae %	100	100	100	100
Malformed larvae %	0.0	0.0	0.0	0-.0

➢ The means that have the same letter horizontally are insignificant.

Table 4: Effects of LC_{50} concentrations of the tested insecticides on pupal stage of *S. frugiperda*.

Biological aspects	Control	Methomyl	Chlorpyrifos	Spinosad
Pupal durations (days)	11.29 ± 0.47 a	11028 ± 0.54 a	10.74 ± 0.01 a	10.58 ± 0.33 a
Female pupal durations (days)	10.44 ± 0.26 a	10.8 ± 0.27 a	10.0 ± 0.2 a	10.3 ± 0.43 a
Male pupal durations (days)	12.17 ± 0.23 a	12.38 ± 0.43 a	11.50 ± 0.2 ab	11.09 ± 0.31 b
Normal pupae %	100	100	94.0	94.0
Malformed pupae %	0.0	0.0	6.00	6.00
Pupal weight (gm.)	0.1824 ± 0.01 c	0.1998 ± 0.01 bc	0.2292 ± 0.01 a	0.2261 ± 0.01 ab
Female pupal weight (gm.)	0.1773 ± 0.004 c	0.1927 ± 0.004 b	0.2137 ± 0.001 a	0.2126 ± 0.008 a
Male pupal weight (gm.)	0.1923 ± 0.004 a	0.2152 ± 0.006 a	0.2495 ± 0.011 b	0.2451 ± 0.001 b
Pupal mortality %	6.0	6.00	7.0	21.0
Emergence %	94.0	94.0	93.0	79.0

➢ The means that have the same letter horizontally are insignificant.

Table 5: Effects of LC_{50} concentrations of the tested insecticides on adult stage of *S. frugiperda*.

Biological aspects	Control	Methomyl	Chlorpyrifos	Spinosad
Adult malformation %	0.0	0.0	0.0	7.0
Sex ratio % (♂ : ♀)	1:1	1:1.8	1:1.3	1:1.7
Adult longevity (days)	12.0 ±1.08 a	11.75 ±1.11 a	11.83±2.48 a	12.25±0.75 a
Female longevity (days)	11.25 ±0.85 a	10.5 ±0.29 a	11.0 ±0.58 a	11.0 ±0.0 a
Male longevity (days)	13.75 ±1.25 a	11.75 ±1.11 a	14.0 ±0.41 a	13.5 ±0.5 a
Pre-oviposition period (days)	3.0 ±0.71 a	3.0 ±0.41 a	2.25 ±0.25 a	3.0 ±0.29 a
Oviposition period (days)	6.0 ±0.41 b	6.75 ±0.63 ab	7.5 ± 0.29 a	6.0 ±0.41 b
Post-oviposition period (days)	1.0±0.71	0.0	0.75±0.48	0.0
Fecundity (No. eggs / female	2202.5±105.17 a	1991.25±45.0 a	2166.5±105.53 a	2006.75±157.22 a

➢ The means that have the same letter horizontally are insignificant.

Table 6: Effects of LC_{50} concentrations of the tested insecticides on egg stage of *S. frugiperda*.

Biological aspects	Control	Methomyl	Chlorpyrifos	Spinosad
Hatchability %	98	90	85	90
Incubation period (days)	2.75 ± 0.25 a	2.75 ± 0.25 a	3.0 ± 0.0 a	2.75 ± 0.25 a

- The means that have the same letter horizontally are insignificant.

DISCUSSION

In the existing work, known-applicable three insecticides; methomyl, chlorphyrifos, and spinosad have been chosen against 4th instar larvae of *S. frugiperda* to evaluate their toxicity and their latent effect on the larvae, pupae and emerged adults

The findings of the current investigation demonstrated that all of the synthetic insecticides tested were significantly effective against *S. frugiperda* larvae in their 4th instar. Researchers from all over the world have recently extensively examined the different possible management tactics used to combat FAW in Africa and India**,** were among the regions where registered pesticides were tested in the field and laboratory as an emergency measure after this invasive insect severely harmed the maize crop (Kumela *et al.,* 2019; Kassie *et al.,* 2020), (Kumar, and Mohan 2022, Kumar *et al.,* 2023). However, this was the first investigation to assess the toxicity of these specific pesticides to *S. frugiperda* larvae in a laboratory setting in Egypt.The findings of the current investigation showed that *S. frugiperda* larvae in their fourth instar were susceptible to these synthetic pesticides; nonetheless, Chlorpyrifos was the most effective one on the 4th instar *S. frugiperda* larvae, followed by spinosad and then methomyl. Based on fiducial limits at 95%, there were significant differences in $LC_{50's}$ among the tested insecticides, Insecticide toxicity regression lines showed homogeneity between tested populations and tested insecticide concentrations. The current study's findings are in accordance with (Viana & Costa 1998). Also, Ahissou *et al.,* (2021) mentioned that methomyl, abamectin benzoate and chlorpyriphos-ethyl are extremely effective insecticides from different seven insecticides used against the 3rd larvae instar fall armyworm in Burkina Faso. Spinosad provided excellent control of beet armyworm, meanwhile, pyridalyl was lower in efficiency (Mascarenhas *et al.,* 1997 and Torrey *et al.,* 1999). A notable increase was observed in the total duration of the sequent larval instars after the 4th instar *S. frugiperd*a larvae treated with methomyl, chlorphyrifos and spinosad at LC_{50} concentrations. Clinical manifestations due to toxicity were in the form of nervous tremors of the thoracic legs and mouthparts and the larva become was unable to feed. Hence, prolongation of the larval instars and a reduction in the pupation percentage and adult emergence were the results of impairment in the feeding of treated larvae. A study by Abdel-Rahim (2011) showed that second and fourth larval instars of *S. littoralis* deal with pyridalyl and methomyl prolonged the duration of the treated *S. littoralis* larva than their control. The results of this study indicated that the larval duration of the 4th instar treated with methomyl was significantly increased (p=0.01) to an average of 17 days, compared to 12 days for the control group. Chlorpyrifos and Spinosad insecticides at sub-lethal concentration enhanced deterrent activity feeding of *S. litura* larvae (Singh and Sohi, 2007). Further, it was noticed that *P. gossypiella* of the larval stage treated by LC_{50} Radiant (spinetoram) exhibited an extension in larval and pupal developmental periods (El-Barkey *et al.,* 2009). Abd El-Kareem (2016) found that mortality rates gradually increased at 2nd and 4th instar larvae of *S. littoralis* when fed on treated cotton leaves with LC_{50} of tested bioinsecticide included Protecto® (*Bacillus thuringeinsis* kurstaki), Viruset® (*Spodoptera littoralis* NPV), and Profect® (mixture of BTK & SLNPV) until reaching the 5th-day post application.

Interestingly, for unknown reasons, our results showed that the male and female pupal stage duration was not affected by the LC_{50} concentration of the three tested insecticides for 4th instar *S. frugiperda* larvae. While exposure to chlorpyrifos or spinosad significantly increased the weight of the sequential pupal stage, this can be explained by the original weight of the larvae and its effect on the insecticides. These results are agreeing with Ismail *et al.* (2022), who treated *S. littoralis* with five different insecticides among them spinosad. They found that the larval duration increased and spinosad was superior in its residual effect on 2nd and 4th larvae.

Treatments 4th instar *S. frugiperd*a larvae with LC_{50} of spinosad led to a decrease in the percentage of adult emergence. Quite similar results were obtained by Abouelghar *et al.* (2013), When treated cotton leafworm with sublethal and lethal doses of spinosad, reductions in adult emergence, fecundity and fertility.

Treatment with LC_{50} values of the three aforementioned insecticides was insignificantly reproductive potential for the tested pest. Meanwhile, the lowest Egg hatchability was recorded in 4th instar *S. frugiperd*a larvae treated by chlorpyrifos followed by methomyl and spinosad was the same. Similarly, El-Barkey *et al.* (2009) revealed that spinetoram resulted in a significant lowering in the deposited *P. gossypiella* female eggs.

Thus, in addition to inadequate dietary intake and impaired, it's probable that lethal doses of chlorpyrifod fed to FAW had an impact on the insect metabolism after treatment with the insecticide. Besides, delays in insect development are a minor manifestation of endocrine processes and have hormonal effects as shown in Yang *et. al.* (2023) who discovered that fall armyworm (FAW) larvae when exposed to LC_{30} chlorantraniliprole induced a deceleration in the production of juvenile hormone esterase (*SfJHE*) which have implications for their development and survival, as JH plays a critical role in regulating insect growth and metamorphosis.

The obtained results of the present work show the extent of the importance of methomyl, chlorphyrifos, and spinosad for the invasive eradication of the pest *S. frugiperd*a in Egypt. Each of the three insecticides exhibits a different and untraditional mode of action in treated insects. At the same time, it's important to have a wide range of insecticides that kill pests right away and effectively. The obtained results would be important in preventing or delaying the appearance of resistance in treated insects and therefore considered in an IPM program for the control of these economically important and invasive lepidopterous insects. Follow up physiological studies are ongoing to evaluate the effect of these three insecticides on the FAW body enzymes

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The Ethical Approval:

The experimental procedure concerning this work was conducted and approved by the Institutional Review Board for Animal Experiments of South Valley University according to the Ethical Guidelines for the Animals Handling in laboratory experiments of the Faculty of Science, South Valley University, Qena, Egypt (approval no. 010/11/22).

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