Efficacy of certain chemical and bio-insecticides on potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) under laboratory conditions.

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ABSTRACT

The potato tuber moth *Phthorimaea operculella* (Zeller) is the most destructive pest of potato crop in Egypt. The effect of six compounds on this insect was studied under laboratory conditions. These compounds were Tracers 24% SC (spinosad), Coragen 20% SC (chlorantraniliprole), Malathion 57% EC (malathion) and three different commercial formulations from *Bacillus thuringiensis* such as Agerin 6.5% W.P., Dipel 2x 6.4% WP and Protecto 9.4% WP. The LC_{50} values of the tested compounds were 0.2008, 0.8257, 1.0445, 0.1568, 0.2525 and 0.1844 ppm, respectively. These experiments were carried out in the same Department. Dipel 2x, Protecto and Agerin prolonged the duration of larval stage significantly when compared with other tested treatments including control, respectively. However, the tested compounds reduced the pupation rate when compared with the control, while, the highest pupation were 60% for both Malathion and Protecto insecticides, 56.67% for Dipel 2x, 53.33% for Agerin, 46.67% for Coragen and 43.33% for Tracer. The number of adults was significantly reduced in all treatments comparing with the untreated. Moreover, Tracer, Coragen and Malathion were significantly prolonged females preoviposition period compared to control. On the other hand, Tracer treatment was a significantly elongated oviposition comparing with reminds treatments including control. Moreover, there were significant decreases in the number of eggs laid females^{-1} resulted from Tracer, Protecto, Agerin and Dipel 2x treatments, respectively. Also, there were high reduction percentages in eggs hatchability with Coragen treatment. Coragen have the highest significant elongation of life span when compared with other treatments including the untreated control.

Kaywards: potato tuber moth (PTM) *Phthorimaea operculella,*spinosad, chlorantraniliprole, malathion and *Bacillus thuringiensis* insecticides.

INTRODUCTION

The importance of the potato *Phthorimaea operculella* as a key food source in the global diet is evident both by the quantity produced and by its nutritional value. Potatoes are produced throughout the world and are grown both during the summer in temperate areas of the northern hemisphere and during the winter in subtropical areas (Gavara *et al.*, 2021). Potato is a product known by the general public for its undeniable agronomic interest. It constitutes one of the most important crops for human nutrition worldwide and is a healthy source of carbohydrates, high quality protein, essential vitamins, minerals and trace elements (Hannour *et al.*, 2017). Egypt ranks among the world's top potato exporters (Mohamed *et al.*, 2013) and the whole cultivated area was 423000 fed., which produces 5200000 tons by average of 12.29-ton . in 2019 of all seasons (Anonymous, 2019). Ensuring the sustainable production of potato is an important challenge facing agriculture globally. Insect pests are major biotic constraints affecting potato yields and tuber quality (Kroschel *et al.*, 2020).

Potatoes are infested by *Phthorimaea operculella* (Lepidoptera: Gelechiidae) which is a harmful insect causes destruction to many economic crops all over the world (Sabbour, Magda and Solieman, Nayera, 2020). The (PTM) is one of the most economically significant insect pests for potato in both field and storage worldwide (Zheng *et al.*, 2020).Potato is one of the major food crops in the world. The damage due to (PTM) in the field and storage has been major issue to various countries and researchers. It can cause damage up to 100% if the potato is left untreated in the stores (Aryal and Jung, 2015). The potato tubers can be exposed to several generations of the PTM. They can be destroyed under non-refrigerated storage conditions within a few months if the tubers are not treated against this pest (Kroschel *et al.*, 2020). Potato tuber moth by making irregular tunnels leaves excreta behind and led to a considerable yield loss (Imam, Iman and Usama, 2019). Potato tuber moth is the most destructive pest of stored potato tubers in Egypt (Azab *et al.*, 2018).

Recently, natural plant products such as extracts, powders and oils, bio-insecticides (such as spinosad, protctor and biological control agents (BCAs) such as the parasite wasp Trichogramma) which are mammalian safe and effective on the insect control are presently used as alternatives for chemical insecticides (Azab*et al*., 2018). Liu *et al*. (2017) tested 23 insecticides on lepidopteran moths and reported that sublethal concentrations of spinosad significantly reduced oviposition. Also, Chlorantraniliprole was highly effective when compared to a wide variety of insecticides including profenofos, chlorpyrifos, quinalphos, phoxim, triazophos, methomyl and thiodicarb have been reported from South Asia.

Many sublethal effects of insecticides were addressed for several chemical groups, such as diamide, insect growth regulators (IGRs), neonicotinoids, organochlorides, organophosphates, pyrethroids and others. The sublethal effects may be manifested as reductions in life span, development rates, population growth, fecundity, fertility, changes in sex ratio, deformities, changes in behavior, feeding, searching and oviposition. Thus, toxicants can exert subtle as well as overt effects that must be considered when examining their total impact (De França *et al*., 2017).

Therefore, the aim of this study is to investigate the effect of spinosad, chlorantraniliprole**,** malathion,at three different commercial formulations of *Bacillus thuringiensis* (Agerin 6.5% W. P,.Dipel 2x 6.4% WP and Protecto 9.4% WP). Insecticides under laboratory condition on PTM larvae includes; evaluation of the abovementioned insecticides and their delayed effects against newly hatched larvae of *Ph. operculella.*

MATERIAL AND METHODS

The experiments were carried out at the laboratories of the Department of Plant Protection, Faculty of Agriculture, Cairo, Al-Azhar University.

Rearing process and protocol:

A laboratory stock culture of *Phthorimaea operculella* that started with eggs was obtained from the experimental field. Eggs were kept in glass jars (15x15x20 cm^3) with a small potato tuber as food, the containers should be covered/closed by means of fine gauze material fitted tightly over the opening with a large elastic band. Any filter paper will do, but the thin tissue paper or filter paper (Watman® No.2 with a 70 mm diameter) should be used as the substrate for better egg laying. It is placed flat on the upper outside of the fine gauze material with glass Petri dish (20 mm diameter) as weight on top. The weights ensure contact of the tissue paper/filter paper with gauze material. The thin tissue paper/filter paper will allow enough circulation of air and will not negatively influence the moths.

Consequently, moths lay their eggs on the underside through the gauze material onto the paper. The tissue/filter paper is removed and replaced every morning. With this method, eggs can be removed without opening the container. Adults should keep at least for 5 to 7 days in the rearing container. Moths mate during the first day after hatching and start laying eggs normally on their second day in the container. Eggs are only collected on days two and five and moths lay most eggs on the third and fourth days. The collected eggs should be stored at 4 ˚C (to slow down its development temporarily). After seven days moths rearing, it will stop eggs laying. These adults with container should be placed in a deep freezer at -20 ˚C for two to three days that kills all moths and any eggs that may be left inside the container (Maharjan and Jung, 2011).

Feeding:

The glass jar was provided with Pads of cotton soaked with a 10% sugar solution and covered with fine gauze material fitted tightly over the opening with a large elastic band, and sugar solution were replaced daily (Maharjan and Jung, 2011).

Final testing for each insecticide use was initiated only after preliminary studies which were conducted to determine best practices for conducting bioassays with neonate larvae of potato tuber moth *Ph. operculella* on treated leaf discs.

The experiment was carried out to evaluate the efficacy of six insecticides on neonate larvae of potato tuber moth *Ph. operculella*. The tested concentrations were; 0.10, 0.15, 0.30, 0.50, and 0.75 ppm for Tracer, 0.20, 0.50, 1, 2 and 5 ppm for Coragen, 0.10, 0.15, 0.50, 1, and 5 ppm for Malathion, 0.10, 0.15, 0.30, 0.45 and 0.60 ppm for Diple 2x, 0.1, 0.15, 0.3, 0.4 and 0.5 ppm for Protecto and 0.05, 0.10, 0.15, 0.30 and 0.40 ppm for Agerin. The cabbage, *Brassica pekinensis* leaf discs (40 mm diameter) were selected for testing instead of potato leaves because they would last the duration of the trials (up to 14 days) without wilting as severely as potato leaves. The LC_{25}, LC_{50} and LC_{90} values were determined using the leaf dipping technique. Cabbage leaf discs were dipped for 30 seconds in the above-mentioned concentrations for each insecticides. The leaf disks were then allowed to dry for one hour at which time ten neonate larvae (<24 hours post hatching) were individually placed on each disk by a small paintbrush. Three replicates were used for each concentration of each treatment,in addition to leaves dipped in water served as control. After placing all larvae, bioassay containers were held in an incubator at 27 ˚C ±2. Each replicate was evaluated at 24, 48, 72 and 96 hours after larval placement on leaves. Containers holding the treated leaf disks were examined under a dissecting microscope to count total numbers of live and dead larvae. Larvae were considered dead if they did not move when prodded or if larvae took longer than five seconds to roll over when oriented with their dorsal surface facing the substrate.

Percentages of mortality were corrected when needed according to Abbott's formula (Abbott, 1925).

The parameters were recorded as follows:

Adult longevity (days) reduction%, fecundity (number of deposited eggs female), egg hatchability%.

The Sterility % was calculated by Toppozada *et al*. (1966) formula as follow:

Sterility % = {1 - (a x b / A x B)} x 100.

Where:

A = Number of eggs laid female^{-1} in the untreated group.

B = Percent of hatchability in the untreated group.

a = Number of eggs laid female^{-1} in the treated

b = Percent of hatchability in the treated.

Statistical methods:

The obtained data were statistically analyzed with one-way analysis of variance (ANOVA) (*P<0.05*) according to Snedecor and Cochran (1980), and multiple range test means were analyzed by using method of Duncan (1955).

RESULTS AND DISCUSSION

The experiments were carried out under laboratory conditions to determine the toxicities of examined insecticides [i.e., spinosad 24% SC, chlorantraniliprole, malathion and *Bacillus thuringiensis* at three different products (Dipel 2x 6.4% WP, Protecto 9.4% WP and Agerin 6.5% W.P.)] to newly hatched larvae of potato tuber moth. The concentration mortality regression lines of the tested compounds were designed and LC_{25}, LC_{50} and LC_{90} values were estimated. The mortality percentages were calculated and corrected using formula described by Abbott's (1925).

Biological effects:

Results in Table (1) showed the biological efficacy of spinosad 24% SC, chlorantraniliprole, malathion and *Bacillus thuringiensis* at three different formulations (Dipel 2x 6.4% WP, Protecto 9.4% WP and Agerin 6.5% W.P.) against newly hatched larvae of potato tuber moth.

The LC_{50} values of the tested compounds were 0.2008, 0.8257, 1.0445, 0.2525, 0.1844 and 0.1568 ppm with upper and lower confidence limits of 0.2263 and 0.1763 for Tracer, 1.0219 and 0.6589 for Coragen, 1.5773 and 0.7274 for Malathion, 0.3506 and 0.1752 for Dipel 2x, 0.2071 and 0.1628 for Protecto and 0.1827 and 0.1293 for Agerin, respectively.

Latent effects on potato tuber moth:

The data tabulated in Table (2) and illustrated in Fig (1) demonstrated the delayed effects from LC_{50} values of tested insecticides against newly hatched larvae of potato tube moth compared to the untreated one. The results showed that in Table (2) and Fig (1) Dipel 2x, Protecto and Agerin insecticides prolonged the duration of larval stage significantly compared with other treatments including control, when the estimated periods were 14.33, 14.33, 14.00, 13.00, 13.00 and 12.66 days/larvae for Agerin, Protecto, Dipel 2x, Coragen, Malathion and Tracer, respectively, compared to 12.66 days for untreated.

However, the tested compounds reduced the pupation rate compared with the untreated control as shown in (Table 3 and Fig 2); the highest pupation were 60% for both Malathion and Protecto, while 56.67% for Dipel 2x, 53.33% for Agerin, 46.67% for Coragen and 43.33% for Tracer where all values were less than the control value.

Therefore, the effect of the tested insecticides on the pupal stage of PTM indicated that there was an increase in the number of pupae in all treatments compared to control but there were insignificant increases between all treatments themselves and control. The results indicated that there were insignificant increases in pupal weights between all treatments including untreated control.

Regarding the data presented in Table (4) and illustrated in Fig. (3): resulted from tested insecticides on the adult stage of PTM. The data clearly indicated that the number of adults was significantly reduced in all treatments compared with the untreated one, where the recorded adult numbers were 04.00, 04.66, 06.00, 05.33, 05.00 and 05.33for Tracer, Coragen, Malathion,Protecto, Agerin and Dipel 2x, respectively compared with 09.33 adult for control. Moreover, the statistical analysis of the effect of using insecticides on preoviposition period (days) resulted in the fact that Tracer (03.00), Coragen (03.33) and Malathion (03.00) were significantly prolonged females preoviposition period when compared with 02.00 days for untreated check for emerged females that resulted from treated newly hatched larvae. On the other hand, Tracer treatment significantly caused oviposition elongate (07.33 days) when compared with all treatments and control. However, insignificant elongation for postoviposition periods was seen between all treatments containing untreated check.

Effect of the tested insecticides on reproductive parameters of PTM:

The data recorded in Table (5) and illustrated in Fig. (4) cleared that there were significant decreases in the number of eggs laid females^{-1} that resulted from Tracer, Protecto, Agerin and Dipel 2x treatments since the main numbers of laid eggs for them were 098.33, 094.66, 093.33 and 091.33 eggs/female, respectively, corresponding to 115.33 eggs female^{-1} of control. Thus, there were high reduction percentages in eggs hatchability in only one case of Coragen (70.35%) compared with 97.11% for the untreated group. Moreover, all treatments were insignificant elongation of total immature stages of PTM resulted from treated newly hatched larvae except in only one case of Coragen (22.33 days) compared with (18.00 days) for the untreated group. The same results showed the effect on life span. Coragen insecticide cleared the highest significant elongation for 36.33 days, when compared with other treatments including the untreated one, where these values were 33.33, 30.33, 30.00, 30.00 and 29.66 for Tracer, Malathion, Protecto, Agerin and Dipel 2x insecticides respectively.

Generally, it was concluded that all tested compounds exhibited highly effects on potato tuber moth that are resulted from treated newly hatched larvae. Thus, Dipel 2x, Protect oand Agerin insecticides prolonged the duration of larval stage significantly when compared with other treatments including control. The highest pupation was achieved by Malathion and Protecto insecticides and all results were less than the control. Also, the number of pupae increases in all treatments when compared with control. Moreover, the number of adults are significantly reduced in all treatments compared with the untreated group. The statistical analysis of the effect of using insecticides on preoviposition period (days) resulted in the fact that Tracer, Coragen and Malathion were prolonged females preoviposition period when compared with the untreated ones for emerged females that resulted from treated newly hatched larvae. On the other hand, Tracer treatment was significantly elongated oviposition) when compared with all treatments and control treatment.

These results were harmonized with Azab *et al*. (2018). The results revealed that spinosad insecticide reduced the number of mines by 76.3, 94.08, 98.44 and 100.0 % and the LC_{50} value was 0.247 ppm. Moustafa *et al.* (2021) stated that chlorantraniliprole and indoxacarb LC_{10} and LC_{50} values ranged from 0.014 to 0.323, and 0.06 to 1.07 mg L^{-1}, respectively, while the LC_{90} values were 0.34 to 3.54 mg L^{-1}. Both tested insecticides significantly increased the larval and pupal duration and decreased pupation rate.

Imam, Iman and Usama (2019) evaluated the effect of *Bacillus thuringiensis* against newly emerged larvae of PTM. The total larval death recorded 14 and 58% of larval death at 1.25 and 10 (colony forming units) CFU ml^{-1}, respectively. Shiberu and Getu (2017) studied the effectiveness of Coragen against *Tutaabsoluta* and found that there was highly significant difference among treatments in the laboratory.

Zahran *et al*. (2010) revealed that Dipel 2x was more effective than Protecto on the tested insect and the percentages mortality of newly hatched larvae that was increased by increasing the applied concentration.

Our results are in agreement with Liu *et al*. (2017) who tested 23 insecticides on lepidopteran moths (*Helicoverpa armigera*) and the results revealed that Chlorantraniliprole, emamectin benzoate, indoxacarb, larvin, spinetoram, spinosad, endosulfan, flubendiamide, amitraz, abamectin and phoxim were highly effective with mortalities of 100%, 100%, 100%, 100%, 100%, 100%, 86.67%, 77.78%, 57.78%, 53.33% and 53.33%, respectively.De Castro *et al.* (2018) reported that chlorantraniliprole was the most toxic to *Spodoptera exigua*, followed by spinosad, pyrethrin and azadirachtin+pyrethrin, with relative toxicity of 1.00, 10.99, 16.75 and 28.19, respectively. Smirle *et al.* (2013) reported that there was considerable variation in mortality after exposure to insecticides within and among all three Cutworm species. For *Abagrotisorbis*, spinetoram was the most toxic to neonates, followed by chlorantraniliprole, methoxyfenozide, spinosad, permethrin, pyrethrin,malathion and carbaryl.

It have been reported that subdivisions of life span of female moths (pre-oviposition-, oviposition-and post-ovipositional- periods) showed varied effects in response to different tested compounds (Spinosad, *B. thuringiensis* and Cypermethrin) However, the female longevity was significantly reduced at all treatments. The three tested compounds proved significant differences on female's fecundity, fertility and sterility%. Number of laid eggs female^{-1} (fecundity) was significantly decreased at all treatments (El- Sheikh, 2012). Gomaa (2005) used spinosad against the cotton leaf worm *Spodoptra littoralis*. The apparently normal moths were small in size giving few numbers of small egg masses and even the tiny egg masses were sterile. Smirle *et al.* (2013) reported that susceptibility within cutworm species. It is noteworthy that malathion and carbaryl insecticides are substantially less toxic to all cutworm species. Many sublethal effects of insecticides were addressed for several chemical groups, such as diamide, insect growth regulators, neonicotinoid, organochlorides, organophosphates, pyrethroid and others may be manifested as reductions in life span, development rates, population growth, fertility, fecundity, changes in sex ratio, deformities, changes in behavior, feeding, searching and oviposition. (Solange *et al*., 2017).

CONCLUSION

It could be concluded that under the conditions tested, all insecticides showed toxicity to potato tuber moth and Agerin insecticide has the highest toxicity. Dipel 2x, Protecto and Agerin insecticides prolonged the duration of larval stage and the highest pupation achieved by Malathion and Protecto insecticides. Moreover, there was an increase in the number of pupae in all treatments compared to control. Also, there were an insignificantincrease in pupal weights between all treatments including control. In addition, the number of adults was significantly reduced in all treatments when compared with the untreated group. Coragen and Malathion insecticides were significantly prolonged females preoviposition period compared to control. On the other hand, Tracer treatment was significantly elongated oviposition when compared to remind treatments and control. Moreover, there were significant decreases in the number of eggs laid by females resulted from Tracer, Protecto, Agerin and Dipel 2x treatments. Also, there were high reduction percentages in eggs hatchability in only Coragen treatment. The results showed that Coragen insecticide have the highest significant elongation of life span when compared with other treatments and control. Thus, toxicants as insecticides can exert subtle as well as overt effects that must be considered when examining their total impact.

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The treatments:

Insecticides used:

Insecticides (common name)	Trade name
Spinosad	Tracer® 24 % SC
Chlorantraniliprole	Coragen® 20% SC
Malathion	Malathion® 57 % EC
Bacillus thuringiensis	Dipel 2X® 6.4 % WP
Bacillus thuringiensis	Protecto® 9.4 % WP
Bacillus thuringiensis	Agerine® 6.5 % WP

Table 1: Lethal concentration values of six insecticides used against newly hatched larvae of potato tuber moth, *Phthorimaea operculella*, (Zeller) under laboratory conditions.

Treatments	LC_{25}	LC_{50}	LC_{90}	Confidence limits		Slope
				Upper	Lower	
(Spinosad) Tracer ® 24% SC	0.1068	0.2008	0.6671	0.2263	0.1763	2.4582 ± 0.2182
(Chlorantraniliprole) Corragen® 20% SC	0.2434	0.8257	8.4111	1.0219	0.6589	1.2714 ± 0.1323
(Malathion) Malathion® 57% EC	0.1571	1.0445	38.186	1.5773	0.7274	0.8200 ± 0.1124
(Bacillus thuringiensis) Dipel 2x 6.4% WP	0.1608	0.2525	0.5954	0.3506	0.1752	3.4403 ± 0.2531
(Bacillus thuringiensis) Protecto WP 9.4%	0.1032	0.1844	0.5552	0.2071	0.1628	2.6769 ± 0.2713
(Bacillus thuringiensis) Agerin 6.5% WP	0.0711	0.1568	0.7042	0.1827	0.1293	1.9643 ± 0.2798

Table 2: Effect of the tested insecticides at their LC_{50} values on larvae resulted from treated newly hatched larvae of *Phthorimaea operculella* under laboratory conditions.

Biological aspects Treatments	Larval duration (days)	No. of larval mortality (during larval stage)	Mortality%
(Spinosad) Tracer ® 24% SC	12.66 b	05.66 a	56.66
(Chlorantraniliprole) Corragen® 20% SC	13.00 b	05.33 ab	53.33
(Malathion) Malathion® 57% EC	13.00 b	04.00 b	40.00
(*Bacillus thuringiensis*) Diple 2x 6.4% WP	14.00 a	04.33 ab	44.33
(*Bacillus thuringiensis*) Protecto® 9.4% WP	14.33 a	04.00 b	40.00
(*Bacillus thuringiensis*) Agrien 6.5% WP	14.33 a	04.66 ab	46.66
Control	12.66 b	00.66 c	06.00

Data belong to the same letters are not significantly different at 5%level according to (Duncan, 1955).

Table 3: Effect of the tested insecticides at LC_{50} values on pupae resulted from treated newly hatched larvae of *Phthorimaea operculella* under laboratory conditions.

Treatments	No. of pupae	Pupation %	Pupal weight (mg $pupa^{-1}$)	Pupal duration (days)
(Spinosad) Tracer ® 24% SC	04.33 c	43.33	10.00 ab	06.33 a
(Chlorantraniliprole) Corragen® 20% SC	04.66 bc	46.67	10.20 a	06.33 a
(Malathion) Malathion® 57% EC	06.00 b	60.00	09.10 b	05.33 a
(Bacillus thuringiensis0 Diple 2x 6.4% WP	05.66 bc	56.67	10.10 a	05.67 a
(Bacillus thuringiensis) Protecto® 9.4% WP	06.00 b	60.00	09.80 ab	05.67 a
(Bacillus thuringiensis) Agrien 6.5% WP	05.33 bc	53.33	09.50 ab	06.00 a
Control	09.33 a	93.33	09.90 ab	05.33 a

Data belong to the same letters are not significantly different at 5%level according to (Duncan, 1955).

Table 4: Effect of the tested compounds at LC_{50} values on adult stage resulted from treated newly hatched larvae of *Phthorimaea operculella* under laboratory conditions.

Treatments	No. of adults	Adult emergence %	Adult sex ratio (%)		Adult longevity (days)		
			Male	Female	Preoviposition	Oviposition	Postoviposition
(Spinosad) Tracer ® 24% SC	04.00 d	40.00	41.67	58.33	03.00 ab	07.33 a	03.33 a
(Chlorantraniliprole) Corragen® 20% SC	04.66 cd	46.66	50.00	50.00	03.33 a	07.00 ab	03.66 a
(Malathion) Malathion® 57% EC	06.00 b	60.00	44.45	55.55	03.00 ab	06.00 ab	03.33 a
(*Bacillus thuringiensis*) Protecto® 9.4% WP	05.33 bc	53.33	56.25	43.75	02.33 bc	06.33 ab	02.66 a
(*Bacillus thuringiensis*) Agrien 6.5% WP	05.00 bcd	50.00	46.67	53.33	02.33 bc	06.66 ab	02.66 a
(*Bacillus thuringiensis*) Diple 2x 6.4% WP	05.33 bc	53.33	56.25	43.75	02.33 bc	06.33 ab	02.66 a
Control	09.33 a	93.33	57.14	42.68	02.00 c	05.67 b	03.00 a

Data belong to the same letters are not significantly different at 5%level according to (Duncan, 1955).

Table 5: Effect of LC_{50} of the tested insecticides on fecundity, hatchability, sterility, life cycle and lifespan of *Phthorimaea operculella* resulted from treated newly hatched larvae under laboratory conditions.

Treatments	Fecundity	Hatchability %	Sterility %	Life cycle (days)	Life span (days)
(Spinosad) Tracer ® 24% SC	98.33 bc	89.49	21.43	19.66 b	33.33 b
(Chlorantraniliprole0 Corragen® 20% SC	105.66 ab	70.35	33.63	22.33 a	36.33 a
(Malathion) Malathion® 57% EC	109.33 a	89.33	12.80	18.00 b	30.33 c
(*Bacillus thuringiensis*) Protecto® 9.4% WP	94.66 c	87.68	25.74	18.66 b	30.00 c
(*Bacillus thuringiensis*) Agrien 6.5% WP	93.33 c	84.65	29.46	18.33 b	30.00 c
(*Bacillus thuringiensis*) Diple 2x 6.4% WP	91.33 c	81.75	33.34	18.33 b	29.66 c
Control	115.33 a	97.11	00.00	18.00 b	29.00 c

Data belong to the same letters are not significantly different at 5%level according to (Duncan, 1955).

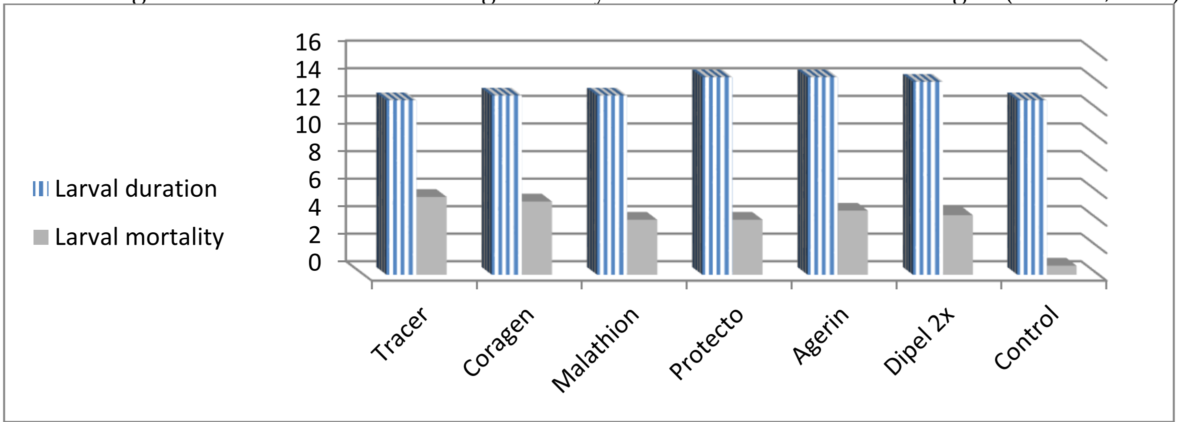

Figure 1: Effect of the tested insecticides at their LC_{50} values on larvae resulted from treated newly hatched larvae of *Phthorimaea operculella* under laboratory conditions.

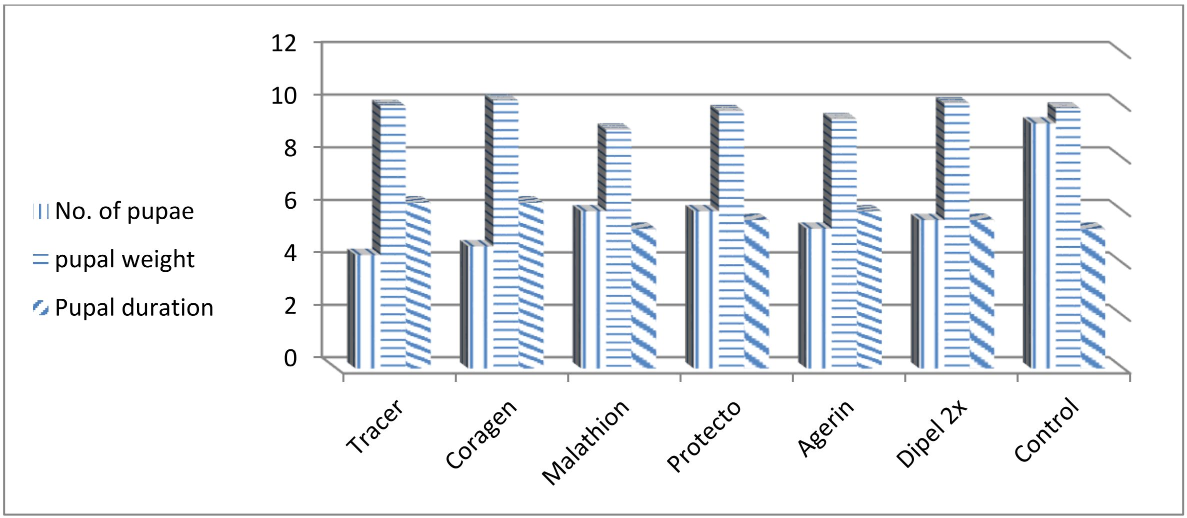

Figure 2: Effect of the tested insecticides at LC_{50} values on pupae resulted from treated newly hatched larvae of *Phthorimaea operculella* under laboratory conditions.

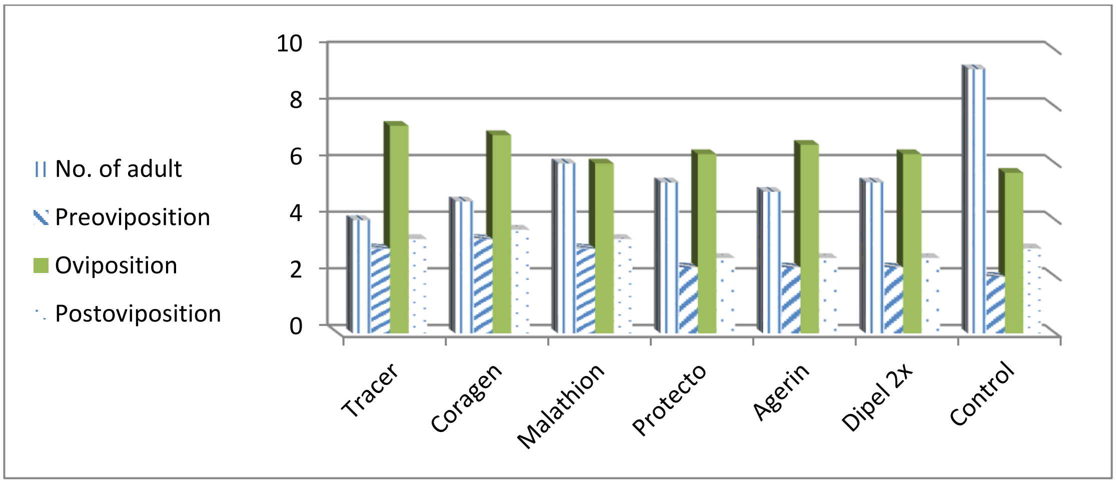

Figure 3: Effect of the tested compounds at LC_{50} values on adult stage resulted from treated newly hatched larvae of *Phthorimaea operculella* under laboratory conditions

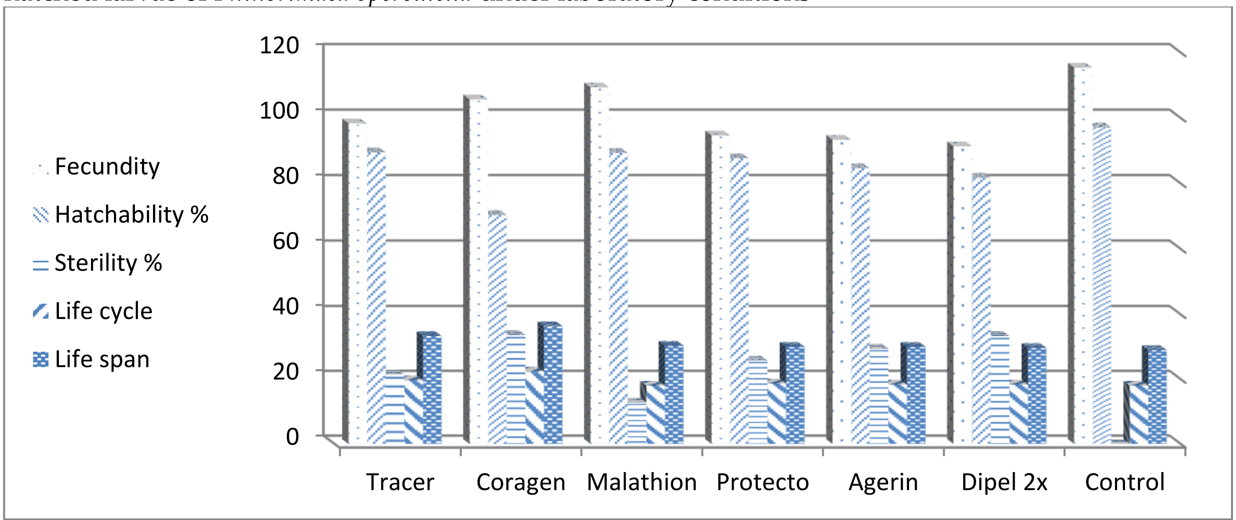

Figure 4: Effect of LC_{50} of the tested insecticides on fecundity, hatchability, sterility, life cycle and lifespan of *Phthorimaea operculella* resulted from treated newly hatched larvae under laboratory conditions.

فعالية بعض المبيدات الكيمياوية الحيوية على فراشة درنات البطاطس *Phthorimaea operculella* تحت ظروف المعمل.

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الملخص العربي

تعتبر فراشة درنات البطاطس من أكثر الآفات تدميرًا للبطاطس في مصر. وفى هذا البحث تمت دراسة فعالية مبيدات الإسبينوساد والكلورانترانيليبرول والملاثيون وبكتريا *Bacillusthuringiensis* بثلاث مستحضرات تجارية مختلفة (دايبل 2x وبروتكتو و أجرين) تحت ظروف المعمل. ولقد أوضحت النتائج أن التركيز النصفي المميت للمركبات المختبرة هو٠,١٦ و٠,١٨و ٠,٢٠و ٠,٢٥و ٠,٨٣و ١,١٨ جزء في المليون لكل من أجرين وبروتكتو والإسبينوساد ودايبل 2xو الكلورانترانيليبرول والملاثيون على الترتيب. ولقد أدي استخدام المبيدات الحشرية دايبل 2x وبروتكتو و أجرين إلى إطالة فترة العمر اليرقي بشكل معنوي مقارنة بالمعاملات الأخرى بما في ذلك الكنترول. فى حين أن كل المركبات المختبرة قللت من معدل التعذير مقارنةً بالكنترول وكانت أعلى نسبة تعذير ٦٠٪ لكل من الملاثيون والبروتكتو ٥٦,٦٧٪ دايبل 2x و ٥٣,٣٣٪ للأجيرين٤٦,٦٧٪ للكوراجين و٤٣,٣٣٪ للإسبينوساد حيث كانت كل النسب أقل من الكنترول. ولقد انخفض عدد الحشرات الكاملة بشكل معنوي في جميع المعاملات مقارنة بالكنترول. علاوة على ذلك، فإن المبيدات الحشرية المستخدمة إسبينوساد و كوراجين والملاثيونقد أطالت فترة ما قبل وضع البيض بشكل ملحوظ مقارنة بالكنترول ومن ناحية أخرى، تسببت المعاملات بشكل كبير في إطالة فترة وضع البيض مقارنة بجميع المعاملات والكنترول.

الكلمات الاسترشادية: فراشة درنات البطاطس، المكافحة الحيوية، المكافحة الكيميائية.