Effect of certain bioinsecticides on the infestation rate and biological aspects of *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) in store

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Abstract: The effects of the bioinsecticides Neemix, Virotecto, Agerin, Dipel 2x and Spinosad on infestation rates and biological aspects of *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) were studied under storage conditions. Neemix and Spinosad were evaluated as spray treatment, whereas Virotecto, Agerin and Dipel 2x were evaluated as dust and spray treatments. Data revealed that the percentage of tuber infestation reached 100% in control treatment after three months of storage. Among tested treatments, Spinosad and Dipel dust were the most effective bioinsecticide treatments in reducing tuber infestation and number of *P. operculella* recovered pupae. The effects of Virotecto and Agerin treatments were inferior to Spinosad and Dipel treatments but still significant to control; however, Neemix was ineffective with the lowest reduction percentage of infestation at 6.67% after three months of storage. Moreover, there were significant differences among bioinsecticide treatments in forms of the number of *P. operculella* tunnels in stored potatoes as well as percentages of edible part after three months of storage. The tested bioinsecticides had a significant negative impact on *P. operculella* bioparameters including percentage of egg hatch, pupation, deformed adults, adult emergence and egg-adult survival, either in *P. operculella* F1 or F2 progeny. Weight of *P. operculella* pupae was also significantly affected by the tested bioinsecticides; being greatest (10.90 mg) in control and lowest (7.15 mg) in Dipel 2x dust. The tested bioinsecticides also showed significant effects on ovipositional period, post ovipositional period, total fecundity, larval period, pupal period and total development period. On the other hand, male and female longevity was not affected by the tested bioinsecticides.

Keywords: bioinsecticides, *Phthorimaea operculella,* infestation, development, fecundity, survival

INTRODUCTION

Potato (*Solanum tuberosum* L.) is considered one of the most important vegetable crops worldwide. In Egypt, it is cultivated in 257033 feddans, with a total of 2760164 tons in 2007 season (Statistics of Ministry of Agriculture of Egypt, 2007). This crop is subjected to the attack by scores of insect pests including aphids, leafhoppers, lepidopterous pests with the potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) being the most important insect pest. *P. operculella* also attacks other solanaceous crops such as tomato, tobacco, eggplant and pepper in tropical and subtropical countries, but potatoes still the preferred host plant (Shelton and Wayman, 1979; Shoukry *et al.*, 1997; Sileshi and Teriessa, 2001). Keasar and Sadeh, 2007).

In potato fields, females of PTM lay their eggs on the underside of the potato leaves or on the exposed tubers particularly where potatoes are cultivated under flooding irrigation system. PTM larvae mine the foliage, stems, and tubers (Islam *et al.*, 1990; Shoukry *et al.*, 1997). The larvae may also form blotches in leaves and fold leaves over for shelter and bore into petioles and stems (Shoukry *et al.*, 1997). The new mines, harboring the neonate larvae, are always concentrated in the upper part of the potato canopy, whereas the old blotches, harboring the older larvae of PTM, are likely occupied the lower parts of potato canopy particularly near the soil surface (Shoukry *et al.*, 1997). Often, more than 10% of potato tubers are infested with PTM but it may reach 100% if preventive measures are not followed (Shelton and Wayman, 1979; Shoukry *et al.*, 1997; Sileshi and Teriessa, 2001).

In potato stores, *P. operculella* also causes serious damage to stored potatoes. Larvae of PTM tunnel inside the tubers. This leads to partial or complete rotting by subsequent infestation with fungi and/or bacteria, which turn the infested tubers to become unmarketable (Shelton and Wayman, 1979; Sarhan, 2004; Keasar and Sadeh, 2007).

Fortunately, biological control using bioinsecticides (Farrag, 1998; Temerek, 2003) and insect parasitoids and predators (Agamy, 2003; Sarhan, 2004; Keasar and Sadeh, 2007) has become the backbone in potato protection, either in field or in stores and has gained more credibility in the last decades. Despite the significant reduction in *P. operculella* populations in natural-enemy treatments as compared to control ones, none of these attempts gave a satisfactory protection against *P. operculella* infestation to the level, which reaches the consumer's satisfaction (Sileshi and Teriess, 2001; Sarhan, 2004; Keasar and Sadeh, 2007). This, in turn, leads to the concentration in using bioinsecticides against this pest particularly in potato stores.

Therefore, the main objective of the current study was to evaluate the effectiveness of certain bioinsecticides (Neemix, Virotecto, Agerin, Dipel 2x and Spinosad) in controlling *P. operculella* under storage conditions. In addition, the effect of these bioinsecticides on the reproductive biology of *P. operculella* was also investigated.

MATERIAL AND METHODS

Rearing of *P. operculella*:

The laboratory culture of *P. operculella* was originated from the stock colony kept on potato tubers in Biological Control Center, Suez Canal University under the laboratory conditions of 25±2°C, 60±10% R.H. and 14 h photophase. *P. operculella* was reared using the method described by Shoukry *et al.* (1997). A glass jar (20 cm in height × 15 cm in diameter) covered with a piece of muslin cloth was used as an ovipositional cage for *P. operculella* moths. Muslin sheets bearing *P. operculella* eggs were collected daily and exposed to potato tubers in glass jar (30 cm in height × 20 cm in diameter). A fine layer (2 cm) was placed under the potato tubers to serve as pupation site for the full grown larvae of *P. operculella*.

Tested bioinsecticides:

Five bioinsecticides were selected and evaluated in protecting the stored potatoes against *P. operculella* infestation (Table 1). These bioinsecticides were Agerin and Dipel 2x (*Bacillus thuringiensis*-based insecticides), Virotecto (*P. operculella*-virus), Spinosad and Neemix. Agerin, Dipel 2x and Virotecto were evaluated as dust and spray applications; whereas Spinosad and Neemix were tested only as spray application (Table 1).

Table (1): List of tested bioinsecticides, their active ingredients and recommended doses.

Biorational pesticide	Active ingredient	Recommended dose	
		Dust	Spray
Neemix	Azadirachtin	-	0.5 ml / 1 L
Virotecto	Granulosis virus	150 gm / 1 ton	1.0 gm / 1L
Agerin	*Bacillus thuringiensis*	250 gm / 1 ton	250 gm / 40-60 L
Dipel 2x	*Bacillus thuringiensis*	150 gm / 1 ton	0.85 gm / 1L
Spinosad	(Spinosyn A and D)	-	0.5 ml / 1 L

Effectiveness of bioinsecticides against *P. operculella* in store:

This experiment was conducted in a laboratory (4 m in width × 4 m in length × 3.5 m in height) at abiotic conditions of 25±2 °C, 60±10% R.H. and 14 h photophase. Potato tubers were purchased from the wholesale markets in Ismailia, transferred to the laboratory, sorted out and only healthy tubers were used. Seven kilograms (each kilogram contained 6-7 tubers) of potato tubers were assigned to form one replicate. Each treatment of biocides was performed in six replicates with a total of 42 kilograms per treatment. The tested treatments were Neemix, Virotecto spray (VS), Virotecto dust (VD), Agerin spray (AS), Agerin dust (AD), Dipel spray (DS), Dipel dust (DD) and Spinosad.

In dust treatments, the assigned weight of potato tubers per each replicate was placed on a clean piece of cloth and dewed by distilled water using a small handle sprayer. After that, the dewed tubers were dusted with the assigned bioinsecticide using small handle duster. Treated tubers were then left to dry out for 2-3 hours before being filled in the gunny bags, which were treated by dusting with the tested biocides as well. Control treatment was performed using the same protocol and replicates but without bioinsecticide application. Gunny sacks were sealed tightly, labeled and placed over each other on a steel stand under storage conditions. A fine layer of clean sand (3-5 cm) was placed under these sacks to serve as pupation site for full grown larvae of PTM.

In spray treatments, fresh solutions of the tested bioinsecticides were prepared just prior application. Gunny bags were treated by dipping into the tested biocide solution for 10 seconds. The experimental setup and protocol including replicates, size of replicates and storage methods were the same as mentioned above.

An artificial infestation was made using the rate of 6 *P. operculella* pupae/kg tubers at a total of 252 pupae per treatment. Pupae were placed into a Petri dish (9 cm) beside each treatment. Having released *P. operculella* in the store, tubers were then checked weekly to remove the spoiled tubers. When *P. operculella* larvae started to drop into the sand layer for pupation, the sand layer was sieved thoroughly once a week to collect the developed *P. operculella* pupae. Moreover, 20 tubers from each treatment were selected each month to calculate the percentages of infestation and edible part. This experiment lasted three months. By the end of the experiment, the rates of infestation and the subsequent reduction in infestation, percentages of reduction in number of *P. operculella* pupae as well as number of its tunnels in the infested tubers were calculated for each treatment.

Effect of bioinsecticides on the biological aspects of *P. operculella*:

This experiment was conducted at the previously mentioned abiotic conditions. Each treatment was performed in six replicates with 100 *P. operculella* eggs each. These eggs were taken from the laboratory colony and were reared on potato tubers treated with the tested bioinsecticides and kept in glass jars (10 cm in diameter × 20 cm in height). Fine layer of clean sand was provided beneath the tubers in each jar. When larvae dropped into the sand layer, pupae were collected, counted and weighted. These pupae were kept in Petri dish (9 cm) till the emergence.

Emerging adults were sexed and each couple was confined in clean glass tube (10 cm in diameter × 20 cm in height) covered with a piece of cloth, which also served as an oviposition substrate for *P. operculella* females. Small droplets of 20% honey solution and water were added on the inner wall of the glass tube to serve as food for the moths. Ten replicates of each treatment were used. The glass tubes were checked daily. Data were recorded in the forms of pre-ovipositional, ovipositional and post-ovipositional periods, longevity as well as the daily and total number of deposited eggs by each female during its lifetime.

Deposited eggs were collected daily and placed in clean Petri dishes (9 cm) till hatching at the previously mentioned laboratory conditions. The hatching larvae were transferred directly to glass jars (10 cm in diameter × 20 cm in height) with a small untreated potato tuber (80 gm) to serve as food for *P. operculella* larvae. A fine layer of clean sand (1-2 cm) was added to serve as pupation site. Jars were kept under continuous observation till the completion of the larval development and the larval duration was then calculated. *P. operculella* newly formed pupae were collected from each jar and kept in clean Petri dishes. Upon emergence, rates of moth emergence as well as pupal periods were also calculated.

Statistical analysis:

All obtained data were analyzed using SAS package 8.2 v (SAS Institute 2003). Data were compared using ANOVA analysis of variance. When F values were significant, means were separated using Fisher least significant differences (LSD) at a 0.05 level of significance (SAS Institute 2003).

RESULTS

Effect on *P. operculella* infestation

As shown in Fig 1, Dipel dust and Spinosad treatments showed full protection for stored tubers, with reduction percentages of 100% up to two months of storage, then percentage of reduction in both treatments declined after three months to 97.51 and 95.83%, respectively. The reduction rates of *P. operculella* infestation differed significantly among tested bioinsecticide treatments after a month (F= 8.05; P= 0.0001), two months (F= 14.57; P= 0.0001) and three months (F= 63.90; P= 0.0001) of storage.

All bioinsecticide treatments caused great reduction in the number of *P. operculella* recovered pupae (Table 2). Agerin dust, Dipel spray, Dipel dust and Spinosad caused the greatest overall average reduction percentages of *P. operculella* recovered pupae at 93.60, 96.85, 100 and 100%, respectively. However, the effect of Neemix, Virotecto spray, Virotecto dust and Agerin spray treatments after three months of storage was comparable with reduction percentages of 66.93, 73.71, 80.64 and 70.52%, respectively (Table 2).

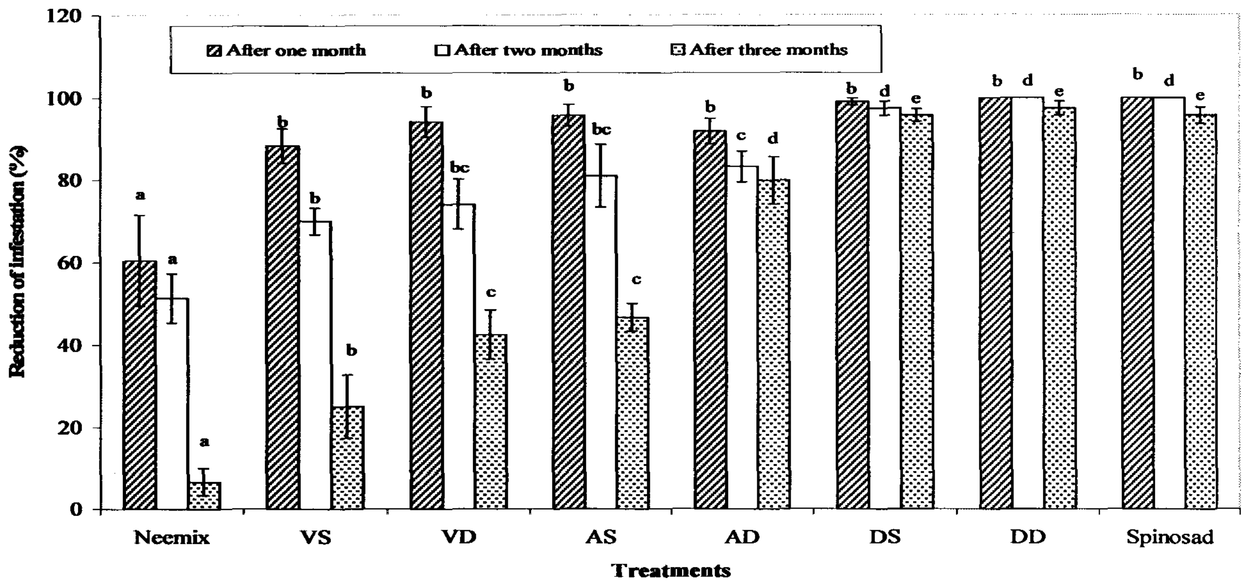

Fig (1): Percentages reduction of infestation with *P. operculella* in potato tubers treated with different bioinsecticides in stores.
Bras with the same letters are not significantly different (LSD; P> 0.05)

Table (2): Percentages reduction in numbers of *P. operculella* pupae recovered from potato tubers treated with different bioinsecticides in stores.

Treatments	% Reduction in PTM pupae after,			
	1 month	2 months	3 months	Average
Neemix	71.48	76.31	60.63	66.93
Virotecto spray	75.70	78.39	70.65	73.71
Virotecto dust	90.49	82.28	76.86	80.64
Agerin spray	66.46	77.46	67.96	70.52
Agerin dust	89.69	95.46	93.89	93.67
Dipel spray	98.21	97.78	95.97	96.85
Dipel dust	100	100	100	100
Spinosad	100	100	100	100

Data in Table 3 revealed that percentages of edible part decreased gradually as storage period increased. Spinosad afforded full protection with an edible part of 100% after three months of storage. There were significant differences among tested bioinsecticides in percentages of edible part after a month (F= 24.61; P= 0.0001), two months (F= 25.73; P= 0.0001) and three months of storage (F= 24.48; P= 0.0001, Table 3).

Moreover, the tested bioinsecticides had a negative impact on the number of *P. operculella* mines in stored potatoes; being the greatest in control at 118.17 mines/20 tubers and the lowest in Dipel dust and Spinosad treatments at 0.33 and 3.00 mines/20 tubers, respectively (Table 3). Significant differences were also existed among biocide treatments in the number of mines in the stored tubers (F= 29.20; P= 0.0001).

Effect on biological aspects of *P. operculella*

Among tested treatments, rapid development of *P. operculella* immature stages was observed in control at 33.00 days (Fig 2). When *P. operculella* was developed in treated tubers with Neemix, Virotecto spray, Virotecto dust, Agerin spray and Agerin dust, the total developmental period was 4.25, 1.95, 2.55, 1.9 and 0.25 days longer than that of control, respectively. Significant differences among treatments were found in larval period (F= 1.83; P= 0.1230), pupal period (F= 3.62; P= 0.0068) and the total development period (F= 3.99; P= 0.0037; Fig 2).

Table (3): Effect of application of different bioinsecticides on the percentage of edible part and number of *P. operculella* mines in stored tubers.

Treatments	% Edible parts after,			No. of PTM mines
	1 month	2 months	3 months	(M±SE)
Control	56.00±6.20 [a]	21.00±5.79 [a]	0.00 [a]	118.17±9.93 [a]
Neemix	72.00±3.39 [b]	48.00±6.63 [b]	0.00 [a]	109.17±12.74 [a]
Virotecto spray	97.00±2.00 [d]	68.00±3.74 [c]	20.00±9.35 [ab]	97.50±13.46 [a]
Virotecto dust	98.00±1.22 [d]	68.00±7.35 [c]	25.00±11.18 [b]	23.00±5.07 [bc]
Agerin spray	80.00±3.54 [bc]	49.00±7.81 [b]	0 [a]	116.50±17.46 [a]
Agerin dust	87.00±4.64 [c]	69.00±3.67 [c]	38.00±11.90 [bc]	42.00±4.80 [b]
Dipel spray	100 [d]	85.00±2.24 [d]	48.00±11.68 [c]	16.33±2.11 [bc]
Dipel dust	100 [d]	98.00±1.22 [de]	93.00±3.00 [d]	0.33±0.21 [c]
Spinosad	100 [d]	100 [e]	100 [d]	3.00±0.93 [c]
F value	24.61	25.73	26.48	29.20
P value	0.0001	0.0001	0.0001	0.0001

Means followed with the same letters (column wise) are not significantly different (LSD; P> 0.05)

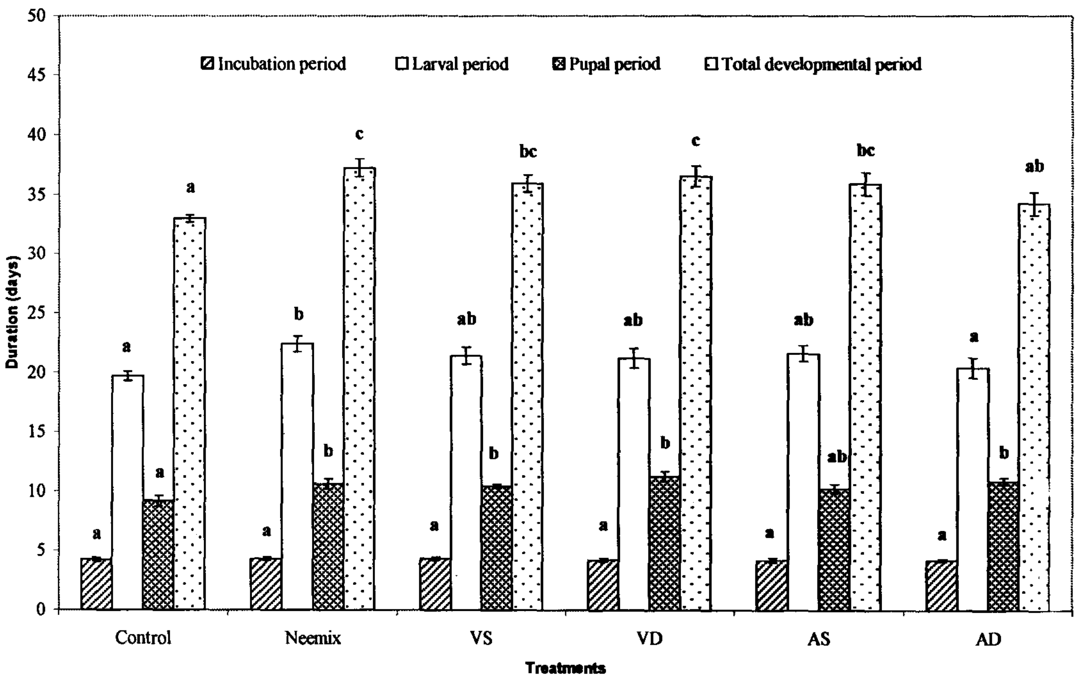

Fig (2): Duration of *P. operculella* immature stages reared on potato tubers treated with the recommended doses of bioinsecticides under laboratory conditions.

Bras with the same letters are not significantly different (LSD; P> 0.05)

As shown in Table 4, the tested bioinsecticides had negative impact on all recorded bioparameters of *P. operculella* F1 progeny. Significant differences were found among tested bioinsecticides in forms of number of formed pupae (F= 35.53; P= 0.0001), rates of adult emergence (F= 1.13; P= 0.3901), deformed adults (F= 2.81; P= 0.0410) and egg-adult survival rate (F= 77.13; P= 0.0001). Moreover, weight of *P. operculella* pupae differed significantly (F= 10.99; P= 0.0001) among tested bioinsecticide treatments; being greatest at 10.90 mg in control treatment and lowest at 7.15 mg in Dipel 2x dust treatment (Fig 3).

The tested bioinsecticides had no effect on the length of pre-ovipositional period (Table 5); however, their effect was significant on ovipositional period (F= 5.05; P= 0.0007) and post oviposition period (F= 2.45; P= 0.0451). Apparently, females of *P. operculella* lived longer than males with no significant difference among tested bioinsecticide treatments (Table 5). Data also indicated that the greatest fecundity of *P. operculella* females was observed in control at 124.20 eggs/female and the lowest one was recorded in Agerin dust treatment at 77.20 eggs (Fig 4). Significant differences were existed among biocide treatments in terms of total lifetime fecundity (F= 2.0; P= 0.0863) and daily laid eggs (F= 1.50; P= 0.2062; Fig 4).

The effect of the tested biocide treatments on *P. operculella* F2 progeny is presented in Table 6. The greatest percentages of egg hatching, pupation, adult emergence and generation survival were observed in control at 91.59, 88.25, 90.52 and 74.33%, respectively. The lowest figures for the respective bioparameters were recorded in Agerin spray treatment at 33.70, 15.32, 50.33 and 6.26% (Table 6). There were significant differences among bioinsecticide treatments in percentages of egg hatching (F= 8.21; P= 0.0001), pupation (F= 12.19; P= 0.0001), adult emergence (F= 2.10; P= 0.0792), and generation survival (F= 9.22; P= 0.0001; Table 6). However, percentages of deformed adults in F2 progeny did not differ significantly among tested treatments (F= 0.70; P= 0.6235).

Table (4): Mean (±SE) number of formed pupae, percentages of eclosed adults, deformed adults and egg- adult survival of *P. operculella* F1 progeny reared on treated tubers with bioinsecticides.

Treatments	No. of formed pupae	Emergence (%)	Deformed adult* (%)	Generation survival (%)
Control	74.33±6.36 a	97.10±1.47 a	0 a	72.00±5.20 a
Neemix	42.33±6.01 b	82.18±2.78 ab	6.91±3.53 b	35.00±4.16 b
Virotecto spray	39.00±2.89 b	71.92±0.89 ab	0 a	28.00±1.73 bc
Virotecto dust	34.00±2.65 cb	75.38±7.43 ab	3.37±1.93 ab	25.33±1.86 cd
Agerin spray	27.00±4.46 c	82.100±9.43 ab	0 a	21.33±0.88 cd
Agerin dust	24.00±3.46 c	80.09±8.03 ab	3.71±1.87 ab	18.67±0.88 d
Dipel spray	2.00±0.58 d	61.11±10.03 ab	0 a	1.00 e
Dipel dust	1.00±0.58 d	50.00±18.87 b	0 a	0.67±0.33 e
F value	35.53	1.13	2.81	77.13
P value	0.0001	0.3901	0.0410	0.0001

Means followed with the same letters (column wise) are not significantly different (LSD; P> 0.05)
* emaciated moths with twisted and crumpled wings which failed to survive after emergence.

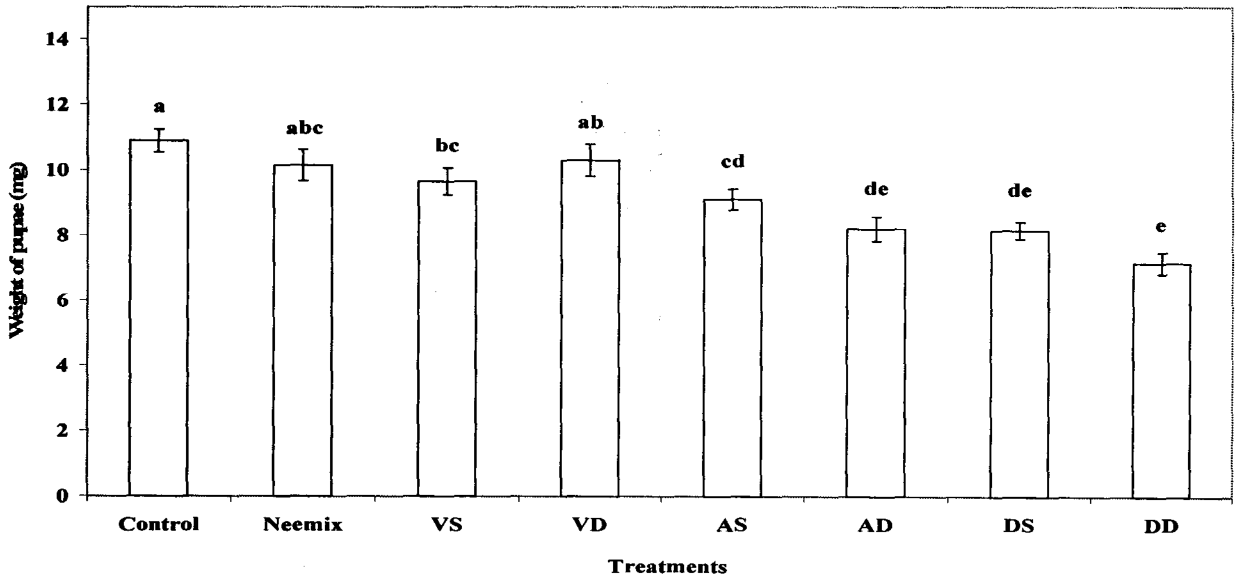

Fig (3): Mean (±SE) weight of *P. operculella* pupae reared as larval stages on potato tubers treated with different bioinsecticides.
Bars with the same letters are not significantly different (LSD; P> 0.05)

Table (5): Ovipositional periods and longevity of *P. operculella* adults reared as immature stages on treated potato tubers with different bioinsecticides.

Treatments	Oviposition period (days)			Longevity (days)	
	Pre-ovipositional period	Ovipositional period	Post-ovipositional period	Male	Female
Control	1.20±0.33 a	4.70±0.45 a	4.30±0.68 ab	7.60±0.73 a	10.20±0.81 a
Neemix	1.60±0.16 a	4.60±0.60 a	6.20±0.87 a	7.50±0.72 a	12.40±0.91 a
Virotecto spray	1.10±0.10 a	5.10±0.84 a	5.00±0.79 ab	6.30±0.33 a	11.20±1.01 a
Virotecto dust	1.80±0.39 a	5.40±0.95 a	3.60±0.37 b	7.80±0.55 a	10.50±0.93 a
Agerin spray	1.40±0.40 a	6.40±0.91 b	3.90±0.87 b	6.80±0.77 a	11.70±1.96 a
Agerin dust	1.40±0.16 a	5.50±0.70 a	3.60±0.43 b	6.90±0.43 a	10.50±0.85 a
F value	1.04	5.05	2.45	0.88	0.54
P value	0.4031	0.0007	0.0451	0.5008	0.7423

Means followed with the same letters (column wise) are not significantly different (LSD; P> 0.05). n = 10

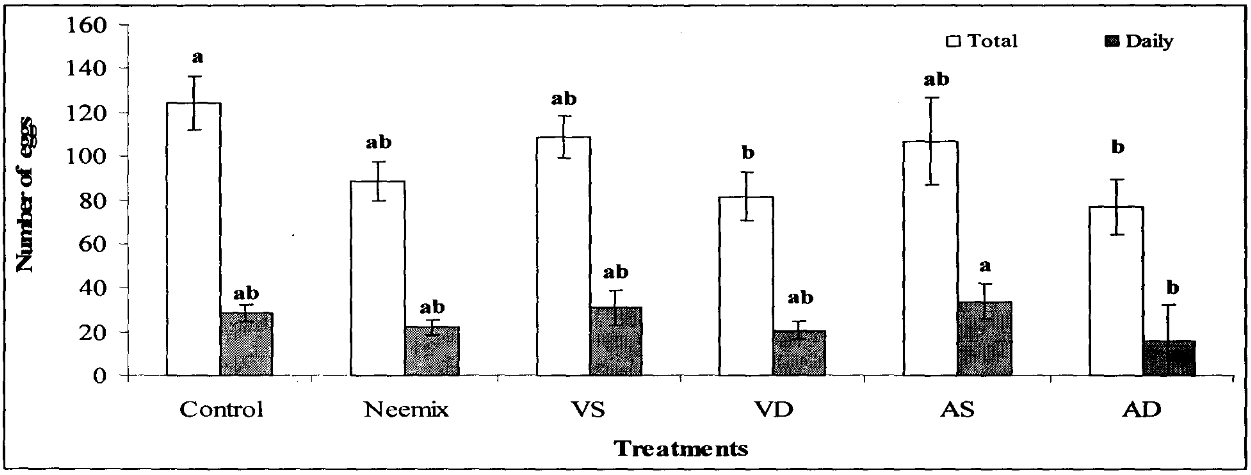

Fig (4): Fecundity of *P. operculella* females came from larvae reared on treated tubers with different bioinsecticides.
Bars with the same letters are not significantly different (LSD; P> 0.05)

Table (6): Percentages of egg hatching, pupation, emerged adults, deformed adults and egg-adult survival of *P. operculella* F2 progeny reared in F1 on treated tubers with different bioinsecticides.

Treatments	Egg hatching (%)	Pupation (%)	Emergence (%)	Deformed adult* (%)	Egg-adult survival (%)
Control	91.59±2.58 a	88.25±4.05 a	90.62±3.08 a	0 a	74.33±5.08 a
Neemix	73.81±4.81 ab	26.15±7.15 cd	68.29±9.25 ab	10.79±9.94 a	14.95±3.77 bc
Virotecto spray	48.58±7.28 cd	35.41±4.98 bcd	63.16±8.23 ab	3.45±0.57 a	13.06±2.36 bc
Virotecto dust	65.71±7.28 bc	48.50±8.13 b	57.78±5.02 b	11.78±3.84 a	17.38±2.77 b
Agerin spray	33.70±9.82 d	15.52±6.77 d	50.33±4.02 b	0 a	6.26±2.32 c
Agerin dust	42.59±11.17 d	41.62±10.41 bc	55.06±2.81 b	9.92±2.34 a	17.76±5.12 b
F value	8.21	12.19	2.10	0.70	9.22
P value	0.0001	0.0001	0.0792	0.6235	0.0001

Means followed with the same letters (column wise) are not significantly different (LSD; P> 0.05)
*emaciated moths with twisted and crumpled wings which failed to survive after emergence.

DISCUSSION

In the current study, the infestation rate in control treatment reached 100% after three months of storage. The same finding was reported by Hossain *et al.* (1994) who reported an infestation rate of 100% in control treatment after two months of potato storage.

The two Bt-based biocides, Agerin and Dipel 2x, differed dramatically in their effectiveness against *P. operculella*. Agerin was not effective as Dipel in the two methods of application (dust or spray treatments). The differences in the results may due to the commercial formulations of both biocides and to their recommended doses. These findings are in consistent with those reported earlier. For example, Salama *et al.* (1995) reported that the use of Bt at higher doses was very effective against *P. operculella* up to 255 days of storage, the longest ever storage period. Also, Farrag (1998) found that Dipel 2x gave a full protection against *P. operculella* in potato stores. However, it is important to state that not all trials with Bt-based insecticides against *P. operculella* yielded satisfactory control. Salama and Salem (2000), for example, found that Dipel

8 L did not afford an acceptable protection against *P. operculella*.

Spinosad was as effective as Dipel 2x up to three months of storage. The percent of infestation was minimal, with about 3 tunnels/ 20 tubers. These tunnels were mostly superficial and never observed deeply in the tubers treated with Spinosad. Moreover, no *P. operculella* pupa was recovered from Spinosad treatment throughout the storage period. The present findings are in conformity with those reported by Temerak (2003) and Gomaa and Nenaey (2006). In their studies, Spinosad showed 100% protection against *P. operculella* infestation with very long persistence through the whole storage period.

Neemix was totally ineffective for controlling *P. operculella*. This conclusion was in consistent with that reported by Chandel and Chandla (2005) who found that Achook 300 ppm Azadirachtin failed to afford an acceptable protection when it was used against *P. operculella*. On contrast, neem treatments were very effective against *P. operculella* in store up to three months (Hossain *et al*., 1994; Debnath *et al*., 1998) and neem oil was equally effective against *P. operculella* as the insecticide, Sevin (Salama and Salem, 2000).

In the current study, Virotecto was not effective for controlling *P. operculella*. This finding is in agreement with that recorded by Islam *et al.* (1991) who found that granulosis virus (GV) did not protect potatoes from *P. operculella* infestation and was not effective up to two months of storage. However in other studies, GV was very effective in controlling *P. operculella* either in potato stores or fields either in dust, spray or as soil treatments (Chandel and Chandla, 2005). Moreover, Gomaa and Nenaey (2006) found that treatment of stored potato tubers with Virotecto or GV infected larvae were very effective in controlling PTM infestation than Bt-based insecticides.

The tested bioinsecticides differed in reducing the number of mines per tuber. Both Spinosad and Dipel 2x performed well and caused substantial reductions when compared to other tested bioinsecticides. The other treatments *viz*., Neemix, Virotecto and Agerin caused significant reduction in number of *P. operculella* mines as compared to control. The same finding was recorded by Moawed *et al.* (1998) who found that number of mines in stored tubers was significantly decreased in Bt, GV and profenofos treatments when compared to that of control. Also Gomaa and El-Nenaey (2006) found that number of *P. operculella* tunnels after 60 days decreased at number of 0, 0, and 2 mines/ Kg tubers in Dipel, Sumithion and Caffeine compared to 226.7 mines/Kg tubers in control treatment.

Agerin, Neemix and Virotecto caused substantial reductions in number of formed *P. operculella* pupae. These findings were in conformity with those of Arx and Gebhardt (1990) who found that survival rate of *P. operculella* (from egg to adult) was lowest (0.4%) and no reproduction occurred when larvae were fed on tubers treated with Thuricide HP. Survival of insects treated with granulosis virus was also significantly reduced.

When reared *P. operculella* on treated tubers with bioinsecticides, the development of all immature stages of *P. operculella* was treatment-dependent. The larval, pupal and total developmental periods lasted longer in all tested biocides as compared to control. This might be due to the reduced food uptake as a consequence of insecticide effect.

In this study, the treatment with the tested bioinsecticides caused deformation in adults of *P. operculella*. The deformation symptoms included emaciated adults with twisted and crumpled wings, which failed to survive after emergence. The highest rates of deformed adults were recorded for Virotecto and Neemix at 11.78 and 10.79 %, respectively. Our results are lower than those reported by Salem (1991) who recorded a deformation rate of 100% in *P. operculella* adults when its pupae were treated with neem oil.

It could be concluded that one application of Spinosad and Dipel 2x at their recommended doses afforded full protection against *P. operculella* in store up to three months of storage. Agerin, Neemix and Virotecto were less pronounced and did not prove that they can be deployed in *P. operculella* control program in stores. The tested bioinsecticides had a negative impact on some biological aspects of *P. operculella* in terms of lower fecundity, longer developmental period as well as shorter adult life.

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تأثير بعض المبيدات الحيوية على معدل الإصابة والجوانب البيولوجية لفراشة درنات البطاطس (*Phthorimaea operculella*) فى المخزن

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تم دراسة كفاءة المبيدات الحيوية النيمكس ،و الفيروتيكتو، والأجرين ، والدايبل 2x ، و السبينوساد ضد فراشة درنات البطاطس فى المخزن علاوة على تأثير تلك المبيدات الحيوية على بعض الجوانب البيولوجية لتلك الآفة. تم تقييم كل من مبيد النيمكس و السبينوساد كمعاملات سائلة (رش)، بينما تم تقييم كل من مبيد الفيروتيكتو ، والأجرين، و الدايبل كمعاملات رش و تعفير. أظهرت النتائج أن نسبة الإصابة فى معاملة الكنترول بلغت (١٠٠%) بعد ثلاث شهور من التخزين. كانت معاملتى السبينوساد و الدايبل تعفير هما الأكفأ فى خفض نسبة الإصابة فى الدرنات وكذلك فى خفض عدد عذارى فراشة درنات البطاطس الناتجة من كل معاملة. كان تأثير مبيد الفيروتيكتو و الأجرين أقل فاعلية مقارنة بالسبينوساد والدايبل وعلى الرغم من ذلك كان تأثيرهما معنوياً مقارنة بالكنترول، أما مبيد النيمكس فكان غير فعال مصحوباً بأقل نسبة خفض فى الإصابة قدرها (٦,٦٧%) وذلك بعد ثلاثة شهور من التخزين. كان هناك أيضاً فروق معنوية بين معاملات المبيدات الحيوية والكنترول فى كل من عدد الأنفاق بالدرنات وكذلك نسبة الجزء القابل للأكل بعد ثلاثة شهور من التخزين. كان للمبيدات الحيوية المختبرة تأثيراً سلبياً ومعنوياً على جميع المقاييس البيولوجية لفراشة درنات البطاطس مثل نسبة الفقس، نسبة التعذير، نسبة الفراشات المشوهه، نسبة خروج الفراشات و نسبة البقاء من طور البيضة وحتى الحشرة الكاملة سواء فى أفراد الجيل الأول أو الجيل الثانى من فراشة درنات البطاطس. كان هناك أيضاً تأثيراً معنوياً لمعاملات المبيدات الحيوية المختبرة على وزن عذارى فراشة درنات البطاطس حيث بلغ أعلى وزن (١٠,٩٠ مجم/عذراء) فى معاملة الكنترول وأقل وزن (٧,١٥ مجم/عذراء) فى معاملة الدايبل تعفير. أظهرت المبيدات الحيوية المختبرة أيضاً تأثيراً معنوياً على فترة وضع البيض ، فترة ما بعد وضع البيض، القدرة التناسلية الكلية، فترة نمو الطور اليرقى ، فترة نمو طور العذراء ، وفترة النمو الكلية لفراشة درنات البطاطس. وعلى العكس من ذلك، لم تتأثر طول فترة حياة الحشرات الكاملة للإناث أو الذكور بالمبيدات الحيوية المختبرة.