EFFICACY OF VARIOUS SELECTED NATURAL PRODUCTS AND SEX PHEROMONE TRAPS AGAINST POTATO TUBER MOTH, *PHTHORIMAEA OPERCULELLA* (ZELLER) (LEPIDOPTERA: GELICHIIDAE)

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ABSTRACT

The efficacy of various selected natural products as well as sex attractant traps against potato tuber moth (PTM), *Phthorimaea operculella* was evaluated under field and storage conditions during seasons 2002 and 2003, at El-Beheira Governorate.

Proclaim (Emamectin benzoate) was the most effective compound against PTM larvae with mean percentages of reduction reached 97.08 and 98.9% for both seasons 2002 and 2003, respectively, followed by Spinosad (Tracer 24%) with a reduction of 96.38 , and 96.9%. Dipel 2X and Natural oil were the lowest and recorded a reduction reached 89.03 and 71.29% for the first season (2002) and 83.51 and 71.81, for the second season (2003), respectively.

Under storage conditions, 60-90 days posttreatment with Tracer 24%, Dipel 2X and Virotecto, the percentages of reduction expressed as number of larvae/100 tubers were decreased and ranged between 87.0 to 96.6% for Tracer; 66-88% for Dipel 2X and 64-70% for Virotecto, respectively. The same trend was recorded in 2003 season. The average numbers of tunnels/100 tubers were 50.8±1.67, 10.2±3.5, and 5.0 ±1.62 mines for potatoes treated with Virotecto, Dipol 2X, and Tracer, respectively.

The present results show that the two tested seed dressing insecticides, Dinotefuran (20% WP) and Imidacloprid (70% WP) significantly reduced the population density of PTM larvae as compared with untreated control.

The efficacy of sex pheromone traps for controlling PTM was also investigated. The statistical analysis revealed the presence of significant differences

between tuber moth larvae inhabiting plant foliage and the corresponding number of male moths captured by sex pheromone traps situated in the tested potato fields. The reduction in levels of infestation with PTM larvae were 80.95% and 81.69% for 2002 and 2003 seasons, respectively. The obtained results reveal that mass trapping affect reduction of infestation in tubers equal to 47.62 and 82.76% in 2002 and 2003 seasons, respectively.

INTRODUCTION

Because Egypt is one of the world's developing countries that suffer from population increase, potato, *Solanum tuberosum* L. is considered as the most economically important feeding crop (Shaheen, 1979).

Potato tuber moth, *Phthorimaea operculella* (Zeller), is a serious pest of the potato, *S. tuberosum* L., in subtropical and tropical systems around the world (Sporleder *et al.*, 2004). Larvae of *Ph. operculella* attack green plant foliage and then turn to stems characterized by blotch mines between both leaf surfaces and tend to infest uncovered potato tubers imbedding in sub soil stratum prior to harvesting date and continue larval attacking to tubers in storage which lead to partial and complete tuber rotting by subsequent insect pest infestations. The infested tubers suffer in advance from both bacterial and fungi infections. In this case, the infested tubers become completely unmarketable and not suitable for human feeding (Westedt *et al.*, 1998).

The insecticide market has been dominated by the organophosphate, carbamate, and pyrethroid classes of insecticides (Argentine *et al.*, 2002). There is a continuing need for new, safe, effective and economical insecticides for crop protection and public health (Casida and Quistad, 2005). Recently, a number of new insecticide classes have been discovered and commercialized (Argentine *et al.*, 2002). Avermectins, a group of chemicals produced by soil-inhibiting streptomycete bacteria, have demonstrated high toxicities to a number of insects, mites and nematode pests (Putter *et al.*, 1981). Abamectin is a fermentation product composed of two avermectins derived from the soil bacterium *Streptomyces avermitilis*. Emamectin benzoate (Proclaim®) is an analog of abamectin, produced by the same fermentation system as abamectin (Ware and Whitacre, 2004). Spinosyns are among the newest classes of insecticides, represented by spinosad (Success®, Tracer Naturalyte®). Spinosad is a fermentation metabolite of the actinomycete *Saccharopolyspora spinosa*, a soil-inhabiting microorganism. It has both contact and stomach activity against lepidopteran larvae, leaf miners, thrips, and termites, with long residual activity (Thompson *et al.*, 1999; Dow AgroSciences Co., 2001).

The purpose of the present study, however, is to evaluate the efficiency of various selected natural products as well as sex attractant traps against PTM, *Ph. operculella*, under field and storage conditions during the two successive seasons, 2002 and 2003, at El-Beheira Governorate.

MATERIAL AND METHODS

Field experiments were carried out during two successive potato-growing seasons, 2002 and 2003. A private known farm was selected at El-Berka village, Abou-Hommos, El-Beheira Governorate, for achieving such field experiments.

1- Evaluation of certain bio-insecticides against potato tuber worm infestation

a- Under field conditions

A field experiment was conducted at El-Berka village, El-Beheira Governorate, during summer plantations of 2002 and 2003 on potato variety, Spunta, to determine the efficiency of four selected natural products.

An area of 2100 m^2 was divided into five equal plots and each selected plot was 26.3 m^2 in size containing 5 rows of 0.75 m^2 wide and 7 m long (four replicates of each treatment and control). Three sprays for each natural product were applied at 10 days intervals when the infestation with PTM was appeared. Samples of 25 potato plants were chosen randomly from each plot of each tested compound and control, pre-and post-application, to recognize initial infestation and reducing infestation levels, respectively. The percentage of reduction in potato tuber moth larvae was calculated according to Henderson and Tilton (1955) equation.

The tested Natural products: The tested natural products used in the field experiments were: Tracer 24 EC (Spinosad 30 ml/100 L water) is produced by Dow AgroSciences Co., Proclaim 5% SG (15 gm/100 L) supplied by Syngenta Co., Dipel 2X (*Bacillus thuringenesis* sub *kurstaki* (150 gm/100 L) produced by Abbott Laboratories, and soybean oil (Naturals 96% EC, 625 ml/100 L water).

b- Under storage conditions

An experiment was conducted to evaluate the efficiency of some selected bio-insecticides in reducing the PTM infestation on potato under storage conditions. Such experiment was carried out at El-Berka village, El-Beheira Governorate, during the two successive seasons, 2002 and 2003. Each treatment consisted of 400 kg for every tested compound. Potato heaps were covered with layers of rice straw and inspected 6 times on two weeks intervals on samples of 25 tubers randomly chosen replicated four times. Storage and different treatments began on 30 May in both seasons 2002 and 2003. Samples were taken on June 14th, June 29th, July 13th, July 28th, August 12th and August 27th for the two seasons. The number of infested tubers and number of holes in each treatment were counted and recorded after every inspection.

The tested Natural products: Tracer 24 (Spinosad WP) at the rate of 30 gm/100 L water, Dipel 2X (10% WP) a commercial product of *Bacillus thuringensis* sub *kurstaki* at the rate of 150 gm/ton and Virotecto (4% WP) a commercial product of granulosis virus (GV) containing 5x109 viral particles (PIB/gm) at the rate of 150 gm/ton were used under storage conditions.

2- Field evaluation of certain Seed dressing insecticides

Field experiments were conducted at El-Berka Village, El-Beheira Governorate, during summer plantations of 2002 and 2003 on potato variety, Agria, to evaluate the effect of two neonictonoids; Gaucho 70% WS (Imidacloprid) and MTI-446 20% WP (Dinotefuran) as seed dressing insecticides on the incidence of PTM infestation. The experiments were conducted in a randomized complete block design in four replications. Potato tubers of variety Agria were treated with the tested insecticides at the rates of 15 and 70 gm/100 kg tubers for Gaucho and MTI-446, respectively before cultivation and another four plots were left untreated as control treatment. After 6 weeks from the planting date, a random sample of 25 plants from each plot was taken weekly for 7 successive weeks. The number of larvae was counted and reduction of pest numbers as percentage was calculated according to Abbott's formula.

3- Mass trapping of moths

Monitoring the changes in the population density of potato tuber moth was studied based on number of male moths using water pheromone trap catches.

The water pan trap consists of rectangular plastic container. This container is of 40 x 20 cm and 10 cm height. Traps were covered by a plastic cover with the same dimensions and fixed to the four corners of the container at 5 cm height. Pheromone capsule were hooked at the center of the plastic board.

Pheromone capsules were fixed for two or three weeks and changed with new ones after three weeks. The sex attractant substance used was a mixture of 1:1.5 of two synthetic components; i.e. trans – 4, cis – 7 – tridecadien – 1 - ol acetate (PTM_1) and trans – 4 – cis – 7, cis – 10 – tridectren – 1 – 01 acetate (PTM_2) (0.4 mg of PTM_1 + 0.6 mg of PTM_2). The pheromone substance was impregnated on rubber caps kept frozen to preserve their effectiveness until needed. Rubber capsules were put on 2 cm from the trap and filled with mixture of 90% water and 10% soap as deterring liquid.

An experimental area of about one feddan was cultivated with Diamont variety on 15 February and five pheromone traps were distributed in the field on the first week of March. Pheromone traps were fixed to the soil by using wooden rods at the height of 50 cm from the ground in the selected area and calibrated just above potato plant canopy. Also, the same area in another field, 5 kilometers apart, was left without pheromone traps under the same conditions as a control treatment. Traps were investigated daily and the mixture of water and detergent soap was changed and numbers of captured males were recorded. Larvae of 100 plants were counted weekly in both treated- and untreated-experimental area. The sex pheromone caps were obtained from the Plant Protection Research Institute, Ministry of Agriculture, Dokki, Giza, Egypt.

The above-mentioned data were statistically analyzed to obtain the analysis of variance (ANOVA) and least significant differences (L.S.Ds) by the method of Steel and Torrie (1984) according to which the data were transformed, when desired, using square root and angular transformation.

RESULTS AND DISCUSSION

Effect of natural products against *Ph. operculella* larvae: under field and storage conditions during two growing seasons 2002 and 2003

Potato tuber moth, *Ph. operculella* is the most important insect pest of potato in Egypt. The ability of this pest to develop resistance to approved toxic chemical insecticides is a principal reason for its key-pest status. Many investigators in Egypt and other countries tried to evaluate the bio-effect of plant extracts, mass trapping technique and bio-insecticide formulations which demonstrate a promising effective control parameter against *Ph. operculella* infesting potato yield in the field and store houses. These measurements act as means of preventing or reducing probable occurrence of hazardous pollution and insect developed resistance.

The present experiment was carried to evaluate certain natural products against *Ph. operculella* larvae both in the field and store as trial to suppress as far as possible its population size below the economic injury level.

A- Field experiments

The efficiency of the four natural products; Proclaim (Emamectin benzoate), Tracer 24 % (Spinosad), Dipel-2X and the natural oil was evaluated against *Ph. operculella* larvae on potato variety. Diamont, during summer plantations of 2002 and 2003 seasons at El-Beheira Governorate. One hundred plants were inspected three times 10 days after spraying from each treatment. The total number of larvae and percentages of population reduction were recorded and calculated according to the equation of Henderson and Tilton (1955).

In season 2002, Data presented in Table (1) show the mean number of PTM larvae/ 100 plants and percentages of reduction for three successive sprays. It was observed that there were insignificant differences in the total numbers of larvae/100 plants and percentages of reductions between all tested bio-insecticides and control group.

Proclaim (Emamectin)at the recommended field rate was the most effective compound against PTM larvae with mean percentage of reduction reached 97.08%, followed by Tracer 24% (Spinosad) which recorded mean percent reached 96.38%. However, Dipel 2x and natural oil were the lowest in their efficiency, less than 90% in reduction, being 89.03 and 71.29%, respectively. As expected, the highest mean number of larvae/100 plants was recorded in the untreated area (32.0±4.11 larvae), while the lowest was in the area treated with proclaim that had less than one larva/100 plants.

Among season 2003, results obtained in 2002 potato growing season were confirmed during summer plantation of 2003 season (Table 2). Proclaim with a rate of 15 gm/100 L and Tracer 24% (30 ml/100 L) were the most effective bioinsecticide for control of PTM with means percent in reduction of larval population reached 98.9 and 96.9%, respectively, followed by Dipel 2x and natural oil with percentages of reduction reached 83.51 and 71.81%, respectively. Emamectin is a mixture of two avermectines. avermectin Bia (i) and avermectin Bia (ii) introduced as an insecticide/acaricide by Merck Sharp and Dohme Agvet, now owned by Novartis. It is recommended for control of a wide range of mites, leaf miner, suckers, fire ants and it is recommended for use on vegetables, potatoes and many other crops. However, present results are in full agreement with the results of Abdel-Megeed *et al.* (1998) who reported that under field conditions abamectin was the most effective against *Ph. operculella* survivors followed by profenfos, *B. t.* and granulosis virus, respectively. While under the storage conditions, abamectin was also the most effective bioinsecticide followed by fentrothion, *B. t.* and granulosis virus.

TABLE (I)

Effect of certain bio-insecticides against larval stage of *Ph. operculella* under field conditions during potato growing season 2002 at El-Beheira Governorate.

Bio-insecticide	Rate/100 L. water	No. of larvae/ 100 plants	Number of PTM larvae/100 plants and percentages of population reduction							
			1st inspection (15 days after treat.)		2nd inspection (30 days after treat.)		3rd inspection (45 days after treat.)		Mean	
			Total no.	Red. %	Total no.	Red. %	Total no.	Red. %	Mean no.	Red. %
Proclaim	15 gm	14	1±0.50 c	93.8	1±0.50 b	97.5	0±0.00 b	100.0	0.68±0.39 b	97.08 a
Tracer 24	30 ml	15	2±0.58 c	92.6	2±0.58 b	98.8	1±0.50 b	98.1	1.68±0.51 b	96.38 a
Dipel-2X	150 gm	15	4±0.81 c	83.6	3±0.50 b	87.9	3±0.98 b	95.6	3.40±0.72 b	89.03 a
Natural oil	625 ml	15	10±1.29 b	57.5	6±0.58 b	68.7	5±0.50 b	87.7	7.00±0.96 b	71.29 b
Control		16	22±1.29 a		26±2.5 a		46±5.0 a		32±4.11 a	
"F" value			26.86**		25.99**		19.75**		55.92**	6.52
L.S.D.			1.28		1.64		3.48		1.27	

TABLE (II)

Effect of certain bio-insecticides against larval stage of *Ph. operculella* under field conditions during potato growing season 2003 at El-Beheira Governorate.

Bio-insecticide	Rate/100 L. water	No. of larvae/ 100 plants	Number of PTM larvae/100 plants and percentages of population reduction							
			1st inspection (15 days after treat.)		2nd inspection (30 days after treat.)		3rd inspection (45 days after treat.)		Mean	
			Total no.	Red. %	Total no.	Red. %	Total no.	Red. %	Mean no.	Red. %
Proclaim	15 gm	15	1±0.50 b	96.90	0±0.00 b	100.0	0±0.00 b	100.0	0.32±0.29 d	98.90 a
Tracer 24	30 ml	13	2±0.58 b	92.70	1±0.50 b	97.7	0±0.00 b	100.0	1.00±0.45 d	96.90 a
Dipel-2X	150 gm	15	7±0.96 b	72.45	3±0.96 b	94.05	3±0.50 bc	84.05	4.32±0.90 c	83.51 b
Natural oil	625 ml	12	4±1.41 b	65.42	4±0.82 b	71.31	7±0.96 b	79.93	7.68±0.90 b	71.81 c
Control		12	16±4.82 a		23±1.71 a		30±1.29 a		22.32±1.93a	
"F" value			10.01*		19.73**		90.28**		78.83**	2.43
L.S.D.			1.45		1.49		1.02		0.56	

B- Storage experiments

B-1- Infestation expressed as number of larvae/100 tubers

In season 2002, Data in Table (3) reveal that the three tested bio-insecticides, Tracer 24%, Dipel 2x, and Virotecto gave full protection to potato tubers against PTM larvae till 30 days after treatment. Two weeks later, this full protection continued with Tracer 24% (Spinosad) but decreased to 94.5 and 89.0% for Dipel 2x and Virotecto, respectively. During the next three inspections (60-90 days after treatment), these percentages of reduction decreased and ranged between 87.0 to 96.6% for Tracer 24; 66-88% for Dipel 2x and 64-70% for Virotecto, respectively.

The average seasonal infestation showed that Tracer 24% reduced the infestation more than Dipel 2x and Virotecto. Mean number of PTM larvae/100 tubers was 14.3, 12.0 and 11.2 for Virotect, Tracer 24%, and Dipel 2x, respectively. Also, Tracer 24 had the highest ability to reduce populations of PTM larvae (95.5%) in comparison to the other two bio-insecticides, Dipel 2x and Virotecto (89 and 81.8 %, respectively).

Among season 2003, and as previously observed in 2002 season, the same trend was obtained again in 2003. Tracer 24 gave full protection to tubers against PTM larvae for 45 days after treatment. Within the next 45 days its ability to reduce the population of larvae decreased and ranged between 92-97%. The other two natural products (Dipel 2x and Virotecto) gave full protection against infestation for one month only after that this protection decreased and ranged between 89.1-97.2% for Dipel 2x and 83.0-92.6% for Virotecto, respectively.

As an average for the whole period of investigation, Tracer 24 ranked first with an average of reduction reached 97.2% followed by Dipel 2x (94.4%) and Virotecto (88.9%) (Table 3). Statistical analysis proved that, when the general mean of the six inspection are considered, there were significant differences between the three tested bio-agents in larval content when compared to untreated check.

B-2- Infestation expressed as number of tunnels/100 tubers

In season 2002, Data in Table (4) indicate that during the first two inspections (i.e. one month after treatment), the number of tunnels made by PTM larvae was zero in potato tubers due to treatment of each of the three tested natural products. From the 3^{rd} inspection (45 days after treatment), till the end of the examination period (90 days after treatment), the number of mines in potato tubers gradually increased till it reached 156±4.32 in tubers treated with Virotecto, 35±2.62

and 15±0.96 in tubers treated with Dipel 2x and Tracer 24, respectively. The mean number of tunnels/100 tubers (for the whole period of investigation) reached 50.8±16.7, 10.2±3.5 and 5.0±1.62 tunnels for potatoes treated with Virotecto, Diple 2x and Tracer 24, respectively. The corresponding number of tunnels in the untreated check was 785.9±72.66/100 tubers.

So, it is strongly recommended from the present results it is useful to apply Tracer 24% (Spinosad) with the rate of 30 gm/ton to protect potato tubers from *Ph. operculella* infestation in storehouse.

Among season 2003, Data in Table (4) confirm the same results obtained with the larval content in potato tubers. The total number of tunnels/100 potato tubers after one month of treatment was zero for all tested natural products. After that, the number of tunnels increased and ranged between 4-22, 4-35 and 9–76 tunnels/100 tubers in tubers treated with Tracer 24, Dipel 2x and Virotecto, respectively. There were no significant differences between the three bio-insecticides in their efficiency against *Ph. operculella*. There were significant differences in the number of tunnels in tubers treated with the three tested bio-agents when compared to untreated check.

In this respect, Campbell (1981) used Vertemic which is an acaricide or insecticide, based on natural metabolites derived from the actinomycete (*Streptomyces avermitilis*) against mites, dipterous leaf miners and some lepidopterous insects like spiny bollworm. Henderson (1997) used Spinosad which was also considered as natural metabolites derived from the actimomycete (*Streptomyces spinosa*) for controlling lepidopterous insects. Results of El-Aw (2003) indicated that the two tested bio-insecticides, Proclaim (Emmamectin) and Spinosad, are potentially potent for control of *Spodoptera littoralis* larvae.

2- Efficacy of seed dressing insecticides for controlling *Ph. operculella* larvae

Data in Table (5) when statistically analyzed it yielded a significant "t" value between the two tested insecticides which reveal the reliable reduction in infestation according to the values in the untreated check. The initial efficiency of MTI-446 and Gaucho (imedacloride) harbor 71.4 mortality in season 2002 and 100% for the second season (2003). The residual bio-efficiency of MTI-446 (dinotefuran) was 55.6, 60.0 and 65.0% for the 2nd, 3rd and 4th inspections, respectively. The residual efficiency, however, were obviously reduced after the 5th, 6th and 7th inspections reaching 27.8, 22.6 and 22.7%, respectively for 2002 season. On the other hand, the residual efficiency of Gaucho demonstrates the following mortality rates: 33.3, 66.7 and 60.0% after the 2^{nd}, 3^{rd} and 4^{th} inspections, respectively, thus demonstrating serial reduction percentages of 31.0, 14.3, and 9.1% for the 5^{th}, 6^{th}, and 7^{th} inspections, respectively.

The residual efficiency of MTI-446, however, was 75, 66.7, 60 and 41.2% after the 2nd, 3rd, 4th and 5th inspections, respectively reaching 36.4 and 33.3% after the 6th and 7th inspections in 2003 season. The residual efficiency of Gaucho was 50, 55.6, 50 and 25% after the 2nd, 3rd, 4th and 5th inspections, respectively and 27.3 and 25% for the 6th and 7th inspections, respectively. When the average data figures representing he reduction percentages within the seven inspections is considered, the obtained results revealed insignificant "F" value thus revealing the presence of insignificant differences between the tested compounds. MTI-446 demonstrated the highest mortality figures as seed dressing insecticide (44.5%) and Gaucho came next in this respect (36.3%). In addition, these results indicate that the bio-residual effect of the tested seed dressings gradually decrease after the 4th inspection.

Chemical insecticides are currently used to control the leaf miner, *Liriomyza trifolii* but development of resistance as well as environmental concerns restrict their use as efficient control agent (Al-Amad *et al*., 2001). However, the control of this insect pest can be optimized by some application techniques such as seed dressing with systemic insecticides as could as possible.

Our results indicated that the two tested neonicotinoid compounds (Dinotefuran; MTI-446 20% WP) and (Imidacloprid; Gaucho 70% WS) were effective as seed dressing insecticides against *Ph. operculella* and gave good protection up to four weeks after sowing. Thus, the use of Dinotefuran and Imidacloprid, the active ingredient of MTI-446 and Gaucho 70% with application rate of 15 and 70 g/100 kg of potato tubers will provide the potato grower with an additional tool of IPM for *L. trifolii* on common bean plants with less environmental impact and increased applicator and consumer safety compared to standard technology (using systemic insecticides as foliar spray)as reported by Mullins (1995), Injac *et al*. (1997), Igric *et al*. (2000) and Erlichowski *et al*. (2003).

3- Mass trapping of *Ph. operculella* male moths based on catches of sex pheromone traps

A- The simultaneous relationship between larval infestation to foliage and the corresponding number of male moths inhabiting potato fields

This part of study was under taken to evaluate the efficacy of sex pheromone traps for controlling PTM through the prevention of mating and subsequently laying infertile eggs. The total number of captured male moths .. reduction percentages in number of larvae inhabiting plant foliage with pheromone traps and the corresponding number of larvae without pheromone traps are shown in Table (6) for the two tested seasons, respectively

The statistical analysis of the data obtained and tabulated in Table (6) yielded a significant "F" value (67.33) thus reveal the presence of significant differences between tuber moth larvae inhabiting plant foliage and the corresponding number of male moths captured by sex pheromone traps situated in the tested potato fields. Numbers of larvae inhabiting potato fields free from sex pheromone traps demonstrated the highest reduction levels of infestation thus revealing the presence of 80% reduction (Table 6). The only significant and positive correlation (r = 0.7173) was obtained when the number of captured moths represents the number of corresponding larvae inhabiting potato plant canopy in the untreated area during 2002. The estimated average number of larvae, however, was 24 larvae/100 plants which demonstrate an average infestation equal to 1% based on sex pheromone trap catch. For the untreated fields, a number of 126 larvae/100 plants was counted during 2002 growing season yielded 1% infestation (unit effect).

For 2003 potato growing season (summer plantation), a number of 13 larvae/100 plants in the treated area was estimated. In fields without sex pheromone traps, a number of 71 larvae/100 plants was obtained. The simple correlation when worked out for 2003 season, it yielded insignificant "r" value between captured male moths and the simultaneous number of larvae inhabiting potato fields (r = 0.2114).

Very low rates of PTM1 and PTM2 (0.4 + 0.6 mg) are required to cause mating disruption. PTM1 is volatile and distributes throughout the crop easily attracting male moths to trap. The pheromone mixtures have been to maintain population of PTM moth effectively at economically tolerable levels during the time between development (7 March) and harvest (16 May) in 2002 and (4 March) and harvest (12 May) in season 2003. Also, the pheromone mixtures have been shown to maintain populations of PTM larvae on field plants at economically tolerable levels resulting 80.95% reduction in 2002 and 81.69% in 2003 seasons, respectively.

Monitoring the changes in the population density of PTM as number of male moths was achieved in the present study using water pheromone trap catches. However, sex pheromone baited water traps seem to be effective as a means of detecting and monitoring the potato tuber moth at an early stage (Chandla *et al.*, 1987) and it may be possible to predict peaks in larval infestations using pheromone traps (Herman, 1990).

TABLE (III)

Effect of certain bio-insecticides against *Ph. operculella* under storage conditions expressed as number of larvae during potato growing seasons, 2002 and 2003 at El-Behera Governorate.

Days Post-treatment	2002								
	Bio-insecticide							F	L.S.D.
	Tracer (30 gm/ton)		B.t. (150 ml/ton)		G.V. (150 ml/ton))		Control	No. of larvae	Red. %
	No. of larvae	Red. %	No. of larvae	Red. %	No. of larvae	Red. %			
15	0±0.0 b	100	0±0.0 b	100	0±0.0 b	100	9±0.36 a	22.09**	0.77
30	0±0.0 b	100	0±0.0 b	100	0±0.0 b	100	39±2.22 a	77.38**	1.77
45	0±0.0 b	100	4±0.82 b	94.5	8±1.41 b	89	73±3.86 a	77.06**	3.16
60	4±0.82 c	96.6	13±1.51bc	88	19±0.87 b	70	100±0.00 a	164.5**	2.77
75	10±0.58 c	90.0	16±1.41bc	86	23±2.63 b	68	100±0.00 a	234.5**	2.20
90	12±0.82 b	87.0	34±1.29 b	66	36±1.60 b	64	100±0.00 a	163.7**	2.37
Mean	12±0.24 c	95.5	11.2±3.18c	89	14.3±3.73	81.8	70.2±9.11 a	133.8**	1.03
	2003								
15	0±0.0 b	100	0±0.0 b	100	0±0.0 b	100	4±0.82 a	6.02**	0.65
30	0±0.0 b	100	0±0.0 b	100	0±0.0 b	100	11±1.26 a	19.11**	1.01
45	0±0.0 b	100	2±0.85 b	97.2	4±0.82 b	92.6	76±2.58 a	169.11**	3.16
60	3±0.96b	97	4±0.58 b	96	10±1.29 b	70	100±0.00 a	164.5**	2.77
75	6±1.50 b	94	10±1.73 b	90	22±1.29 b	83	100±0.00 a	234.5**	2.20
90	8±0.82 b	92	35±2.62 b	89.1	27±0.96 b	91.2	100±0.00 a	163.7**	2.37
Mean	5.5±1.79d	97.2a	10.2±3.50c	94.4c	10.5±2.81b	88.9 c	65.2±10.70a	133.8**	1.03

TABLE (IV)

Effect of certain bio-insecticides against *Ph. operculella* under storage conditions, expressed as number of tunnels/100 tubers, during potato growing season 2002 and 2003 at El-Beheira Governorate.

Days Post-treatment	2002								
	Bio-insecticide							F	L.S.D.
	Tracer (30 gm/ton)		B.t. (150 ml/ton)		G.V. (150 ml/ton)		Control	No. of larvae	Red. %
	No. of larvae	Red. %	No. of larvae	Red. %	No. of larvae	Red. %			
15	0±0.0 b	100	0±0.0 b	100	0±0.0 b	100	4±0.20 a	22.09**	0.77
30	0±0.0 b	100	0±0.0 b	100	0±0.0 b	100	41±2.58 a	77.38**	1.77
45	0±0.0 b	100	5±0.60 b	99.0	5±0.60 b	99	497±12.57 a	77.06**	3.16
60	4±0.81 b	99.6	6±0.58 b	99.4	19±2.21c	98.1	945±32.78 a	164.5**	2.77
75	11±0.95 b	99.1	18±2.38 b	99.1	125±7.7 c	90.2	1300±62.58 a	234.5**	2.20
90	15±0.96 b	99.1	35±2.62 b	98.1	156±16.7b	91.2	1845±24.16 a	163.7**	2.37
Mean	5±1.62 c	99.6a	10.2±3.50 b	99.3 b	50.8±16.7c	96.4b	785.9±72.7a	133.8**	1.03
	2003								
15	0±0.0 b	100	0±0.0 b	100	0±0.0 b	100	4±0.21 a	6.02**	0.65
30	0±0.0 b	100	0±0.0 b	100	0±0.0 b	100	10±1.29 a	19.11**	1.03
45	0±0.0 b	100	4±0.8 b	95.3	9±1.9 b	91.6	99±5.26 a	169.11**	4.76
60	4±0.81 b	99.3	8±0.81 b	98.5	11±0.50 b	97.7	551±23.30 a	164.5**	18.43
75	10±1.29 b	98.4	20±1.38 b	97.5	43±3.95 b	92.8	880±30.14 a	234.5**	34.37
90	22±1.29 b	98.3	35±2.63 b	97.1	76±4.24 b	92.8	1035±14.8a	163.7**	12.18
Mean	13.8±1.50b	99.3 a	11.2±3.45 b	98.1a	23.2±7.39b	95.6 b	429.5±10.8a	133.8**	6.06

TABLE (V)

Effect of certain seed dressing insecticides on the population density of potato tuber moth larvae under field conditions of 2002 and 2003 at Behera Governorate.

Treatment	1st inspection		2nd inspection		3rd inspection		4th inspection		5th inspection		6th inspection		7th inspection		Mean	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A*	B*
Season 2002																
Dinoteduran	2	71.4	4	55.6	6	60.0	7	65	13	28.1	18	28.6	17	22.7	9.14	50.1
Imidacloprid	2	71.4	6	33.3	5	66.7	8	60	12	31.0	18	14.3	20	9.1	10.14	44.5
Control	7		9		15		20		18		21		22		18.30	
Season 2003																
Dinoteduran	0	100	1	75	3	66.7	4	60	7	41.2	7	36.4	8	33.3	4.3	48.8
Imidacloprid	0	100	2	50	4	55.6	5	50	9	25.0	8	27.3	9	25.0	5.3	36.9
Control	1		4		9		10		12		11		12		8.4	
Mean of the two seasons 2002 and 2003																
Dinoteduran	1	71.1	2.5	59.7	4.5	63.3	5.5	63.3	10.0	33.3	11	31.2	12.5	26.5	6.7	44.5
Imidacloprid	1	71.1	4.0	35.5	4.5	63.3	6.5	53.3	10.5	30.0	13	18.8	14.5	14.7	7.7	36.3
Control	3.5		6.2		12.0		15		15.0		16		17.0		12.1	

A = Number of larvae/100 plants.
B = Reduction percentage according to Abbott's formula (1925).
* = Overall mean of the two seasons 2002 and 2003.

F" value for 2002 season = 12.9* LSD = 8.4
"F" value for 2003 season = 22.3** LSD = 3.1
"F" value for mean = 13.1* LSD = 2.6

TABLE (VI)

The fluctuations in the captured male moths of *Ph. operculella* as indicated by sex pheromone traps and the corresponding number of larvae inhibiting potato fields, during potato growing seasons 2002 and 2003, at Abo-Hommos region, El-Beheira Governorate.

Date of inspection	Season							
	2002				2003			
	No. of captured male moths	number of larvae/100 plants			No. of captured male moths	number of larvae/100 plants		
		With pheromone traps	Without pheromone traps	Red. %		With pheromone traps	Without pheromone traps	Red. %
7/3	13	0	0	0.0	10	0	0	0.0
14	30	0	0	0.0	44	0	0	0.0
21	69	2	2	0.0	48	0	0	0.0
28	98	2	3	33.3	112	0	0	0.0
4/4	133	3	11	72.7	57	0	3	100.0
11	117	5	14	64.3	23	0	12	100.0
18	120	5	13	61.5	40	4	11	63.6
25	179	2	18	88.9	64	2	14	85.7
2/5	148	2	28	92.9	97	4	16	87.5
9	122	2	25	92.0	182	2	6	66.7
16	172	1	7	85.7	201	0	1	100.0
23	471	1	5	80.0	76	1	8	87.5
Total	**1672**	**24**	**126**	**80.95**	**954**	**13**	**71**	**81.69**
In tubers (on harvest day)		**26**	**50**	**47.62**		**5**	**29**	**82.76**
'r'	**0.7173****				**0.2114**			

These results agreed with Raman (1982); Doss (1984); Trematera *et al.* (1996); Herman and Clearwater (1989) and Chandel *et al.* (2001) showed that larval populations remained low (0.06-1.38/plant) throughout the cropping period from January to May under field conditions. At harvesting in May, tuber infestation ranged from 2.14-3.98%.

The integration of the data tabulated in Table (6), however, shows that potato tuber moth was more abundant during May, while April and March months came next in this respect. The highest number of captured male moths, however, was achieved during summer months. The third and fourth weeks of May harbored the highest numbers; i.e. 471 and 201 moths/5 pheromone traps for the two summer growing seasons of 2002 and 2003. when the data for the treated and untreated plants were analyzed according to Abbott's formula, it appears that the reduction expressed as number of larvae was around 80%; i.e. 80.95% and 81.69% for 2002 and 2003 seasons, respectively.

This agrees with results found by Shaheen (1979) in Egypt who indicated that the reliable damage of potato tuber moth occurred in February. El-Sayed (1983) found that summer plantation harbors severe potato tuber worm infestation on the foliage and tubers. He also mentioned that symptoms of PTM infestation were firstly appeared on the foliage at the second half of March; Ali (1993) in Sudan, reported that population increased slowly at the beginning of the season, then more rapidly during crop establishment and throughout the harvest period, after which the pest declined sharply. He also added that planting in the 2nd week of November resulted in less insect damage and Moawad *et al.* (1998) showed that infestation by *Ph. operculella* was higher on late-planted cultivations than the earlier ones. Monitoring the changes in the population density based on pheromone traps showed that there was an increase in the mean number of males caught during the night from the 4th week of March to the 3rd week of May.

B- Infestation of tubers

The careful examination of the data tabulated in Tables (6) reveals the changes in the population density of *Ph. operculella* larvae infesting tubers. Tubers seem to harbor significantly quite reliable levels of infestation during both seasons; i.e. 2002 and 2003. On the other hand, it appears from the data that the sex pheromone traps are used in both monitoring the changes in the population density and mass trapping of *Ph. operculella* male moths. Infestation was estimated as 50% in potato fields without sex pheromones in 2002 and 29% for 2003 season. The infestation in fields treated with pheromone traps was estimated as 26% and 5% in 2002 and 2003 seasons, respectively. The obtained results reveal that mass trapping affect reduction in tubers equal to 47.62% in 2002 season and 82.76% in 2003 season.

However, the integrated pest management (IPM) program for PTM will recommend the Desire pheromone traps baited with 1:1.5 blend of pheromone to be used for monitoring moth population in potato crops (Herman and Clearwater, 1989). In full agreement with Chandla *et al.* (2000), it is concluded from the present results that the IPM program for PTM may include different management practices to control the pest in stores and fields such as the cultural (sex pheromones), biological (Avermectin, Spinosad, B.t. and G.V) as well as seed dressing insecticides such as the two neonictonoids, Gaucho 70% WS (Imidacloprid) and MTI-446 20% WP (Dinotefuran).

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