BIOLOGICAL CONTROL OF THE POTATO TUBER MOTH, *PHTHORIMAEA OPERCULELLA* (ZELLER) IN POTATO FIELDS AND STORAGE .

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Abstract

On large-scal farm trials, the effectiveness of Bacillus thuringiensis (B.T.), Granulosis virus (G.V.) and the organophosphate compounds; Fenitrothion and Profenofos against P.operculella were studied at El-Gharbia, El-Monifia and El-Behera Governorates, in 1995 season. Results from field experiments indicated that Bacillus thuringiensis, G.V. and the chemical insecticides reduced the incidence of P.operculella on potato tubers. There was no significant difference between B.t., G.V. and profenofos in the percentage of PTM infestation, number of holes in potato tubers and rotten tubers. Using PTM sex pheromone traps would help in determining the suitable time for biological or chemical insecticides application. Also, the correlation between the environmental conditions such as temperature and R.H., and the population density of PTM should be taken into account. Under storage conditions, after 42 and 63 days of application, the percentage reduction in PTM infestation of potato tubers for the biological agents was higher than Fenitrothion. Although potato tuber moth larvae hide in the tunnels that they burrow in the leaves and tubers, B.thuringiensis and G.V. applications reduced their population levels considerably and reduced the percentage of infestation, number of PTM larvae, and yield loss in potato tubers in comparison with that provided by Fenitrothion. No significant differences in the efficacy against the PTM between the application of stored tubers with one application of the tested compounds or two applications.

Key words: Phthorimaea operculella (Zeller), Bacillus thuringiensis, Granulosis Virus, sex pheromone.

INTRODUCTION

Problems associated with indiscriminate insecticides usage, human poisonings, environmental contamination, and residues in foods continue to be some of the critical issues facing agriculture and agrochemical industries. So, efforts to reduce the use of traditional chemical pesticides through the use of biological control agents and

integrated pest management are starting to have a significant impact.

On the other hand, the potato tuber moth, *Phthorimaea operculella* (Zeller) is the most important potato pest in Egypt. Populations are low during the cold and rainy winter period, but increase to significant levels during the hot and dry summer months. PTM cause damage to potato tubers in the field particularly if the harvest is delayed, and in traditional rustic stores. Losses to farmers consist of discards, reduced prices for damaged potatoes, increased handling costs, and expenditures on pesticides. Farmers also sustain an opportunity cost when they are forced to sell at low prices to avoid pest damage. Control of P.operculella has incorporated the use of transgenic potato which offer certain degree of protection against feeding damage by potato tuber moth (Ebora *et al.*, 1994, Haines 1977 and Raman and Redolfi, 1982), repellent plant extracts (Lal, 1987 and Raman *et al.*, 1987). Also, the sex pheromone has been found highly effective in monitoring and mass trapping PTM males under field conditions (Raman, 1982, 1984 and 1988). Replacement of the commonly used parathion with less toxic pesticides such as synthetic pyrethroids or Bacillus thuringiensis has been reported by El-Sayed *et al.*, 1979, Collantes *et al.*, 1986; Von Arx *et al.*, 1987; Suriaatmadja, 1988 and Broza and Sneh, 1994 .

The aim of the present work was to study the effectiveness of B.thuringiensis, granulosis virus in comparison with the chemical insecticides in controlling the potato tuber moth under storage conditions.

MATERIALS AND METHODS

In this set of experiments, 2 chemical insecticides and 3 biological insecticides were considered. The chemical insecticides included of Fenitrothion 3% W.P. (0.0 dimethyl 0- (4-nitro-m-tolyl) phosphorothioate) at the rate of 3 kg/ton and Profenofos (0, (4-bromo-2-chlorophenyl) - 0-ethyl-S-propyl phosphorothioate) were used. Fenitrothion and profenofos are produced by Sumitomo and Ciba-Geigy, respectively.

The biologicals were 2 formulations of *Bacillus thuringiensis* kurstaki namely; Protectocide (32000 IU/mg W.P.) and Diple 2x (32000 IU/mg). and Baculovirus, PTM granulosis virus. Protectocide is produced by Plant Protection Research Institute, Agricultural Reseach Center, Ministry of Agriculture, Egypt. Diple 2x is pro-

duced by Abbott Laboratory, North Chicago, USA. PTM granulosis Virus (PTM GV 4% W.P.) were used at the rate of 2000 and 60 larval equivelant (L.E.) per ha and ton, respectively. Granulosis virus (G.V.) was produced by Plant Protection Research Institute, Agricultural Research Center in collaboration with the International Potato Center (CIP), Kafr El-Zayat, Egypt.

Field experiments were carried out at CIP station in Kafr El-Zayat, Gharbia governorate, Egypt in 1995 season. Experimental plot replicated 3 times. The plot area was 1/24 feddan. The first spray was done at the 1st week of April. Three applications were undertaken at two weeks intervals. Thereafter, to evaluate the effectiveness of B.t., G.V. and Fenitrothion against PTM, samples of potato plants (one hundred each) were inspected at fortnight intervals after spray in 4-5 replicates at random from the different plots, to reveal the percentage of infested plants and number of larvae. Also, at the end of season, the number of infested tubers and number of holes were recorded.

In storage, two experiments were carried out. The first was undertaken as large scale trials at Gharbia, Behera and Monifia governorates by using Protectocide, Dipel, G.V. and profenofos. The biocides were dusted on to potato tubers after mixing with Talc powder (magnesium silicate) at the rate of 3kg of the mixture per ton. Control potato tubers were left untreated. The second experiment was carried out at CIP station in Kafr El-Zayat, Gharbia governorate, Egypt, in 1995 season. It consisted of comparing 2 applications vs 1 application of Diple 2x (B.t.), G.V., and Fenitrothion on protection of potato tuber from PTM infestation. To evaluate the effectiveness of B.t., G.V. and Fenitrothion against PTM, samples of potato tubers (one hundred each) were taken at 20 days intervals in 4 replicates at random from the different treatments. The percentage of infested tubers, number of larvae, and number of holes were recorded.

Statistcal analysis were carried out using Duncan Multiple Range Test (DMRT) by Costat Programme. Also, calculation percentage of reduction in PTM infestation was calculated according to Fleming and Retnakaran (1985) as follows :-

% Population Reduction =

$$\left(1 - \frac{\text{Posttreatment population in treatment}}{\text{Pretreatment population in treatment}} \times \frac{\text{Pretreatment population in check}}{\text{Posttreatment population in check}}\right) \times 100$$

RESULTS AND DISCUSSION

1. Field experiments

Percentage of infestation on potato plants

Results indicated that all treatments significantly reduced the percentage infestation and the number of holes and PTM larvae in comparison to the control, Table 1. Profenofos treatment had the highest yield in ton/ha (27.5) followed by G.V. (26.9), Diple 2x (26.4) and control (22.6), respectively. There was no significant difference between G.V. and profenofos in the percentage of PTM infestation, number of holes in potato tubers and rotten tubers. There were positive trends between the percentage of PTM infestation, number of holes in potato tubers and rotten tubers. There were positive trends between the percentage of PTM infestation, number of holes in potato tubers, percentage of rotten tubers and the yield in ton/ha in the different treatments, Table 2. From our observations in the summer season, P.operculella migrate from adjacent tomato fields and previously harvested potato field to cause severe damage to potato fields especially at the end of growing season through April and May. Thus, crop rotation and early planting would help in reducing the infestation level in potato fields .

Table 1. Efficacy of *Bacillus thuringiensis* Kurstaki (B.t.), Granulosis Virus (G.V.) and profenofos on the PTM infestation in Kfr El-Zayat, Gharbia Governorate, Egypt, 1995 season.

Treatments	1st Inspection				2 nd Inspection				3 rd Inspection			
	Infect. Plants Count	Infect. leaves Count	Total larvae Count	Infec. larvae Count	Infect. Plants Count	Infect. leaves Count	Total larvae Count	Infec. larvae Count	Infect. Plants Count	Infect. leaves Count	Total larvae Count	Infec. larvae Count
G.V.	0.6a	1.6a	1a	1a	3	14.3a	3a	3a	7a	9.6a	6a	5a
Diple 2 x	1.3a	3a	1.6ab	0.6a	3.3a	16.6a	4a	2.3a	7a	14.3b	5.6a	4.3a
profenofos	2a	4.6a	2.3ab	0.3a	3.3a	14.3a	4.3a	0.3b	13.6b	10.3ab	6a	0.3b
Control	2.3a	5.6a	3.6b	0a	5a	12.3a	13.6b	0b	9.3a	13.6b	16b	0a
LSD	1.5	2.98	2.5	0.8	2.24	2.66	3.07	1.53	3.95	3.88	2.71	1.54

The values in columns having the same letter vertically are not significantly different at the level (p = 0.05).

To achieve succesful control of this pest, effective scouting is important to determine the correct timing of biological or chemical insecticides application. For this purpose, sex pheromone traps could be used to monitor the population density of PTM. These results agree with Haydar and El-Sherif, 1987. In field trials they eval-

uated the effect of two commercial preparations of B.t. (Dipel and Thuricide HP) on the population of Phthorimaea operculella on potato plants in Egypt. Their results indicated that Dipel and Thuricide treatments as well as Gusathion (Azinophosmethyl) treatment were efficient in reducing potato tuber moth infestation and thus led to a high yield.

On the other hand, since the specificity of Bacillus thuringiensis activity reside largely with the structure of its insecticidal crystal proteins (ICPs) and the role of toxin-receptor binding in the host insect mid-gut. Phthorimaea operculella is susceptible to at least 3 insecticidal crystal proteins from Bacillus thuringiensis : Cry1A (b), Cry1B, and Cry1C. So, transgenic potato plants expressing B.t. crystal genes could be a suitable tool in controlling PTM under field conditions and devising insect resistance management strategies. Ebora *et al.* (1994) found that 10% of mortality of first instar P.operculella was obtained after 48 h of feeding on leaf disks from transgenic plants. While the second instar P.operculella was slightly less capable of surviving on leaf disks form transgenic plants than on untransformed plants after 240 h.of feeding.

2. Storage Experiments

Results obtained from 35 stores (Nawalla) in Tables (2-8) indicated that there were no significant differences between the different B.t. and G.V. treatments but these differences were clear between the tested biological compounds and the chemical insecticides under the same storage conditions.

Taking into account the percentage of PTM infestion under storage conditions, after 21 days of application, the tested compounds could be arranged in descending order as follows : Protectocide, Dipel 2 x, G.V. and Sumithion. After 42 days of application, the different compounds revealed the same order of efficacy except Protectocide and Dipel exchanged their position. The reduction in PTM infestation ranged between 68.6-74.4% in Protectocide treatment while ranged between 51.5-84.9, 45-87.9 and 12.0-72.0% in Dipel, G.V. and Sumithion treatments, respectively.

Ali (1991) evaluated the efficacy of a suspension of granulosis virus obtained from infected dead homogenized larvae of Phthorimaea operculella in controlling an infestation of PTM in stored potatoes. He found that percentage infestation in treated tubers was reduced by 20-32.8% compared with the untreated control. Also, Das *et al.* (1992) found that a granulosis virus (GV) preparation at 5 kg/ton of tubers was effective against P.operculella for up to 2 months of storage. Deltamethrin (0.05% Decis dust at 7.5 kg/ton of tubers) was effective for up to 4 months of storage and sprouting and there were very few infestations by the pest in the treated tubers.

Table 2. Evaluation of biological control agents (B.t. and G.V.) in the field compared to insecticide against potato tuber moth in Kafr El-Zayat, Gharbia Governorate, 1995 season .

Treatments	G.V. infected larvae 2000 larvae/ha	B.t. Diple 2x 800 gm/ha	Insecticide Selecron 1800 cm3/ha	Control	L.S.D.
Yield Ton/ha	26.9a	26.4a	27.5a	22.6b	1.2
PTM Infestation %	7.3a	7.67a	8.0a	20.67b	8.5
No. of holes (count)	10.33a	10.33a	13.67a	31.0b	1.21
Rotten Tubers %	1.0a	0.66a	1.33a	7.67b	1.0

The values in rows having the same letter vertically are not significantly different at the level (p = 0.05).

Table 3. Effect of some biological and chemical Insecticides before and after treatment on potato tuber moth (rotten and infested tubers and galleries) in Tanta district, 1995 season.

Treatments	Before Treatment		1st Sorting (21 days)		2nd Sorting (42 days)		3 rd Sorting (63 days)	
	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.
Diple	1a	4a	3a	3a	13a	7a	1a	14a
Protect.	1a	4ab	3a	4ac	12a	6.3b	3a	13a
G.V.	1a	2b	3a	6bc	3b	8.7ac	1a	5b
Control	1a	2b	2a	7.6b	18.7c	15d	25b	63c
L.S.D.	0.94	1.88	1.63	2.03	2.61	2.03	4.51	5.24

The values having the same letter vertically are not significantly different at the level (P = 0.05).

Variety : Diamant.

Table 4. Effect of some biological and chemical insecticides before and after treatment on potato tuber moth (rotten and infested tubers and galleries) in Tanta district 1995 season.

Treatments	Before Treatment		1st Sorting (21 days)		2nd Sorting (42 days)	
	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.
Diple	1a	11a	3a	8.6a	5a	4.6ab
Protect.	1a	5a	3a	5.3a	4a	3a
G.V.	1a	9a	4a	9.3ab	4a	7b
Control	1a	8a	4a	13b	5a	23c
L.S.D.	0.94	6.02	3.48	3.88	3.56	3.31

The values in columns having the same letter vertically are not significantly different at the level (P = 0.05).

Table 5. Effect of some biological and chemical insecticides on potato tuber moth (rotten and infested tubers and galleries before and after treatment) in Tanta district minoufia governorate, 1995 season.

Treatments	Before Treatment		1st Sorting (21 days)		2nd Sorting (42 days)		3 rd Sorting (63 days)	
	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.
Protectocide	1a	7a	1a	6a	4a	8a	4a	8a
Profenofos	1a	7a	3b	9b	5a	11b	5a	11b
L.S.D.	0	3.75	1.60	3.26	2.26	2.26	2.26	2.26

The values have the same letter vertically are not significantly different at the level (P = 0.05).

Variety : Diamant.

Table 6. Effect of some biological and chemical insecticides before and after treatment on Potato Tuber Moth (rotten and infested tubers and galleries) in Tanta District 1995 season.

Treatments	Before Treatment		1st Sorting (21 days)		2nd Sorting (42 days)		3 rd Sorting (63 days)	
	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.	Rotten Tub.	Infested Tub.
Diple 2x	4a	10a	6a	12a	5a	16a	4a	21ab
G.V.	9.5b	8b	16b	9b	9.5b	14a	3a	19a
Protect.	1c	8b	1c	2c	1c	11b	3a	19a
Sumithion	0c	1c	6.2a	12a	5a	19c	5a	24b
Talc	0c	1c	3d	9b	5a	33d	6a	56c
Control	1c	2c	2cd	7.6d	18.8d	15a	25b	63d
L.S.D.	2.76	1.57	1.57	1.92	2.48	2.80	3.54	4.24

The values have the same letter vertically are not significantly different at the level (P = 0.05).

Table 7. Percentage reduction of ^^ infestation in stored potato tubers in Different treatments after application in Gharbia, Minoufia, and Beheira Governorates 1995 season.

Treatments	Days after treatments		
	1 st Sorting 21 days	2 nd Sorting 42 days	3 rd Sorting 63 days
G.V.	45	66.4	87.9
Protect.	68.6	74.4	83.6
Diple 2x	51.5	77.1	84.9
Sumithion	12.0	46.7	72.0

Bactospine 0.2% (Bacillus thuringiensis thuringiensis) was ineffective. Zero to very low infestations in all fields were achieved with several treatment combinations (GV + B.thuringiensis + deltamethrin + Lantana camara, and deltamethrin + B.thuringiensis + GV) even after 4 months of storage.

Data obtained in Table 8 indicated that, no significant differences in the efficacy against the PTM between one application of the tested compounds or two applications. There were significant differences in the percentage of infested and rotten tubers, and the number of galleries between Dipel, G.V., Fenitrothion and control treatments.

Table 8. Effect of biological control (GV and B.t.) compared to insecticide under Nawalla conditions on PTM control in Kafr El-Zayat, Gharbia Govenorate, 1992 season .

Treatment	Rep.	1 st Sorting		2 nd Sorting		3 rd Sorting	
		Infect. tubers count	Rotten tuber count	Infect. tubers count	Rotten tuber count	Infect. tubers count	Rotten tuber count
G.V. (Powder 200 gm/kg tubers)							
Once	X	16.3a	0.3a	28.3b	0.66a	24.7a	1a
Twice	X	16.33a	0.66a	17.33a	1a	23.33a	1.67a
Diple 2 x (solution 15 gr/liter water/100 kg tubers)							
Once	X	14a	-	27b	0.66a	24.33a	0.66a
Twice	X	14a	2b	17	0.33a	23.67a	1.67a
Fenitrothion 3% (Powder 300 gm/100 kg tubers)							
Once	X	24.33a	2b	39.67c	1.67a	47.67b	2.67a
Twice	X	23.33a	2b	20.67b	0.66a	43.67b	2.67a
Control	x	49c	5.67c	86d	6.3b	100c	13b

The values have the some letter vertically are not significantly different at the level (P = 0.05). Variety TPS.

In conclusion, it can safely be said that both B.t. and G.V. based products represent an effective solution to control PTM under both field and storage conditions with some considerations that should be kept in mind :

First, under field conditions, the appropriate time of biological application is an important factor to get good results. The population density of PTM could be de-

termined by using sex pheromone traps. Because of migration of PTM moths from adjacent tomato fields and the other hosts, crop rotation would help in reducing the population in potato fields. Cultural practices such as regular irrigation especially at the end of season, good hoeing and hilling will prevent the PTM adult moths from laying its eggs on the potato tubers or in cracks. Fertilization especially potassium fertilization will help the plant to grow healthy and reduce the infestation level.

Second, under storage conditions, it is important to exclude the infected tubers. Storage facility should have openings in the bottom and top covered with wire to renew the air circulation and protect the tubers from rats and PTM invesion. Also, it should be painted with white colour from the outside to reflect the sun light and keep the temperature inside the store cold. A more widespread use of these biological insecticides (B.t. and G.V.) is to be expected because the good results so far obtained, the possibility to improve the efficacy, the ever greater need for pesticides with lower impact on environment and high selectivity. The increase in using of these biocides depends on reduction of their cost to the farmers. Although potato tuber moth larvae hide in the tunnal that they burrow in the leaves and tubers, B.thuringiensis and G.V. applications reduced their population levels considerably and reduced the percentage of infestation, number of PTM larvae, and yield loss in potato tubers.

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المكافحة البيولوجية لفراشة درنات البطاطس فى الحقل والمخزن

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تمت هذه التجربة خلال الموسم الزراعى ١٩٩٥ بمحافظات الغربية والمنوفية والبحيرة بغرض تقييم استخدام بكتريا الباسيلس ثيورنجنسيس والفيروس المحبب فى مكافحة فراشة درنات البطاطس فى الحقل والمخزن (النوالات) وذلك مقارنة بأحد المركبات الفوسفورية وهو البروفينوفوس. أوضحت النتائج المتحصل عليها أن كل من بكتريا الباسيلس والفيروس المحبب والبرفينوفوس قللت نسبة الاصابة بفراشة درنات البطاطس فى الحقل. ليس هناك اختلاف معنوى بين بكتريا الباسيلس والفيروس والبروفينوفوس فى نسبة الاصابة ونسبة الخسارة والاعفان. كذلك يمكن استخدام الفرمونات الجاذبة فى تحديد انسب الاوقات لاستخدام المركبات او المبيدات الحيوية. ومن خلال ملاحظاتنا يلزم ايضا دراسة العلاقة بين تعداد فراشة درنات البطاطس والعوامل البيئية المختلفة كالحرارة والرطوبة . كما اوضحت النتائج المتحصل عليها اثناء التخزين خلال الفحصات بعد ٢١ ، ٤٢ ، ٦٣ يوم ان معاملات البكتريا والفيروس والبروفينوفوس ادت الى خفض نسبة الاصابة فى الدرنات وتعداد اليرقات فى الدرنات ونسبة الفقد فى المحصول بالمقارنة. ليس هناك اختلاف معنوى بين معاملة المركبات الحيوية مرة واحدة او مرتين فى مكافحة فراشة درنات البطاطس فى المخزن.