Insecticide Resistance in Potato Tuber Moth *Phthorimaea Operculella* Zeller in Egypt

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Abstract: The potato tuber moth *Phthorimaea operculella* Zeller (Lepidoptera - Gelechiidae), is a major pest of the potatoes world-wide attacking the foliage and infest the tubers in both field and store causing serious economic damage. In this study, the efficacies of seven insecticides [organophosphate (Fenitrothion & Pirimiphos-methyl), carbamate (Carbosulfan & Aldicarb), pyrethroid (Lambda-cyhalothrin & Deltamethrin) and imidaclopride (Confidor)] were determined against four strains of *P. operculella* collected from four Governorates in Egypt [Damytta (DAM), Dakahlia (DAK), Behera (BEH) and Menofia (MEN)]. Collected strains were bioassayed and compared with a reference susceptible strain. DAM and BEH strains recorded 193.4 and 23.3-fold resistance, respectively to fenitrothion and also recorded 133.7 and 23.6-fold resistance, respectively to pirimiphos-methyl. DAM and MEN strains recorded 87.2 and 23.8-fold resistance, respectively to lambda-cyhalothrin while DAM and BEH strains recorded 81.2 and 13.7-fold resistance, respectively to deltamethrin. DAM and MEN strains demonstrating 36.1 and 16.6-fold resistance, respectively to carbosulfan while DAM and BEH strains demonstrated 63.4 and 7.1-fold resistance, respectively to aldicarb, and also DAM and BEH strains recorded 134.7 and 15.3-fold resistance, respectively to confidor. These results are discussed in relation to the possible mechanisms of resistance present in the studied *P. operculella* strains and underpin the resistance management strategy for potato tuber moth in Egypt.

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1. Introduction

The potato tuber moth, *Phthorimaea operculella* is one of the primary insect pests of potato crops in tropical and subtropical climates, as well as in other countries in North Africa (**Kirkham, 1995**). This insect is both a field and post harvest pest; in fields, larvae bore into leaves, stem and tubers (**Rothschild, 1986; Fenemore, 1988**), larvae also infest tubers kept in storehouses (**Raman, 1988**), if tubers are left untreated damage can be very sever or total (**Fuglie, 1995**).

In Egypt, the potato tuber moth is considered to be the most damaging insect pest of potatoes (**Bekheit *et al*., 1997**). Damage caused by this pest was around 30% in the field and above 50% in stores when not controlled (**Palacios and Cisneros, 1995**).

The current control strategy in most areas is to protect the potato crop by applying insecticides, but some of the compounds recommended for its control are apparently not providing the desired effect. It has been hypothesized that excessive insecticide applications commonly applied to the potato crop during a single cultivation period, sometimes one to two sprays per day, could have led to the evolution of resistant populations, besides eliminating their natural enemies, and leading to additional occupational hazards.

Insecticide resistance has been reported all over the world to almost every group of insecticides used against insect pests (**Lockwood *et al*., 1984 ; Georghiou 1986; Kay and Collins 1987**). Therefore, it is necessary to develop management tactics to delay or even prevent the evolution of insecticide resistance in insect pest populations, and the detection and monitoring of such phenomena is of key importance to achieve this (**Dennehy *et al*., 1983 ; Tabashnik and Roush 1990**).

The present study was carried out to detect the existence of Egyptian strains of *P. operculella* resistant to the main insecticides used against it and to quantify that resistance and its relationship with insecticide use in diferent governorates in Egypt.

2. Material and Methods

Insect strains

The laboratory standard strain (the susceptible reference strain; SUS) insects were obtained from Plant Protection Research Institute, where it had been maintained in the absence of insecticides since 2001.

Four field strains were collected during 2010, DAM from Damytta governorate, DAK from Dakahlia governorate, BEH from Behera governorate, MEN from Menofia governorate.

All insect strains were laboratory reared using techniques as described by **Fenemore (1977)**. Each batches of 25 to 30 pupae which were collected from infested tubers placed for emergence inside 400 ml. glass containers covered with a 50-mesh muslin as planned for mating. Black quadres paper, 10 x 10 cm in diameter, placed over the muslin provided a suitable oviposition site. Emerged moths were fed on molasses supplied as small droplets a 5% sugar solution. Adults emerged in 2 to 3 days, and as soon as oviposition commenced, the black papers on which eggs were laid were renewed every 2 days. Oviposition decreased after 8 days. The eggs were held at 26ºC until hatching commenced, usually within 2 days. Upon hatching, 1st instar larvae were transferred and placed on whole-potato tubers (Diamont and Sponta varieties) by a fine camel hair brush. Plastic containers (tow liters capacity, 30 cm in diameter and 10 cm in height) were used for rearing. The containers were tightly closed with the lid to prevent escape of larvae.

Insecticides

Formulated of the 7 test insecticides used for bioassays were; organophosphate Sumithion (Fenitrothion, 500 g/l- EC) and Actellic (Pirimiphos-methyl, 250 g/l- EC), carbamate Marshal (Carbosulfan, 10G 10% w/w) and Temik (Aldicarb, 10G 10% w/w), pyrethroid Hallmark (Lambda-cyhalothrin, 50 g/l- EC) and Decis (Deltamethrin, 25 g/l-EC) and Imidaclopride (Confidor, 200 g/l-SL).

Bioassay method

After diluted these insecticides in distilled water potato tubers were dipped in each of the tested concentrations for 20 s, then treated potato tubers were left to dry. Twenty first instar larvae of *P. operculella* were transferred by using fine brush to each treated potato tuber then put in plastic cups 200 ml capacity) this cups were covered and incubated at 25 ±1ºC and 65% RH.

All bioassays were scored at 48 hrs intervals up to and including 14 days following initial exposure to insecticide. Each bioassay used three replicates of five concentrations.

Analysis of bioassays

Dose-response bioassay against standard strain and field strains were conducted using three batches of 20 insects at a minimum of five insecticide concentrations per bioassay. Each assay was repeated at least three times and results pooled for analysis, probit analysis of the concentration dependent mortality data were carried out using the software program POLO-PC (**Anon., 1987**). Resistance factors (RFs) were calculated by dividing the LC50 of the resistant strain by the LC50 of the susceptible strain.

3. Results

Bioassay, organophosphates

Data in table (1) indicate that DAM strain was relatively, the highest resistant to fenitrothion (193.4 fold) while DAK and MEN strains displayed moderate resistance to fenitrothion (59 and 49.5 fold) but BEH strain was the least resistance to fenitrothion (23.3 fold).

DAK, MEN and BEH strains exhibited similarly resistance to primiphos-methyl (29.2, 28.7 and 23.6 fold resistance, respectively). As for DAM strain, resistance factor was generally greater for primiphos-methyl (133.7 fold resistance).

Resistance factors for all strains were generally greatest for fenitrothion than primiphos-methyl.

Table (1): Comparative responses of *Pthorimaea operculella* strains tested against organophosphate

	Fenitrothion					Pirimiphos-methyl				
strains	N.	LC50	95% CLs	slope	RF	N.	LC50	95% CLs	slope	RF
SUS	300	3.70	2.91-4.71	1.8	-	300	4.52	3.74-5.45	2.8	-
DAM	300	715.7	432.0-907.9	2.1	193.4	300	604.2	200.4-931.4	0.6	133.7
DAK	300	218.3	104.1-682.2	0.5	59.0	300	132.2	83.5-314.1	1.2	29.2
BEH	300	86.2	34.68-792.1	0.8	23.3	300	106.7	78.36-151.9	1.1	23.6
MEN	300	183.2	87.4-722.2	0.7	49.5	300	129.7	70.5-307.0	0.5	28.7

All LC50s in ppm

Bioassay, pyrethroids

MEN and BEH strains exhibited 23.8 to 25.9 fold resistance to lambda cyhalothrin, but DAM and DAK strains were more resistance to lambda cyhalothrin (87.2 to 70.0 fold). In comparison BEH strain exhibited unacceptable resistance to deltamethrin (13.7 fold), but the greater resistance to deltamethrin displayed by DAM, DAK and MEN strains (81.2, 63.7 and 41.4 fold resistance, respectively) (Table 2).

Bioassay, carbamates

Data in table (3) showed that DAM and DAK strains displayed moderate resistance to carbosulfan (36.1 and 29.2 fold). While the slight resistance to carbosulfan (17.6 and 16.6 fold) was recorded from BEH and MEN strains.

MEN and BEH strains displayed little or no resistance to aldicarb (13.9 and 7.1 fold) while DAM and DAK strains exhibited 63.4 and 49.7 fold resistance factors to aldicarb. Generally all strains consider more resistant to aldicarb than carbosulfan.

Table (2): Comparative responses of *Pthorimaea operculella* strains tested against pyrethroids

	Lambda cyhalothrin					Deltamethrin				
strains	**N.**	**LC50**	**95% CLs**	**slope**	**RF**	**N.**	**LC50**	**95% CLs**	**slope**	**RF**
SUS	300	2.35	1.96-2.81	2.4	-	300	2.86	2.34-3.46	1.8	-
DAM	300	205.0	102.3-666.4	0.5	87.2	300	232.1	197.2-279.3	1.6	81.2
DAK	300	164.5	83.1-975.5	0.7	70.0	300	182.2	95.3-528.2	0.5	63.7
BEH	300	60.99	44.02-89.95	1.0	25.9	300	39.3	30.89-49.96	2.2	13.7
MEN	300	55.87	43.89-73.04	1.5	23.8	300	118.3	83.4-149.2	1.5	41.4

All LC50s in ppm

Table (3) Comparative responses of *Pthorimaea operculella* strains tested against carbamates

	Carbosulfan					Aldicarb				
strains	**N.**	**LC50**	**95% CLs**	**slope**	**RF**	**N.**	**LC50**	**95% CLs**	**Slope**	**RF**
SUS	300	0.740	0.626-0.874	2.8	-	300	0.62	0.530-0.736	3.1	-
DAM	300	26.7	19.95-38.46	1.4	36.1	300	39.3	30.89-49.96	2.2	63.4
DAK	300	21.6	15.84-28.71	1.6	29.2	300	30.8	24.35-38.61	2.0	49.7
BEH	300	13.0	10.29-16.21	2.1	17.6	300	4.4	3.28-5.70	1.9	7.1
MEN	300	12.3	7.07-18.12	1.2	16.6	300	8.6	6.77-10.97	2.1	13.9

All LC50s in ppm

Bioassay, imidacloprid

Data in table (4) indicate that DAM strain was the highest resistant to imidacloprid (134.7 fold) followed by DAK strain (61.5 fold). Slight 19.7 and 15.3 fold resistance were found to imidacloprid in the MEN and BEH strains.

Table (4) Comparative responses of *Pthorimaea operculella* strains tested against imidacloprid

	Confidor				
strains	**N.**	**LC50**	**95% CLs**	**slope**	**RF**
SUS	300	0.034	0.028-0.040	3.0	-
DAM	300	4.58	3.274-6.370	0.9	134.7
DAK	300	2.09	1.514-2.894	1.2	61.5
BEH	300	0.52	0.383-0.739	1.8	15.3
MEN	300	0.67	0.343-1.27	0.7	19.7

All LC50s in ppm

4. Discussion

The results of current study revealed that all strains showed varied degrees of resistance to the 7 insecticides studied. The highest resistance was recorded at LC50 of 715.7 ppm in DAM strain for fenitrothion, in contrast, the lowest resistant strain was BEH strain for confidor (LC50 0.52 ppm).

Pesticide bioassays are useful for detecting the trends in resistance to insecticides.

The variability of response to these insecticides among strains of the potato tuber moth, which showed different levels of resistance, is probably due to differences in the pattern of insecticides use at the different sites where the strains were collected. The different insecticide resistance levels suggests different selection pressure among populations, genetic diversity in the resistance mechanisms among strains, or both (**Kerns and Gaylor, 1992**). Among the known insecticide-resistance mechanisms, the biochemical ones (i.e. enhanced activity of detoxification enzymes and target site insensitivity) are frequently reported to be the most important (**Brattsten *et al*., 1986; Mullin and Scott, 1992**). Insect detoxification enzymes are important resistant mechanisms and insecticide synergists are very helpful in providing preliminary evidence of their involvement as resistance mechanisms (**Brindley and Selim, 1984; Scott, 1990; Bernard and Philogene, 1993; Ishaaya, 1993**). The persistence of an insecticide on a plant leads to the continuous selection of resistant individuals, which may contribute to a faster resistance evolution (**Roush, 1989**).

Carbamates, organophosphates and pyrethroids are widely used to control *P. operculella* in Egypt, vegetable growers (especially potato and tomato) found that, in order to combat *P. operculella*, one to two insecticide applications per day had to be applied so it was expected that some resistance would be present.

Strains were slightly resistant to imidacloprid, Presently, approximately 80% of imidacloprid applications in Egypt are foliar. It is possible that this is the application method most likely to decrease selection pressure for resistance in insect pests. This is because soil applied or seed treatments tend to persist to the extent that they may leave the population exposed to sublethal doses over long periods.

Imidacloprid is not yet strongly resisted in combination with the remaining efficacy that appears to exist for some carbamates, organophosphates and pyrethroids, it ought to be possible to institute simple alternation strategies that would go some way to solving the potato tuber moth problem whilst conserving insecticide susceptibility.

There is a great need for new insecticides for potato tuber moth control to provide different chemistries to rotate with and so manage insecticide resistance. In addition, greater selectivity of new insecticides is needed to allow the natural enemies of other pests to survive so that growers become less dependent on insecticides.

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