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Research Article
Efficacy of Certain Pesticides Against Potato Tuber Moth, *Phthorimaea operculella* (Zeller), Under Field Conditions

[1]Mohamed Ahmed Ibrahim Ahmed, [2]Mohamed Fawzy Abd El-Mageed, [1]Hossam El-Din Abdel-Rahman Ezz El-Din, [2]Rabih Ali Emam Ali and [1]Tasneem Abdel-Raouf Mohamed Elghareeb

[1]Department of Plant Protection, Faculty of Agriculture, Assiut University, 71526 Assiut, Egypt
[2]Department of Plant Protection, Faculty of Agriculture, Al-Azhar University, 71524 Assiut, Egypt

Abstract

Background and Objective: The potato tuber moth (PTM), *Phthorimaea operculella* (Zeller), is one of the most serious pests affecting potatoes, in fields and stores, in Egypt. In this study, the efficiency of a novel pesticide, sulfoxaflor 24% SC compared with two recommended pesticides, indoxacarb 30% WG and emamectin benzoate 5.7% WG, on *Phthorimaea operculella* under field conditions. **Materials and Methods:** The treatments were alone and combined of them at two applications, 15 days' intervals, at their recommended rates according to the Ministry of Agriculture and Land Reclamation in Egypt against *Phthorimaea operculella* larvae, during the 2021 and 2022 summer seasons at the farm of the Faculty of Agriculture, Assiut University, Assiut, Egypt. The ANOVA was used to perform the analysis of variance and Henderson and Tilton's equation was used to calculate the reduction percentage. **Results:** The foliage infestation in all treatments achieved a robust reduction of *Phthorimaea operculella* population when the maximal values were reported with emamectin benzoate+sulfoxaflor and the mean of reduction percentage for two applications were 70.5 and 72.5% followed by emamectin benzoate+indoxacarb (64.5 and 67%), sulfoxaflor (51.17 and 64.17%), emamectin benzoate (46.5 and 53.5%) and indoxacarb (44.34 and 44.83%) for experiments at seasons 2021 and 2022, respectively. **Conclusion:** The use of sulfoxaflor and emamectin benzoate was the preferred pesticide with less harmful effects on the chewing pests of potato plants under field conditions in Egypt.

Key words: *Solanum tuberosum* L., *Phthorimaea operculella*, emamectin benzoate, sulfoxaflor, integrated pest management, pesticides

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Corresponding Author: Mohamed Ahmed Ibrahim Ahmed, Department of Plant Protection, Faculty of Agriculture, Assiut University, 71526 Assiut, Egypt

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Potato, *Solanum tuberosum* L. is one of the important vegetable crops cultivated all over the world[1] and the world's fourth most important food crop after rice, wheat and maize[2]. Potatoes can be an important factor in beneficent the health of rural populations in developing countries and can also provide food security and national income. They are rich in carbohydrates, protein and vitamin C, making them a good source of energy[3,4]. The average total area under cultivation for the potato crop from 2015 to 2019 was approximately 355.58 thousand feddans or 5.5% of Egypt's estimated annual average total area under cultivation for vegetables, which is estimated to be 6412.3 thousand feddans[5]. Meanwhile, the average total amount of potatoes produced in Egypt was approximately 3.94 million tons or 11.9% of Egypt's estimated annual average total production of vegetables, which is estimated to be 6412.3 thousand feddans[5].

Potatoes are prone to infestation by a lot of insect pests, which cusses reduce yield quality and quantity. The potato tuber moth (PTM), *Phthorimaea operculella*, is considered one of the most earnest insect pests infesting the family Solanaceae[6,7].

In Egypt, *Phthorimaea operculella* has caused up to 100% losses to potato yield in fields as well as in storage[8]. *Phthorimaea operculella* can develop resistance to chemical insecticides so, infesting is increasing in tropical and subtropical areas[9].

The following was a classification of the strong pesticides on *Phthorimaea operculella* based on the spectrum of damages in field conditions: Compared to the control, chlorantraniliprole>indoxacarb>deltamethrin>chlorpyrifos ethyl+cypermethrin>acetamiprid>imidacloprid[10]. Indoxacarb (oxadiazine) was the highest impact followed by methoxyfenozide and lufenuron as insect growth regulators (IGRs) against *Phthorimaea operculella* larvae[11].

Chlorantraniliprole and indoxacarb applied achieved leading control over *Phthorimaea operculella* especially young caterpillars under field conditions has been accomplished by guaranteeing a longer period of protection[10]. The activity of indoxacarb under field conditions needs enough time to metabolize to a bioactive metabolite in the caterpillar's intestines which metabolized to N-decarbomethoxyllated metabolite (DCMP), the bioactive metabolite, so fifteen days' experiments were more appropriate than ten days[11]. Emamectin benzoate is a pesticide of effective semisynthetic antibiotics pesticide that begins to synthesize from the fermented product of avermectin B1 to the double action of contact poison of the existing stomach poison function of insect[12].

Sulfoximines are conceded to be a novel class of pesticides that are effective against a variety of sap-feeding and chewing insect pests. Plus, sulfoxaflor is also recognized to be the top molecule in this new class of sulfoximine pesticides even though its mode of action involves disrupting the Nicotinic Acetylcholine Receptors (nAChRs) in the nervous system[13-21].

Indoxacarb is especially active on foliar-feeding lepidopteran larvae, it blocks the sodium channel and is a slow-acting insecticide with relatively long residual activity[22,23]. The costs of excessive use of insecticides can be reduced by using the combination with different modes of action that developed synergistic, antagonistic, or additive effects against the insect species[24,25].

Emamectin benzoate has since acquired a considerable reduction in effectiveness against 3rd larvae of *Tuta absoluta* when combined with imidacloprid, indoxacarb, profenofos, chlorfenapyr or methomyl[26].

To scale down the pressure for insecticide resistance development, we need to develop effective alternatives to synthetic insecticides[24-28]. This study aimed to evaluate and determined the reduction percentage of the selected pesticide (sulfoxaflor, emamectin benzoate and indoxacarb) alone and in mixed with each other on *Phthorimaea operculella* larvae under field conditions.

MATERIALS AND METHODS

Experimental area: Field experiments were conducted at the Department of Plant Protection, Faculty of Agriculture, Assiut University, Assiut, Egypt.

Selected pesticides: The recommended concentrations of three commercial pesticides, which were obtained from the Central Agricultural Pesticide Laboratory (CAPL), Dokki, Egypt, belonging to different chemical groups were used in this study (Table 1).

Used cultivars: The potato that was tested (The Netherlands variety spunta) was brought from Seed Stock Exchange, Beheira Governorate, Egypt.

Assessment protocols of pesticides against *Phthorimaea operculella*: Field trials were carried out in the form of the Department of Plant Protection, Faculty of Agriculture, Assiut University, Assiut Governorate, during two successive summer seasons, 2021 and 2022.

Table 1: List of tested pesticides used in this study

Trade names and formulations	Active ingredient	Rate of application/fed
Easo plus 30% WG	Indoxacarb	60 g
Egy Chem 5.7% WG	Emamectin benzoate	120 g
Closer 24%SC	Sulfoxaflor	50 cm^3

The potato cultivar used is Sponta. At room temperature, the tubers were placed for two weeks while the modern growths reached 1 cm with a medium size 50-60 g weight.

The Complete Block Design (RCBD) experiments were done. The t-test distribution outline with six treatments including control and replicated three times. An experiment was conducted to evaluate the efficiency of three products against *Phthorimaea operculella* under field conditions, an area of 300 m^2 was divided into 7 plots. Spunta was cultivated on the 1st and 3rd February, 2021 and 2022, respectively. The normal agriculture treatments such as, land preparation, irrigation, mechanical weed control and fertilization were followed according to the Ministry of Agriculture recommendations and weeds were controlled using different agricultural practices. The temperature during the experimental seasons ranged between 8-25°C (from 15th January to 30th May, 2021) and from 9-30°C (from 15th January to 20th May, 2022).

A month after planting, the insects were counted and recorded every week from five randomly selected plants from each plot or 20 tubers near the surface of the soil until *Phthorimaea operculella* numbers reached the economic threshold level (5% live larvae for checked plants). The applications of the chemical were applied for all treatments twice with an interval of 15 days, the first was 75 days after sowing during the 2021 and 2022 seasons. The application was made using a knapsack sprayer loaded with up to 15 L. Samples of 10 leaves were seized randomly from each plot before the first spray directly and after 15 days for each spray. The individual-evaluated pesticides including indoxacarb, emamectin benzoate and sulfoxaflor were sprayed based on the recommendation of the Egyptian Ministry of Agriculture. Simultaneously, the mixtures emamectin benzoate+ indoxacarb and emamectin benzoate+sulfoxaflor were applied at the rate of half recommended dose of each pesticide within the tested mixture. The harvesting time of the yield began after 115 days according to the maturing of the potato cultivar.

Statistical analysis: Reduction percent was calculated according to Henderson and Tilton equation[29] and subjected to Analysis of Variance (ANOVA) using CoStat Statistical software (Microcomputer program analysis version 6.400, CoHort Software, Berkeley, California, USA) as follows:

$$\text{Reduction (\%)} = 1\text{-}\frac{\text{Ta} \times \text{Cb}}{\text{Tb} \times \text{Ca}} \times 100$$

Where:

Cb = Average percent of infestation in control before spray

Ta = Average percent of infestation in treatment plots after spray

Tb = Average percent of infestation in treatment plots before spray

Ca = Average percent of infestation in control after spray

However, the least significant difference (LSD at 5%) was used to compare the treatments.

RESULTS

The effect of two sprays of selected pesticide applications (alone and mixture) on *Phthorimaea operculella* larval infestation and reduction percent during the 2021 and 2022 seasons were presented in Table 2-3 and Fig. 1-2. The mean population of *Phthorimaea operculella* larvae that infested before spray for the two seasons ranged from 2.67 to 7.33 in all treatments and control. After spray, the percentage of mean reduction in infestation differed significantly. For all the two sprays, emamectin benzoate+sulfoxaflor treatment (70.5 and 72.5%, respectively) was the superior, followed by emamectin benzoate+indoxacarb (64.5 and 67%, respectively) and sulfoxaflor alone (51.2 and 64.2%, respectively) during 2021 and 2022 seasons. However, the treatments of emamectin benzoate and indoxacarb demonstrated the lowest mean reduction percent among the tested treatments (for emamectin benzoate was 46.5 and 53.5% and for indoxacarb was 44.3 and 44.8%, respectively) during the two seasons. In general, the mixture of emamectin benzoate and sulfoxaflor was considered the best mixture and treatment in reducing the infestation in potato potatoes.

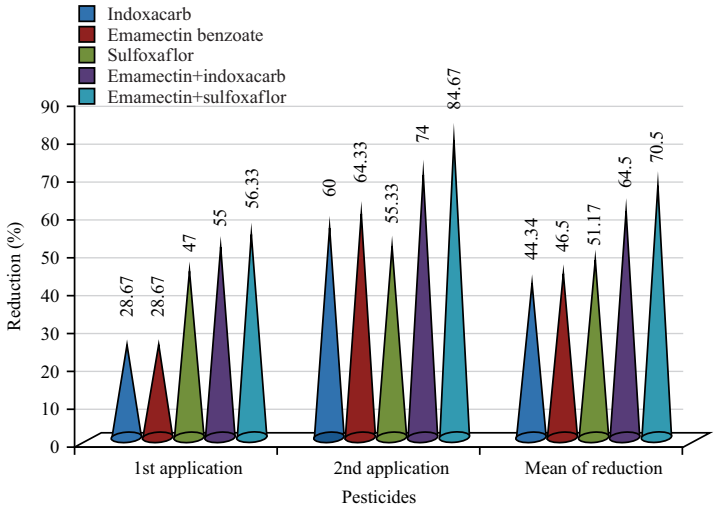

Fig. 1: Reduction percent of certain pesticides against potato tuber moth after the second application from the transplantation in the potato field during the 2021 season

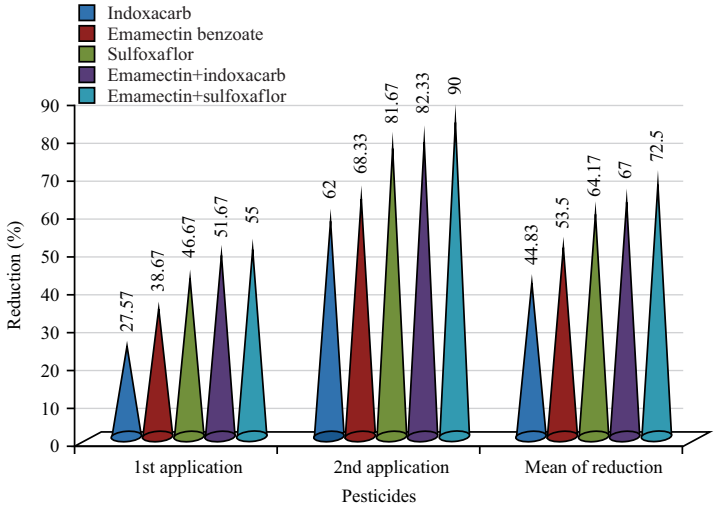

Fig. 2: Reduction percent of certain pesticides against potato tuber moth after the second application from the transplantation in the potato field during the 2022 season

Table 2: Effect of pesticide applications on potato tuber moth of larval infestation under field conditions during 2021 and 2022 seasons

	Mean of population before application immediately			Number of larval infestations		Mean	
Treatments	2021	2022	Application (sprays)	2021	2022	2021	2022
Emamectin benzoate+sulfoxaflor	5.61	5.88	1st	3.0*	2.6	2.0	1.8
			2nd	1.0	1.0		
Emamectin benzoate+indoxacarb	3.67	6.13	1st	2.0	3.3	1.5	2.2
			2nd	1.0	1.0		
Sulfoxaflor (closer 240% SC)	3.34	6.67	1st	2.3	3.6	1.8	2.3
			2nd	1.3	1.0		
Emamectin benzoate (Egy Chem 5.7% WG)	2.67	5.33	1st	2.3	4.0	1.6	2.7
			2nd	1.0	1.3		
Indoxacarb (Easo Plus 30% WG)	3.00	5.33	1st	2.6	4.0	2.0	2.8
			2nd	1.3	1.6		
Control	3.33	7.33	1st	4.0	7.6	4.5	8.0
			2nd	5.0	8.3		

*Mean number of live larvae of three replicates (30 leaves each)

Table 3: Reduction percent of pesticide applications on potato tuber moth larvae under field conditions during 2021 and 2022 seasons

	Population reduction percentage after 15 days from the 1st application		Population reduction percentage after 15 days from the 2nd application		Mean of reduction (%)	
Treatments	2021	2022	2021	2022	2021	2022
Emamectin benzoate+sulfoxaflor	56.33^{a*}	55.00^{a}	84.67^{a}	90.00^{a}	70.5^{a}	72.5^{a}
Emamectin benzoate+indoxacarb	55.00^{a}	51.67^{ab}	74.00^{ab}	82.33^{ab}	64.5^{ab}	67.00^{ab}
Sulfoxaflor Closer 240% SC	47.00^{a}	46.67^{ab}	55.33^{b}	81.67^{ab}	51.17^{bc}	64.17^{ab}
Emamectin benzoate Egy Chem 5.7% WG	28.67^{b}	38.67^{bc}	64.33^{ab}	68.33^{ab}	46.5^{bc}	53.5^{bc}
Indoxacarb Easo Plus 30% WG	28.67^{b}	27.57^{c}	60.00^{b}	62.00^{b}	44.34^{c}	44.83^{c}
LSD values at 5%	16.41	15.61	23.86	27.31	18.46	14.95

*Values with different letters are significantly different at $p \geq 0.05$

DISCUSSION

In general, all treatments have reduced the infestation of *Phthorimaea operculella* during the 2021 and 2022 seasons. However, the combination of emamectin benzoate and sulfoxaflor was a powerful treatment with a reduction percent 70.5 and 72.5% during the 2021 and 2022 seasons, respectively, followed by the mixture of emamectin benzoate with indoxacarb with a reduction percent 64.5 and 67%, respectively. Further, indoxacarb alone was considered the least treatment with a reduction percent 44.3 and 44.8% during the 2021 and 2022 seasons, respectively. In this regard, seven compounds on the *Phthorimaea operculella* larvae under field conditions in Kafr El-Sheikh and, Egypt, emamectin benzoate (proclaim 5% WG), indoxacarb (deltarab 15% SC) and emamectin benzoate 1.5%+indoxacarb 7.5% (penny 9% SC) were effective in reduction percent (79.06, 77.83 and 75.70%, respectively) in 2014 season. However, at Al-Gharbiya Governorate, the reduction percentages were 82.48, 79.36 and 78.11%, respectively[30]. Furthermore, another study which conducted in Sharkia Governorate, Egypt on potato plants (Kara variety) stated that emamectin benzoate (proclaim 5% WG) and emamectin benzoate+indoxacarb (penny 1.5+7.5% SC) were the most potent selected pesticides on *Phthorimaea operculella* larvae and the general mean reduction percentage during 2014/2015 seasons were 85.04% and 84.80%, respectively when diluted in Nile water[31]. Xentari, profenofos and abamectin were the most toxic to 1st instar larvae of *Phthorimaea operculella*[32].

CONCLUSION

Emamectin benzoate in combination with sulfoxaflor and indoxacarb is considered the most powerful treatment against *Phthorimaea operculella* larvae as compared to other treatments under field conditions. These two mixtures going to be recognizable as an alternative to other pesticides in the control of potato chewing pests. However, it is necessary to perform more studies to determine the mechanisms and justifications for how molecular genetics and biochemical interactions can increase the efficacy of pesticide mixtures. Emamectin benzoate must also be combined with other pesticides in trials and the findings must be compared to those obtained, to determine the most effective mixtures for controlling *Phthorimaea operculella* in the field in Egypt.

SIGNIFICANCE STATEMENT

The potato crop is one of the most significant strategic and export crops in Egypt, yet it is plagued by numerous destructive pests, such as *Phthorimaea operculella*, which reduce crop yield significantly. Given that, this study assessed certain pesticides on *Phthorimaea operculella* under field conditions. The results suggested that the selected pesticides evaluated in this study can be used effectively in IPM programs under field conditions in Egypt.

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