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Lethal and sublethal effects of abamectin and deltamethrin on potato tuber moth, *Phthorimaea operculella* (Lepidoptera: Gelechiidae)

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Abstract: The potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) is one of the important pests of potato in tropical regions. In this research, the toxicity of two insecticides, abamectin and deltamethrin on *P. operculella* was studied at 26 ± 1 °C, 65 ± 5% RH and photoperiod of 16:8 h (L: D). The concentrations were determined by preliminary dose setting experiments. Distilled water was used as control. LC_{50} values for egg, first instar larvae and adult stage for abamectin were 0.92, 0.014 and 0.46 mg ai/l and for deltamethrin were 0.09, 0.024 and 0.29 mg ai/l, respectively. The sublethal effects of abamectin and deltamethrin on population growth parameters of *P. operculella* were determined at mentioned conditions. Four hundred 1 day old eggs of the pest were dipped in insecticides solutions (LC_{30}). After egg hatching, the first instar larvae were transferred on potato tubers and placed in transparent plastic dishes. After adults' emergence, 20 females were used for each treatment in life table experiments. Intrinsic rates of increase were estimated to be 0.060, 0.042 and 0.141 day^{-1} In control, abamectin and deltamethrin treatments, respectively. Statistical analyses showed that deltamethrin caused higher toxicity to egg and adult stages of PTM while abamectin caused higher toxicity to its first instar larvae. Since deltamethrin increased the stable population parameters of *P. operculella* specially its intrinsic rate of increase, thus it might not be recommended for control of PTM. However based on lethal and sublethal effects, abamectin could be suitable for management of this pest.

Keywords: *Phthorimaea operculella,* lethal, sublethal, insecticides, demography

Introduction

The potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae), is a worldwide major pest of potato (*Solanum tuberosum* L.), tobacco (*Nicotiana tabacum* L.), tomato (*Lycopersicum esculentum* Mill.), eggplant and pepper in fields and stores, especially in warm temperate and subtropical climates (Sporleder *et al*., 2004). Pest management tactics including mass trapping by pheromones and cultural and chemical control methods have been applied to manage PTM (Hanafi, 1999). There are several reports on resistance of tuber moth to some insecticides from many countries (Haines, 1977). Frequent use of synthetic insecticides causes problems such as resurgence. Resurgence may occur in response to physiological or ecological mechanisms (Ripper, 1956; Luckey, 1968). In order to introduce new and effective insecticides for control of PTM, in present study, the lethal and sublethal effects of two insecticides, abamectin and deltamethrin

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were investigated on *P. operculella*. Abamectin produced by the soil micro organism *Streptomyces avermilitis*, acts as insecticide against agricultural pests (White *et al*., 1997). Deltamethrin is a pyrethroid insecticide that is used to control a range of pests. Deltamethrin affects the nervous system and paralyzes the insect rapidly, giving a quick knockdown effect (Haug And Hoffman, 1990). Abamectin has a rapidly disabling effect on feeding behavior of insects (Hayes and Laws, 1990).

Lethal assays could not fully determine the effects of insecticides on organisms (Walthall and Stark 1996). Thus, evaluating sublethal effect of insecticides is very important (Stapel *et al*., 2000; Stark and Banks 2003). Demographic toxicology is usually considered the best way to evaluate total effects of pesticides. Sublethal doses can make changes in development time (Schneider *et al.*, 2003), percent of hatched eggs and number of laid eggs per female (Wang *et al.*, 2009), fecundity (Haseeb and Amano, 2002, reproduction parameters (Lashkari *et al.*, 2007), and sex ratio (Delpuech and Meyet, 2003). Then, the parameter defined as the intrinsic rate of increase (r_m) has been recommended to evaluate total effects of a pesticide, because it is based on both survivorship and fecundity parameters (Stark and Wennergren 1995). This study was carried out to assess the lethal and sublethal effect of the insecticides on *P. operculella* and to determine the possibility of the application of these insecticides at reduced dose for control of this pest.

Materials and Methods

Insecticides

The tested insecticides were abamectin (Agrimec®, 1.8% EC, Gyah Company, www.gyah.ir) and Deltamethrin (Decis® 2.5% EC, Gyah Company).

Insect rearing

Initial population of *P. operculella* was obtained from the University of Mohaghegh Ardabili, Ardabil, Iran. Adults of PTM were released in transparent plastic container (12 × 9 cm) to lay eggs. The bottom of containers was covered with a filter paper and a slice of potato (Agria cultivar) was placed on it. Insects were reared on potato tubers at 26 ± 1 °C and 65 ± 5% RH and photoperiod of 16:8 h (L: D) in a growth chamber.

Bioassays

Lethal

The concentrations were determined by preliminary dose setting experiments. Distilled water was used as control. One-day-old eggs of tuber moth on the paper disc were dipped in different concentrations of insecticides for 10 seconds and then they were transferred to Petri dishes until hatch (Sauor, 2008). For adult bioassay, Petri dishes were impregnated with insecticides at different concentrations and then PTM adults were transferred to them (Dogramaci and Tingey, 2008). Also, the toxicity of insecticides was assessed on first larvae of PTM using leaf dipping bioassay method. Potato leaves were dipped in the insecticide solutions for 10 seconds and let dry at room temperature for 15 minutes, then the larvae were transferred on them into Petri dishes (Symington, 2003). The mortalities were recorded 24 h after treatment in the larvae and adult stages and after hatching for the egg stage. Each experiment was replicated four times.

Sublethal

Four hundred one-day-old eggs of the pest were dipped in sublethal concentration (LC_{30}) of each insecticide. Then, they were transferred into 90mm Petri dishes. Distilled water was used as control. After egg hatching, the first instar larvae were transferred on potato tubers and placed in transparent plastic containers (4 × 8 cm). After adults' emergence, 20 females from each of the insecticide treatment and the control were individually transferred into plastic vials (5 cm in diameter and 10 cm height). The number of eggs laid by females was recorded daily until death of all females. All experiments were conducted at 26 ± 1 °C, 65 ± 5 % RH and photoperiod of 16: 8 h (L: D). Carey's procedure was used to estimate the population growth parameters (Carey, 1993).

Data analysis

The biological data were submitted to analysis of variance and the means were compared with Tukey's tests using SPSS 16.00 software program (SPSS, 2004). The demographic parameters and their corresponding standard errors were estimated by the jackknife technique (Meyer, 1986).

Results

The toxicity of insecticides, abamectin and deltamethrin to eggs, larvae and adults of *P. operculella* is shown in Table 1. The results indicated that both tested insecticides had toxic and acceptable effect on eggs of *P. operculella* with LC_{50} of 0.92 and 0.095 mg ai/l, respectively. Based on the results, deltamethrin was approximately ten times more toxic to eggs and two times more toxicity to adults of the pest compared with abamectin. In contrast abamectin had approximately two times higher toxic to larvae of the pest compared with deltamethrin. Insecticide concentrations as high as 3000 mg ai/l did not cause considerable mortality on pupal stage in the dipping method. Hence, their LC values were not estimated in the experiments.

Effects of sublethal doses of abamectin and deltamethrin on life table parameters of *P. operculella* are shown in Table 2. Gross reproductive rate (GRR) in deltamethrin was significantly higher than that for abamectin and control treatments ($F = 6.68$; $df = 2, 57$; $P < 0.01$). Also, both the net reproductive rate (R_0) and intrinsic rate of increase (r_m) in deltamethrin were significantly higher than those in control and abamectin treatments ($F = 2.59$; $df = 2, 57$; $P < 0.01$ and $F = 1.54$; $df = 2, 57$; $P < 0.01$, respectively). There was no significant difference between GRR, estimated R_0, r_m and λ for control and abamectin treatment. The value of generation time (T) and doubling time (DT) obtained for deltamethrin was significantly lower than those for the control and abamectin treatments ($F = 1.16$; $df = 2, 57$; $P < 0.05$ and $F = 3.7$; $df = 2, 57$; $P < 0.01$, respectively).

Table 1 Toxicity of abamectin and deltamethrin to developmental stages of *Phthorimaea operculella*

Stage	Insecticides	n	LC_{50}(95%CL) (mg ai/l)	Slope ± SE	χ^2
Egg	abamectin	360	0.92^a(0.59-1.27)	1.03 ± 0.13	1.87
	deltamethrin	360	0.09^b(0.047 – 0.14)	0.94 ± 0.17	1.2
Larvae	abamectin	360	0.014^b(0.006-0.024)	0.74 ± 0.11	1.81
	deltamethrin	360	0.024^a(0.004-0.054)	0.58 ± 0.13	2.21
Adult	abamectin	360	0.46^a(0.29-0.63)	1.72 ± 0.29	2.28
	deltamethrin	360	0.29^b(0.16 – 0.52)	0.86 ± 0.15	1.55

In each stage, values followed by different letters are significantly different (P < 0.05).

Table 2 Life table parameters (mean ± SE) of *Phthorimaea operculell* exposed to sublethal dose of abamectin and deltamethrin

Parameters	GRR	R_0	r_m	λ	T	DT
Control	21.66 ± 3.6^b	4.41 ± 1.33^b	0.060 ± 0.014^b	1.049 ± 0.015^b	27.3 ± 0.98^a	12.95 ± 4.84^{ab}
Abamectin	12.68 ± 0.45^b	2.83 ± 0.92^b	0.042 ± 0.016^b	1.026 ± 0.017^b	28.89 ± 0.65^a	26.93 ±9.04^a
Deltamethrin	46.54 ± 6.5^a	20.42 ± 3.19^a	0.141 ± 0.0066^a	1.15± 0.007^a	21.74 ± 0.29^b	4.87 ± 0.23^b

Means in the same column, followed by different letters are significantly different (P < 0.05).

Discussion

In present study, it was shown that both tested insecticides were effective against PTM. Based on the results, deltamethrin had the highest toxicity to egg and adult stages of PTM and abamectin had the highest toxicity to its first instar larvae. Corbitt *et al*., (1989) reported that abamectin had highest toxicity on first instar larvae of *Heliothis* Sp. Also Bueno and Freitas (2004) reported that abamectin had no effect on eggs of predator, *Chrysoperla externa*. Thus abamectin could be suitable insecticide in PTM control in IPM. In contrast deltamethrin increased the stable population parameters of PTM specially its intrinsic rate of increase, thus it's not recommended for control of this pest.

Our results demonstrated that the deltamethrin significantly affected life table parameters of *P. operculella*, but abamectin had no significant effect on them. Our results are similar to results of Bayram *et al*., (2010) who reported higher intrinsic rate of increase (r_m) in *Telenomus busseolae* after exposure to deltamethrin. Hui-Dong *et al.,* (2004) reported that emamectin caused decreasing parameters including r_m, R0, λ, and T of *Plotella xylostella*. Mahdavi *et al.*, (2011) studied sublethal effects of abamectin on the ectoparasitoid *H. hebetor*. Their results were based on extended laboratory studies. Based on their laboratory results it seems that abamectin is potentially more compatible with a chosen IPM approach. Hamedi *et al*., (2011) reported adverse effects of abamectin on population growth of predator *Phytoseius plumifer*, so the results of their study can be used to develop approximate guidelines for the use of abamectin in order to minimize its impact on *P. plumifer* and related natural enemies.

The intrinsic rate of increase (r_m) is the most important parameter for evaluation of total effects of insecticides on population development, because it is based on both survivorship and fecundity (Carey, 1993, Stark and Wennergren, 1995). Higher intrinsic rate of increase (r_m) in deltamethrin indicated that this insecticide has positive effect on population growth rates in *P. operculella*. Therefore, it is not suitable for control of the pest. Even though results obtained in laboratory conditions may not be realized under natural conditions (Kareiva, 1990), such investigations under the laboratory conditions would be similar to storage conditions and maybe helpful in selecting insecticides for application against this pest without harming its natural enemies.

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اثرات کشندگی و زیرکشندگی آبامکتین و دلتامترین روی بید سیب‌زمینی *Phthorimaea operculella*

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چکیده: بید سیب‌زمینی با نام علمی *Phthorimaea operculella* (Zeller)(Lepidoptera: Gelechiidae) یکی از آفات مهم سیب‌زمینی در مناطق گرمسیر جهان می‌باشد. در این تحقیق، اثرات کشندگی و زیرکشندگی دو حشره‌کش آبامکتین و دلتامترین به بید سیب‌زمینی در شرایط دمایی ۱ ± ۲۶ درجه‌ی سانتی‌گراد، رطوبت نسبی ۵ ± ۶۵ درصد و دوره‌ی نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی مورد مطالعه قرار گرفت. مقادیر غلظت‌ها براساس آزمایش‌های مقدماتی تعیین دز تهیه شدند. آب مقطر به‌عنوان شاهد مورد استفاده قرار گرفت. مقادیر LC_{50} برای مراحل تخم، لارو سن یک و حشره کامل بید سیب‌زمینی به‌ترتیب در آبامکتین معادل ۰/۲۹، ۰/۰۱۴ و ۰/۴۶ mg ai/l و در دلتامترین معادل ۰/۰۹، ۰/۰۲۴ و ۰/۲۹ mg ai/l تعیین شدند. تجزیه‌های آماری نشان داد که دلتامترین سمیت بیشتری به مراحل تخم و حشره کامل و آبامکتین سمیت بیشتری به لارو سن یک بید سیب‌زمینی داشت. همچنین اثرات دز زیرکشنده LC_{30} دو حشره‌کش آبامکتین و دلتامترین روی پارامترهای رشد جمعیت بید سیب‌زمینی در شرایط مذکور تعیین شدند. در شاهد، آبامکتین و دلتامترین نرخ ذاتی افزایش جمعیت به‌عنوان مهمترین پارامتر به‌ترتیب معادل ۰/۰۶۰، ۰/۰۴۲ و ۰/۱۴۱ ماده بر ماده بر روز تخمین زده شد. دلتامترین پارامترهای رشد جمعیت بید سیب‌زمینی به‌خصوص نرخ ذاتی افزایش جمعیت را افزایش داد، بنابراین برای کنترل بید سیب‌زمینی توصیه نمی‌شود. بر اساس نتایج کشندگی و غیرکشندگی، آبامکتین می‌تواند ترکیب مناسبی برای کنترل بید سیب‌زمینی باشد.

واژگان کلیدی: بید سیب‌زمینی، آبامکتین، دلتامترین، پارامترهای رشد جمعیت، اثرات کشندگی و غیرکشندگی