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Research Article

Insecticidal Efficacy of Conventional and Botanical Insecticides against Potato Tuber Moth (*Phthorimaea operculella* (Zeller) Lepidoptera: Gelechiidae)

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Abstract

Potato Tuber Moth (PTM), *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae), is an important pest of potato. It is common that there is in most countries where potatoes are grown. The chemical insecticides are used to control PTM. Because of chemical adverse effect, there is need to find safe alternative to chemical insecticides. For this porpoise, the effect of two botanical insecticides and two new pesticides were investigated on PTM. The effects of three different conventional and two different botanical insecticides against potato tuber moth larvae were investigated under laboratory conditions. The insecticides evaluated were: indoxacarb 150g/L; spinetoram 120g/L; deltamethrin 2.5g/L; Gamma-T-ol as 75% terpene and Fungatol as terpinen-4-ol. The two botanical insecticides evaluated are major components of tea tree oil extracted from the tea tree *Melaleuca alternifolia* (Maiden & Betche Myrtaceae) by distillation. The chemicals were sprayed on potato tubers in insect cages before adult potato tuber moths were introduced. Three dose rates were used of each insecticide. Experiments were carried out as randomised block design and replicated four times plus an untreated control. The data of new larval establishment were collected weekly. It was determined that all of the doses of indoxacarb were effective in controlling the potato tuber moth for up to 112 days. All three doses of spinetoram and Gamma-T-ol (Tea tree oil 75% terpene) were effective up to 22 days. However, higher rates were effective up to 42 days. Both Fungatol (Tea tree oil terpinen-4-ol) and deltamethrin showed low effect. The aim of this paper was to determine by laboratory bioassays, the larvicidal activity of conventional and botanical insecticides against the larvae of the potato tuber moth.

Keywords: Conventional insecticides; Efficacy; Extracts; Potato tuber moth; Tea tree oil

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Introduction

Potato Tuber Moth (PTM), *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae) is a serious major insect pest of potatoes worldwide. It feeds on many Solanaceae, including crops such as potatoes, tomatoes, tobacco, egg plants and some ornamental and wild plants [1].

Potato tuber moth mature adult females produce 80 to 120 eggs or more, depositing them on potato foliage, or on the tubers, usually on the buds (eyes). The eggs are laid singly or in batches. Larvae feed on leaves, stems, petioles and, more importantly, on potato tubers in the field and in storage. The newly hatched larvae create tunnels in leaves by feeding on internal leaf tissue while leaving the upper and lower epidermis of the leaf untouched. In general larvae prefer feeding on young foliage [2]. Typical damage results from larvae boring tunnels in tubers. Larvae depositing silk and frass make tubers unmarketable and unfit for human consumption. Severe infestations have resulted in yield and quality losses during storage when previously infested tubers were stored with undamaged tubers [3,4]. Foliar damage to the potato crop does not usually result in significant yield losses, but infestation of tubers reduces marketability. Losses in storage may be up to 100%, especially in non-refrigerated storage. The greatest amount of tuber damage occurs immediately before harvest if the crop is left in the field prior to harvesting. Additional damage may occur in storage if conditions are not controlled properly [5-7].

Potato growing areas in Turkey have several insect pests that attack and damage potato crops during the growing season. Most important is the PTM, which severely affects the vegetative parts of the growing plants and developing tubers in the field due to cracking soils and in storage. Many potato growers in Turkey use cultural practices to control PTM. Using deep planting and good coverage of potato seeds with soil hilling of more than 10cm helps prevent damage by adults and larvae. However, when the populations of PTM are too high this cultural control practice is not sufficient to control the pests. Recently growers have changed their cultivation practices. Instead of using machinery for hilling soil against plants they are using digging machinery in cultivation which does not effectively hill the soil to cover the exposed tubers. This change in cultivation practice caused an increase in the PTM population which increased potato plant damage and caused high yield losses [8]. According to Ali the greater depth of planting and the more frequent hilling-up significantly lowered the damage to tubers [9]. Although pesticide use is not advised against potato tuber moth, potato farmers use pesticides during both storage and field conditions to control this pest. Therefore, the use of pesticides has increased and caused an increased risk of residues on potato. To eliminate the negative effects of insecticides, researchers have conducted many studies to find an alternative to current insecticides used against potato tuber moth. For example, it was determined that granulo virus may be used to control potato tuber moth under field conditions [10,11]. Steven, et al., reported that *Bacillus thuringiensis* (Bt) spp. kurstaki and Granulo Virus (GV) were significantly effective in controlling potato tuber moth [12]. Gomaa and El-Nenaey found that the application of Virotecto or GV infected larvae more effectively controlled PTM infestation than Bt-based insecticides [13]. Additionally, researchers found that neem treatments afforded acceptable protection against PTM in storage for many months and neem oil was as effective as the insecticide [14-16]. In addition, Abdel-Razek, et al., reported that application with neem formulation could effectively reduce the *P. operculella* population [17]. I recent, some plant extract. Recently, the extract obtained from tea tree oil [*Leptospermum petersonii* (FM Bailey) (Lemon Scented Oil: (LSO)], *Melaleuca alternifolia* L. (Myrtaceae)] were used as bio insecticides to control insects. There are many of studies about this subject. For example, Purwatiningshi, et al., found that the extracts *L. petersonii* had high effect on diamondback moth [18]. [*Plutella xylostella* L. (Lepidoptera: Plutellidae)]. It was concluded the extract of *L. petersonii* caused 100% mortality of the two-spotted spider mite (*Tetranyhchus urticae*) Koch (Acari:Tetranychidae) [19]. Also Kasap, et al., revealed that the extracts obtained from *M. alternifolia* caused high mortality of cotton aphid [*Aphis gossypii* Glover (Hemiptera:Aphididae)] [20].

The objective of this study was to determine the insecticidal effect of three conventional and two botanical products on PTM.

Materials and Methods

Essential oils and synthetic insecticides

In these experiments two components of tea tree oil: Gamma-T-ol 75% terpene; and a formulation called Fungatol whose main component is terpinen-4-ol were used. Local companies supplied the synthetic insecticides which are registered for use in PTM control. Avaunt (indoxacarb 150g/L EC), Radiant (spinetoram 120g/L SC) and Decis (deltamethrin 2.5g/L) were used. Deltamethrin was used as a positive control in addition to a normal (untreated) control in the experiments.

Insect cultures and rearing conditions

Potato tuber moth adults were collected from potato fields at the Central Anatolian Province of Afyonkarahisar and transported to the Plant Protection Central Research Institute Laboratory, Ankara, Turkey. The adults were transferred to one litre size glass jars and provided with a 10% sugar solution as a food source. The lid was removed and replaced with muslin. The adult females laid their eggs on the muslin. The environmental conditions in the laboratory were kept constant (25±1°C; 60±5% relative humidity) and 12:12 light: dark photoperiod. Eggs were collected daily and transferred to similar jars containing several potato tubers for larval establishment under similar laboratory conditions. Larvae were reared on potato tubers using the method described by Mandour [21].

Bioassays

Experiments were carried out as a randomised block design and replicated four times plus an untreated control. Plastic trays were used (40cm x 30cm x 5cm). These trays were divided into three equal sections using sturdy cardboard dividers. Each section in each tray had 10 tubers treated with one of the three concentrations of the insecticides. Potato tubers used in experiments were washed and dried before being sprayed. Each tuber was sprayed individually with a hand held sprayer. Table 1 shows the concentrations of the three doses. Untreated (control) tubers received the same procedure except that they were sprayed with water. After spraying the trays were placed in the insect cages (1m x 1m x 1m). Each insect cage had four trays. The same procedure was used for the remaining insecticides. Each insect cage received 25 male and 25 female adults for egg laying on the treated tubers. As a food source for adults each cage had a 10% sugar water solution supplied using a small jar with a hole drilled in the lid. A dental wick was inserted into the solution with the top end protruding above the lid for feeding. After seven days (1 week) all tubers were checked for larval establishment (larvae boring tunnels into tubers, lining the tunnel with silk and pushing their frass out from the entry point). The data were collected weekly according to new larval establishment. Data were collected on days 7, 12, 22, 42, 72 and 112 (16 weeks). In this research the Marfona variety of potatoes (popular among the potato growers in Turkey) was used.

Active ingredient and rate	Recommendation Dose (ml/L)	Application Dose (ml/L)
Indoxacarb 150g/L EC	10,15,25/100	0.10, 0.15, 0.25
Spinetoram 120g/L SC	10,15,25/50	0.20, 0.30, 0.50
Gamma-T-ol	2.5-3.5-5/L	2.5, 3.5
Fungatol	2.5-3.5-5/L	2.5, 3.5, 5
Deltamethrin 2.5 g/L	15-20-30/50	0.30,0.40,0.60

Table 1: Insecticides and plant extracts used in this study.

Statistical analysis

Effects of the insecticides were calculated according to Abbott as follows [22]:

$$X = a-b/1-b$$

Where;
x=effect
a= number of infestation tuber in treatment
b=number of infestation tuber in control

The obtained results were submitted to variance analyses and the mean values compared by Duncan's test. Significant differences (p=0.05) were calculated by the program: SPSS 20.6.

Results and Discussion

Data (Table 2) showed that all of the doses of indoxacarb were statistically superior to control (100% tuber infestation) in preventing damage to potato tubers by PTM. Amongst the treatments indoxacarb was the most effective (each with an average of per cent tuber infestation). Only two doses of Gama-T-ol and spinetoram had 0% infestation up to 22 days it was noticed that Fungatol and deltamethrin had the highest infestation rate.

Treatments	Doses (ml/L)	7 days		12 days		22 days		42 days		72 days		112 days	
		Ir (%)	E (%)	Ir (%)	E (%)	Ir (%)	E (%)	Ir (%)	E (%)	Ir (%)	E (%)	Ir (%)	E (%)
Indoxacarb	0.10	0	100±0a	0±0a	100±0a	0±0a	100±0a	0±0a	100±0a	0±0a	100±0a	0.00±0a	100±0a
	0.15	0	100±0a	0±0a	100±0a	0±0a	100±0a	0 ±0a	100±0a	0±0a	100±0a	0.00±0a	100±0a
	0.25	0	100±0a	0±0a	100±0a	0±0a	100±0a	0 ±0a	100±0a	0±0a	100±0a	0.00±a	100±0a
Spinetoram	0.20	0	100±0a	0±0a	100±0a	0±0a	100±0a	37.5±8.53b	62.5±0b	100±0b	0±0a	100±0b	0±0b
	0.30	0	100±0a	0±0a	100±0a	0±0a	100±0a	0±0a	100±0a	100±0b	22.5±4.78b	100±0b	0±0b
	0.50	0	100±0a	0±0a	100±0a	0±0a	100±0a	0±0a	100±0a	100±0b	27.5±7.5b	100±0b	0±0b
Gamma-T-ol	2.50	0	100±0a	0±0a	100±0a	0±0a	100±0a	32±4.78b	67.5±6.29b	100±0b	0±0a	100±0b	0±0b
	3.50	0	100±0a	0±0a	100±0a	0 ±0a	100±0a	0±0a	100±0a	100±0b	22.5±4.78b	100±0b	0±0b
	5.00	0	100±0a	0±0a	100±0a	0 ±0a	100±0a	0±0a	100±0a	100±0b	25±6.45c	100±0b	0±0b
Fungatol	2.50	0	85±2.88a	15±2.88d	47.5±7.5bc	42.5±6.29b	42.5±6.24c	100±0c	0±0c	100±0b	0.±0d	100±0b	0±0b
	3.50	0	75±2.88b	25±2.88d	57.5±12.5b	42.5±4.78b	57.5±12.5b	100±0c	0±0c	100±0b	0±0d	100±0b	0±0b
	5.00	0	70±4.08b	30±4.08bc	50±5.25b	50.0±4.56c	22.5±5.5d	100±0c	0±0c	100±0b	0±0d	100±0b	0±0b
Deltamethrin	0.30	0	75±6.45b	25±6.45d	45±14.43c	25.0±2.88b	12.5±4.45f	100±0c	0±0c	100±0b	0±0d	100±0b	0±0b
	0.40	0	55±8.66c	30±4.08bc	42.5±6.24c	57.5±12.5c	22.5±6.29d	100±0c	0±0c	100±0b	0±0d	100±0b	0±0b
	0.60	0	82±2.5ab	17±2.50d	37.5±8.55d	62.±6.29c	17.50±4.78d	100±0c	0±0c	100±0b	0±0d	100±0b	0±0b
Control		0		45±8.66b		75.0±6.45d		100±0c		100±0b		100±0b	

Table 2: Percentage of tubers infested and effectiveness of insecticides in preventing infestation by PTM (%) (Mean±SE)*.

*Within columns, means ± SE followed by the same letter are not significantly different (DUNCAN's multiple F-test), IR: Infestation rate, E: Effect

As shown in table 2, the tested products indoxacarb, spinetoram and Gamma-T-ol were 100 percent effective up to 7 days of treatment and were significantly superior even after 72 days of the treatment with an average infestation of 37.5% as compared to control (100%). It was determined that two concentrations (15 and 20ml) of spinetoram were effective in preventing the damage to potato tubers by PTM during 42 days. It was revealed that the lowest doses of spinetoram protected tubers for 35 days under laboratory conditions. Similarly, it was determined that the second and third doses of Gama-t-ol were effective in prevented the damage to potato tubers for 42 days. The data suggested that Fungatol and deltamethrin offered no protection to tubers against PTM. The treatments of Fungatol, deltamethrin and control obtained similar efficacy results. Indoxacarb treated tubers had no sign of infestation after 112 days. In addition, spinetoram and Gamma-t-ol treated tubers had no sign of infestation after 42 days but there were 27.5% and 22.5% damage respectively after 49 days. This is in contrast to Fungatol and deltamethrin treated tubers, which offered no protection and infestations were similar to that of the control.

The results show that the medium and high doses of Gamma-T-ol treated tubers had no sign of infestation and prevented damage to potato tubers by PTM for 42 days. All of doses Fungatol treated tubers had infestation at after seven days and not effective. The Gamma-T-ol and Fungatol are new extracts which have been tested against a few insect pests before. Only there was a study on effect of PTM. The effect of extract *L. petersonii* on larva of PTM was investigated. In this study, the highest mortality (100%) occurred at concentration of 0.4% while the smallest mortality was at 0.05% the extracts of *L. petersonii* [23]. There are references of using an extract of *L. petersonii* against other insects. For example, the efficacy of LSO against the diamondback moth *P. xylostella* L. was evaluated. According to this study the feeding activity and development were significantly reduced of larval stages on broccoli leaves that had been dipped in LSO. Oviposition deterrence was also found when an adult stage was exposed to treated leaves. Fecundity dropped by 50% at concentrations of 0.5%. The LC_{50} value for third instar larvae was estimated to be 2.93% at 7 days after treatment. In addition, the oil was also tested at concentrations from 0.5 to 6% for oviposition deterrence of an egg parasitoid of the diamondback moth, *Trichogramma pretiosum* (Riley) (Hymenoptera: Trichogrammatidae). LSO deterred parasitisation in choice tests but not in no-choice tests. LSO did not cause mortality of *T. pretiosum* during 24 hours in a contact toxicity test.

It was concluded that LSO had no significant effects on the parasitoid, and therefore LSO is compatible with this biocontrol agent for integrated management of the diamondback moth [18]. Similarly, Erdogan and Hassan [19] revealed that the extract of *L. petersonii* caused 100% mortality of the two-spotted spider mite at 6 days after treatment.

Little is known about the effects of Fungatol (tea tree terpinen-4-ol) and Gamma-T-ol (tea tree oil, 75% Terpene) obtained from the tea tree on insects. Studies on the effect of Fungatol and gamma on insects are limited. The first study the effects of Fungatol and Gamma-T-ol was carried out by Iramu [24]. In this study, the insecticide effect of Fungatol, Gamma-T-ol, Fungatol + Neem and Gamma-T-ol + Neem extracts on *A. gossypii* was investigated in laboratory conditions. The leaf disc dipping method was used in laboratory tests. The highest insecticidal effect showed Fungatol + Neem and Gamma-T-ol + Neem extracts on *A. gossypii*. In addition, it has been reported that these extracts have no effect on the reproduction and development of *A. gossypii.* In another study, researchers have reported that Fungatol + Neem spray (50.0-001) had the highest efficacy on *T. absoluta.* Kasap, et al., investigated the toxic effects of Fungatol and Gamma-T-ol extracts on *A. gossypii* and *T. urticae* under laboratory conditions [25,20]. The researchers reported that extracts of Fungatol (3.50%) and Gamma-T-ol (3.60%) resulted in 42% and 48.9% of mortality, respectively, after 48 hours on *A. gossypii* because of their different concentrations of extracts. The same concentrations of extracts were reported to cause 94% and 93.3% of mortality on *T. urticae* adult females after 72 hours. Kok and Kasap found that the effects of insecticides on *Myzus persicae* Sulzer, (Hem: Aphididae) which cause economic losses in many cultivated plants under laboratory conditions in the same extracts [26]. They reported that extracts of Fungatol (3, 50%) and Gamma-T-ol (3, 60%) resulted in 72% and 80% mortality treatment after 72 hours on *M. persicae* respectively. Gamma-T-ol and Fungatol have been used against other arthropods. For example, it was revealed that the highest mortalities were observed at concentrations of 3.5% of Fungatol and 3.6% of Gamma-T-ol, and the mortalities caused by 3.5 and 3.6% concentrations of Fungatol and Gamma-T-ol, respectively, at 1, 24, 48 and 72 hours, were 0, 52, 74, 94%, 0, 52, 78 and 94% on two spotted mite respectively [27]. In addition, Kasap, et al., revealed that after 1, 24 and 48 h, the highest concentration of Fungatol (3.5%) and Gamma-T-ol (3.6%) obtained from *M. alternifolia* had caused 0, 18, 42% and 0, 20, 48.9% mortality of cotton aphid respectively. moreover, Fungatol and Gamma-T-ol showed the high repellent effect against *T. urticae* under laboratory conditions [20,28].

There are many studies the insecticidal about effect of plant extracts on PTM. For instance, Sharaby, et al., revealed that vapors of *Cymbopogon citrates* Stapf., *Myristica fragrans* Houtt., *Mentha citrate* and a-l on one caused highly significant reductions in the life span of exposed PTM [29]. In another study, Treated potato tubers by methanolic extract of lavender elicited the lowest percentage of first larval PTM penetration, and studying of oviposition-preference demonstrated that the largest number of eggs was laid on control and fumitory with 28 and 10 eggs after three days, respectively [30]. Moreover, it was determined that dried powders of *Allium cepa*, *Curcuma longa*, *Colocasia antigurum*, *Ocimum basilicum*, *Dodonaca viscose* and *Thuja orientalis* played a highly significant role in reducing egg deposition on PTM [31]. Lal found that the leaves of *Lantana aculeate* provided most protection to the tubers, reducing damage than *Eucalyptus globulus* and *Bacillus thurungiensis* [32]. It was observed that extracts of *Piper nigrum* and *Matricaria chamomile* showed high mortality, anti feeding and repellent effect on larva of PTM [33].

Results from this laboratory testing showed that indoxacarb provide efficient control for 112 days. These results confirmed the data presented by Dobie who mentioned about a slower, but at the same time the most continuous, effect of indoxacarb against young larvae of the PTM compared with other tested compounds [34]. Gecheva and Dimitrov revealed that indoxacarb and deltamethrin caused 100% larvicidal mortality 14 days after treatment [35]. The same authors found that after indoxacarb and deltamethrin treatment ovicidal mortality was 38.8 % and 49.6% respectively. Das and Rahman determined that deltamethrin (K-obiol DP2) treatment kept potato tubers free of the pest [36]. The best control over the PTM can be exercised by indoxacarb. In our experiments deltamethrin showed some effect on PTM as Das and Rahman revealed in their studies [36]. In Tunisia Das, et al., found that deltamethrin, granulosis virus and *B. thuringienses* were equally effective in reducing pest damage, and after 3 months storage the treatments showed no significant effect on sprouting [37]. Collantes, et al., who found that deltamethrin was most toxic for adult of PTM [38]. This may be explained that deltamethrin used in our experiments could be a different formulation.

According to our results, spinetoram (15 and 25ml) have been found to be effective in preventing damage to potato tubers by PTM for up to 42 days. In parallel with our results, Dobi revealed that when larvae were exposed to spinetoram mortality increased directly with time of exposure [34]. Mortality was noticed quickly at the 5 minute mark with 10% mortality. This mortality more than doubled at the next time interval of 15 minutes. Between 15 minute and 30 minute intervals, the mortality rate had the highest increase from 28% to 72% mortality. The mortality rate then started to plateau between the 30 minute and the 60 minute interval. By 120 minutes, the evaluation timing, spinetoram had caused 100% mortality. In addition, it was determined that spinetoram was effective in controlling PTM in field conditions, which is in accordance with our results [39].

Conclusion

It was suggested that tubers sprayed with one of three doses (10, 15, or 25ml) of indoxacarb had no infestation by PTM over a 16-week period. The two botanical insecticides (Gamma-T-ol and Fungatol), showed significant effect up to 22 days with the Gamma-T-ol extending into 42 days. Two dose rates of spinetoram (15 and 25 ml/l) were effective on PTM for 42 days. More research is required to develop this initial study further.

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