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

Pervin Erdogan* and Errol Hassan

1Department of Plant Protection, Plant Protection Central Research Institute, Ankara, Turkey
2Department of Entomology, The University of Queensland, Gatton, Australia

**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 purpose, 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

**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 granulovirus may be used to control potato tuber moth under field conditions [10,11]. Steven, et al., reported that Bacillus thuringiensis (Bt) spp. kurstaki and Granulovirus (GV) were significantly effective in controlling potato tuber moth [12]. Gomaa and El-Nenayy found that the application of Virotoecto 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 insect. There are many of studies about this subject. For example, Purenwatiningshi, 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 (Tetranychus urticae) Koch (Acari:Tetranychoidea) [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. Avantu (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.

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

| 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               |
| Deltamethrin 2.5 g/L       | 15-20,30-50                 | 0.30,0.40,0.60         |

**Statistical analysis**

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

\[
X = \frac{a-b}{1-b} \times b
\]

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 Gamma-T-ol and spinetoram had 0% infestation up to 22 days it was noticed that Fungatol and deltamethrin had the highest infestation rate.
The data suggested that Fungatol and deltamethrin offered no protection to potato tubers for 42 days. Similarly, it was determined that the second and third doses of Gamma-T-ol were effective in preventing the damage to potato tubers for 35 days under laboratory conditions. Simultaneously, it was determined that the second and third doses of Gama-t-ol 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 Gamma-T-ol were effective in preventing 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 doses of 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 LC50 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 terpin-en-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-Tol, Fungatol + Neem and Gamma-Tol + 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-Tol + 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-Tol extracts on A. gossypii and T. urticae under laboratory conditions [25,20]. The researchers reported that extracts of Fungatol (3.50%) and Gamma-Tol (3.60%) resulted in 42% and 48.9% of mortality.

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

| Treatments | Doses (ml/L) | 7 days | 12 days | 22 days | 42 days | 72 days | 112 days |
|------------|--------------|--------|---------|---------|---------|---------|----------|
|            | Ir (%)       | E (%)  | Ir (%)  | E (%)  | Ir (%)  | E (%)  | Ir (%)   |
| Indoxacarb | 0.10         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |
|            | 0.25         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |
| Spinetoram | 0.20         | 0      | 100.00a | 0      | 100.00a | 37.5±8.53b | 62.5±0b  |
|            | 0.30         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |
| Gamma-T-ol | 2.50         | 0      | 100.00a | 0      | 100.00a | 32±4.78b | 67.5±6.29b |
|            | 3.50         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |
| Fungatol   | 3.50         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |
|            | 5.00         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |
| Deltame-   | 0.30         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |
| thrin      | 0.40         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |
| Control    | 0.60         | 0      | 100.00a | 0      | 100.00a | 0      | 100.00a  |

*Within columns, means ± SE followed by the same letter are not significantly different (DUNCAN’s multiple F-test), IR: Infestation rate, E: Effect.
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 antiquorum*, *Ocimum basilicum*, *Dodonaca viscosa* 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 thuringiensis* [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]. Gcheva 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-oil 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, granulosus virus and *B. thuringiensises* 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, Dobie 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.

**Acknowledgement**

The authors like to thank Ms. Sonya Fardell and Dr. John Dingle for their time for reading the manuscript and their input. The authors are grateful to Dr. Numam E. Babaroglu for statistical analysis in Plant Protection Central Institute Ankara-Turkey.

**References**

1. Rondon SI (2010) The Potato Tuberworm: A Literature Review of Its Biology, Ecology, and Control. Am J Pot Res 87: 149-166.
2. Triverdi TP, Rajagopal D (1992) Distribution, biology, ecology and management of potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae): A review. Troop Pest Manage 38: 279-285.
3. Malakar-Kuenen R, Tingeys WM (2006) Aspects of tuber resistance in hybrid potato varieties to potato tuber worm. Entomol Exp Appl 120: 131-137.
4. Bacon OG, Calley N, Riley WD, James RH (1971) Evaluation of insecticides for control of the green aphid and tuberworm on Irish potatoes. American Potato Journal 48: 298.
5. Rondon SI, DeBano SJ, Clough GH, Hamm PH, Jensen A, et al. (2007) Biology and Management of the Potato Tuberworm in the Pacific Northwest. NPN 594: 1-8.
6. Von Arx R, Gouider J, Cheikh M, Tenime AB (1987) Integrated control of potato tuber moth *Phthorimaea operculella* (Zeller) in Tunisia. Int J Trop Insect Sci 8: 989-994.
7. Mandour NS, Sarhan AA, Atwa DH (2012) The integration between *Trichogramma evanescens* West. (Hymenoptera: Trichogrammatidae) and selected bioinsecticides for controlling the potato tuber moth *Phthorimaea operculella* (Zell.) (Lepidoptera: Gelechiidae) of stored potatoes. Journal of Plant Protection Research 52: 41-46.
8. Erdogan P (2014) The importance of potato tuber moth *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae), the situation in our country and control. The Journal of Turkey Seed Growers Association 41-42.
9. Ali MA (1993) Effects of cultural practices on reducing field infestation of potato tuber moth (*Phthorimaea operculella*) and greening of tubers in the Sudan. J Agr Sci 121: 187-192.
10. Salah HB, Aalbu R (1992) Field use of granulosis virus to reduce initial storage infestation of the potato tuber moth, *Phthorimaea operculella* (Zeller), in North Africa. Agr Ecosyst Environ. 38: 119-126.

11. Chandel RS, Chandla VK (2005) Integrated control of potato tuber moth (*Phthorimaea operculella*) in Himachal Pradesh. Indian J Agr Sci 75: 837-839.

12. Arthurs SP, Lacey LA, Pruneda JN, Rondon SI (2008) Semi-field evaluation of a granulovirus and *Bacillus thuringiensis* spp. kurstaki for season-long control of the Potato tuber moth, *Phthorimaea operculella*. Entomol Exp Appl 129: 276-285.

13. Gomaa AE, El-Nenacy HM (2006) Evaluation of certain controlling measures for *Phthorimaea operculella* (Zeller) (Lepidoptera, Gelechiidae) on potato in stores. The Egyptian Journal of Agricultural Research 84: 31-41.

14. Hossein SMZ, Das GP, Ala MZ (1994) Use of various indigenous materials and insecticides in controlling Potato tuber moth in storage. Bulletin of Institute of Tropical Agriculture Kyusyu University 17: 79-84.

15. Debnath MC, Khound NJ, Dutta SK and Sarmah PC (1998) Management of Potato tuber moth, *Phthorimaea operculella* (Zeller) in potato storage. Journal of the Agricultural Science Society of North-East India 11: 55-60.

16. Salama HS, Salem SA (2000) *Bacillus thuringiensis* neom and neem seed oil (Azadirachta indica) effects on the potato tuber moth *Phthorimaea operculella* zeller in the field and stores. Arch Phytopathol Pest 33: 73-80.

17. Abdel-Razek AS, Salem AE, Ghany NMB (2014) Sustainable Potato tuber moth *Phthorimaea operculella* (Zeller) control using biopesticides of natural and microbial origin. African Journal of Science and Technology 2: 125-130.

18. Purwatiningshi P, Heather N, Hassan E (2012) Efficacy of *Lepotosperrum petersonii* oil, on *Platella xylostella*, and its parasitoid, *Trichogramma pretiosum*. J Econ Entomol 105: 1379-1384.

19. Erdogan P, Hassan E (2014) The effects of plant extracts of lemon-scented tea tree (*Leptospermum petersonii* [Myrtaceae]) on *Tetranychus urticae* Koch (Acari: Tetranychidae) International Conference on Biopesticides 7 (ICOB7). Antalya, Turkey.

20. Kasap I, Sok S, Hassan E (2016) Effect of Fungatol and Gamma-T-ol from *Melaleuca alternifolia* (Myrtaceae) and *Tetranychus urticae* Koch (Acari: Tetranychidae). Turkish Journal of Entomology 40: 117-123.

21. Mandour NS (1997) Ecological and biological studies on the polymbryonic parasitoid *Cipidiosa desaunisi* Ammeke & Mynhardt parasitic on the Potato tuber moth in Suez Canal area. M.Sc. Thesis, Faculty of Agriculture, Suez Canal University 9: 109-116.

22. Abbot WS (1925) A method of computing the effectiveness of an insecticide. Journal of Economic Entomology 18: 265-267.

23. Erdogan P, Hassan E (2017) Insecticidal Effect of Three Different Plant Extracts On Potato Tubber moth (*Phthorimaea operculella* Zeller (Lepidoptera :Gelechiidae)) Central Anatolia Region 3. Agriculture and Food Congress. October, 26-28, Sivas, Turkey.

24. Iramu ET, George D, Hassan E (2011) Evaluation of the efficacy of essential oil formulations against aphid *Aphis gossypii* Glover (Hemiptera: Aphididae) on *Abelmoschus manihot*. International Conference on Biopesticides 6 (ICOB 6), Chang-Mai, Thailand.

25. Bayindir A, Ozger S, Karaca I, Birgeucu AK, Hassan E (2014) Effects of biopesticides on *Tuta absoluta* (Lepidoptera:Gelechiidae) under laboratory conditions. International Conference on Biopesticides 7 (ICOB7) Antalya, Turkey.

26. Sok S, Kasap I (2016) Natural Insecticides Effects of Two Different Plant Extract on Green Peach Aphid, *Myzus persicae* Sulzer 1776 (Hemiptera: Aphididae). Conscious Healthy Life Journal 12: 209-215.

27. Kasap I, Hassan E (2014) Effects of two different plant extracts on the two spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae). International Conference on Biopesticides 7 (ICOB7) Antalya, Turkey.

28. Sok S, Erdogmus A, Koyun A, Kasap I (2016) Repellent Effect of Fungato and Gamma-T-ol Extracts Derived from *Melaleuca alternifolia* (Myrtaceae) against *Tetranychus urticae* Koch (Acari: Tetranychidae) under Laboratory Conditions. COMU Journal Agriculture. Faculty 4: 93-98.

29. Sharaby A, Rahman HA, Abdel-Aziz SS, Mouawad SS (2014) Natural Plant Oils and Terpenes as Protector for the Potato Tubers against *Phthorimaea operculella* Infestation by Different Application Methods. Ecologia Balanika 6: 45-59.

30. Dastjerdi HF, Khorrami F, Razmjou I, Esmailpour B, Golzadeh A, et al. (2013) The efficacy of some medicinal plant extracts and essential oils against potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae). Journal Crop Protection 2: 93-99.

31. Sharaby A, Abdel-Rahman H, Mouawad S (2009) Biological effects of some natural and chemical compounds on the potato tuber moth, *Phthorimaea operculella* Zell (Lepidoptera: Gelechiidae). Saudi J Biol Sci 16: 1-9.

32. Lai L (1987) Studies on natural repellents against potato tuber moth (*Phthorimaea operculella* Zeller) in country stores. Potato Research 30: 329-334.

33. Khatter NA (2010) Insecticidal Activity of Certain Plant Extracts Against Potato Tuber Moth Larvae of *Phthorimaea operculella* (Zeller). Egypt J Exp Biol (Zoo) 6: 347-355.

34. Dobi CH (2010) Pesticides susceptibility of potato tuberworm in the Pacific Northwest. Thesis of Master’s degree. Washington State University, USA.

35. Gancheva VT, Dimitrov Y (2013) Chemical control of the Potato tuber moth *Phthorimaea operculella* (Zeller) on tobacco. Bulgarian Journal of Agricultural Science 19: 1003-1008.

36. Das GP, Rahman MM (1997) Effect of some inert materials and insecticides against the potato tuber moth, *Phthorimaea operculella* (Zeller), in storage. International Journal of Pest Management 43: 247-248.

37. Das GP, Langnouai A, Salah HB, Souibgui M (1998) The control of the Potato tuber moth in storage in Tunisia. Tropical Science 38: 78-80.

38. Collantes LG, Raman KV, Cisneros FH (1986) Effect of six synthetic pyrethroids on two populations of potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae), in Peru. Crop Protection 5: 355-357.

39. Erdogan P, Hassan E (2017) Determination of Time of Insecticide Application Against Potato Tuber Moth, *Phthorimaea operculella* Zeller (Lep: Gelechiidae) in the Field Conditions in Turkey. Canadian Journal of Pure and Applied Science 11: 4061-4066.
Journal of Anesthesia & Clinical Care
Journal of Addiction & Addictive Disorders
Advances in Microbiology Research
Advances in Industrial Biotechnology
Journal of Agronomy & Agricultural Science
Journal of AIDS Clinical Research & STDs
Journal of Alcoholism, Drug Abuse & Substance Dependence
Journal of Allergy Disorders & Therapy
Journal of Alternative, Complementary & Integrative Medicine
Journal of Alzheimer’s & Neurodegenerative Diseases
Journal of Angiology & Vascular Surgery
Journal of Animal Research & Veterinary Science
Archives of Zoological Studies
Archives of Urology
Journal of Atmospheric & Earth-Sciences
Journal of Aquaculture & Fisheries
Journal of Biotech Research & Biochemistry
Journal of Brain & Neuroscience Research
Journal of Cancer Biology & Treatment
Journal of Cardiology & Neurocardiovascular Diseases
Journal of Cell Biology & Cell Metabolism
Journal of Clinical Dermatology & Therapy
Journal of Clinical Immunology & Immunotherapy
Journal of Clinical Studies & Medical Case Reports
Journal of Community Medicine & Public Health Care
Current Trends: Medical & Biological Engineering
Journal of Cytology & Tissue Biology
Journal of Dentistry: Oral Health & Cosmesis
Journal of Diabetes & Metabolic Disorders
Journal of Dairy Research & Technology
Journal of Emergency Medicine Trauma & Surgical Care
Journal of Environmental Science: Current Research
Journal of Food Science & Nutrition
Journal of Forensic, Legal & Investigative Sciences
Journal of Gastroenterology & Hepatology Research
Journal of Gerontology & Geriatric Medicine
Journal of Genetics & Genomic Sciences
Journal of Hematology, Blood Transfusion & Disorders
Journal of Human Endocrinology
Journal of Hospice & Palliative Medical Care
Journal of Internal Medicine & Primary Healthcare
Journal of Infectious & Non Infectious Diseases
Journal of Light & Laser: Current Trends
Journal of Modern Chemical Sciences
Journal of Medicine: Study & Research
Journal of Nanotechnology: Nanomedicine & Nanobiotechnology
Journal of Neonatology & Clinical Pediatrics
Journal of Nephrology & Renal Therapy
Journal of Non Invasive Vascular Investigation
Journal of Nuclear Medicine, Radiology & Radiation Therapy
Journal of Obesity & Weight Loss
Journal of Orthopedic Research & Physiotherapy
Journal of Otolaryngology, Head & Neck Surgery
Journal of Pathology Clinical & Medical Research
Journal of Pharmacology, Pharmaceutics & Pharmacovigilance
Journal of Physical Medicine, Rehabilitation & Disabilities
Journal of Plant Science: Current Research
Journal of Psychiatry, Depression & Anxiety
Journal of Pulmonary Medicine & Respiratory Research
Journal of Practical & Professional Nursing
Journal of Reproductive Medicine, Gynaecology & Obstetrics
Journal of Stem Cells Research, Development & Therapy
Journal of Surgery: Current Trends & Innovations
Journal of Toxicology: Current Research
Journal of Translational Science and Research
Trends in Anatomy & Physiology
Journal of Vaccines Research & Vaccination
Journal of Virology & Antivirals

Submit Your Manuscript: http://www.heraldopenaccess.us/Online-Submission.php