The effects of essential oils of *Artemisia absinthium* L., *Achillea millefolium* L. and *Artemisia dracunculus* L. against potato tuber moth, *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae)

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ABSTRACT

The potato tuber moth (PTM), *Phthorimaea operculella* Zeller is an important and ubiquitous pest of potato, *Solanum tuberosum* L. in both fields and stores in the subtropical and tropical zones. In this study, oviposition deterrent of essential oils of wormwood, yarrow and tarragon was investigated on this pest. The results showed that the number of laid eggs on treated tubers were significantly less than the control tubers. Also, sublethal effects of mentioned essential oils on biological parameters and life table parameters were studied. The results showed that the number of laid eggs in the essential oils of wormwood and yarrow were significantly less than the control. Although results showed that all three essential oils caused significant reduction of the number of hatched eggs compared with control. Also, life expectancy of the pest in the first day of egg stage and at the time of adults emergence in wormwood, yarrow, tarragon and control were 21.61, 25.87, 21.81 and 26.17 days; 10.50, 11.18, 10.60 and 11.46 days, respectively. The results showed that essential oil of wormwood caused reduction of life expectancy of PTM. Therefore, the use of mentioned essential oils in the store environment can be useful against potato tuber moth.

Keywords: biological parameters, life table parameters, oviposition deterrent, Phthorimaea operculella, Solanum tuberosum, sublethal effects.

INTRODUCTION

The potato tuber moth (PTM), *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae) is a noxious pest of potato under both field and storage conditions (Haines, 1977; Raman and Palacios, 1982). This pest causes serious damage to stored potato through its larval tunneling and feeding which lead to partial or complete rotting by subsequent infestation by fungi and / or bacteria (Moawad and Ebadah, 2007). The use of chemical pesticides to control of potato tuber moth has resulted in harmful side effects such as health hazards from residues (Dikshit *et al*., 1985), reduction in populations of natural enemies (Shelton *et al*., 1981) and the development of insect resistance to pesticides (Haines, 1977; Llanderal-Cazares *et al*., 1996). In the continuous search for new pest control agents, plants are considered one of the richest sources (Abdullah *et al*., 1986). Essential oils (EOs) are volatile and natural compounds characterized by a string odor and are formed as plant secondary metabolites by plants belonging to botanical families, such as Myrtaceae,

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Lauraceae, Lamiaceae, Asteraceae. These compounds have functions in chemical defense, acting as insecticides, acaricides, attracting natural enemies of herbivores (Karamanoli, 2002; Karamanoli *et al*., 2005; Bakali *et al*., 2008). Moawad (2000) showed that the volatile oils of *Cymbopogon citratus* DC., *Myristica fragrans* Houtt., *Mentha citrata* Ehrh. and α-ionone at a high concentration (0.05 ml/ 500 ml) can successfully reduce infestation by potato tuber moth, through shortening the life span of adults and reducing their fertility. As majority of exposed females died before laying eggs and failure of others to lay their full load of eggs. Fallatah (2003) mentioned that vapors of plant oils of cardamom, cinnamon, eucalyptus, coriander and basil inhibited the exposed moths of *P. operculella* from egg oviposition by their repellent effects and protected the potato tubers from the insect infestation up to 2 weeks during the storage period. In the present experiment the efficacy of essential oils which were extracted from plants of wormwood (*Artemisia absinthium* L.), yarrow (*Achillea millefolium* L.) and tarragon (*Artemisia dracunculus* L.) were evaluated on oviposition deterrent of *P. operculella*. Also, the sublethal effects of mentioned essential oils on biological and life table parameters of the pest were studied.

MATERIALS AND METHODS

Insect

The colony of potato tuber moth was obtained from a laboratory of Department of Plant Protection, Faculty of Agricultural Sciences, University of Mohaghegh Ardabili, Iran in summer 2012. Adults were kept in plastic containers (9cm × 17cm × 24cm) and reared on potato tubers. The bottom of containers was covered with a thin layer of clean sand for pupation (El-Sinary, 1995). Colony rearing and experiments were carried out under laboratory conditions at 25 ± 1ºC, 65 ± 5% RH and a photoperiod of 8L: 16D hours.

Preparation of plants and extraction of their essential oils

Dried flowers of wormwood and yarrow were purchased from local market of Ardabil city. Also, fresh leaves of tarragon were purchased from local market and were dried at the shadow and ventilation conditions. The needed parts of plants were grinded and their powders were used for extraction of essential oils by using Clevenger-type apparatus for three hours. The obtained essential oils were stored in vials coating by aluminium paper at 4ºC.

Efficacy of essential oils as oviposition deterrent

In this experiment, each potato tuber was dipped in concentration of 0.50% of essential oils (10 µL of essential oil diluted in 2 ml of acetone) and after evaporation of solvent, they (three potato tubers) were transferred into plastic containers (diameter of 19.5 cm and height of 7.5 cm). In the control treatment, each potato tuber was dipped in 2 ml of solvent alone. Eight pairs of one-day-old adults (males + females) were transferred into each plastic container. The oviposition rate was recorded at 24 hours intervals for three successive days and laid eggs per each day were calculated and removed. This experiment was replicated four times under laboratory conditions.

Sublethal effects of essential oils on biological and life table parameters

In order to determine the sublethal effects of essential oils, number of 150 one-day-old eggs were transferred into 1000 ml glass vials. The filter papers were cut to diameter of 4 cm and were placed in the cap of glass vials. The sublethal concentration (LC_{30}) of essential oils of wormwood, yarrow and tarragon (2.16, 2.00 and 0.88 µL/L air, respectively) were applied on filter papers by

using sampler and the caps of glass vials were covered with Parafilm. In the control distilled water was used. The eggs were transferred into plastic containers (9cm × 17cm × 24cm) containing potato tubers after 24 hours. The eggs were examined daily and the number of hatched eggs and their incubation period were recorded. These experiments were continued until adult's emergence. The larval duration, number of pupae and pupal duration were calculated. In the adult stage, number of 22, 25, 21 and 25 pairs of adults (males + females) were transferred into plastic containers (diameter of 12.5 cm and height of 6 cm) with a hole covered with mesh in wormwood, yarrow, tarragon and control, respectively. Then the filter papers were put on meshes and number of laid eggs and number of hatched eggs were recorded daily. These experiments were continued until all experimental females died. Finally, we calculated biological and life table parameters of this pest by using the equations of Carey (1993).

The biological parameters were as number of laid eggs, number of hatched eggs, female longevity, pre-oviposition, oviposition, post-oviposition and sex ratio ((female/female + male) × 100).

The life table parameters were as life expectancy (e_x), survival (L_x) and age-specific mortality (q_x).

Life expectancy (e_x)

The life expectancy is the mean of number of days that an individual survives after reaching age x and is calculated according to the following equation.

$$l_x = \frac{N_x}{N_0}$$

$$L_x = \frac{l_x + l_{x+1}}{2}$$

$$T_x = \sum_{x=0}^{\omega} L_x$$

$$e_x = \frac{T_x}{l_x}$$

l_x is the proportion of individuals surviving until age x and T_x is the number of days that individuals survived after age x.

Survival (L_x)

The survival is the days that lived in interval x and x+1.

Age-specific mortality (q_x)

The age-specific mortality is the proportion of individuals surviving until age x that in interval x and x+1 died and is obtained according to the following equation.

$$p_x = \frac{l_{x+1}}{l_x}$$

$$q_x = 1 - p_x$$

p_x is the proportion of individuals surviving until age x that in interval x and x+1 also survived.

The relationship between data was estimated by the one way analysis of variance (ANOVA) with SPSS 16.0 for Windows® (SPSS, 2007). The means were compared by using Tukey test ($P < 0.05$) and Student Newman Keuls (SNK) test ($P < 0.05$) in oviposition deterrent and biological parameters, respectively.

RESULTS

Results presented in Table 1 showed that in the first day ($F = 39.55$; df= 3, 12; $P < 0.01$), second day ($F = 85.34$; df= 3, 12; $P < 0.01$) and third day ($F = 38.26$; df= 3, 12; $P < 0.01$) there was a significant difference between essential oils compared with control and the oviposition rate in essential oils was less than control. Also in between essential oils, wormwood and yarrow showed a significant difference with each other. In all three days, process was the same way ($F = 24.25$; df= 3, 44; $P < 0.01$).

Table 1. The mean (±SE) of number of laid eggs of *P. operculella* on treated and non-treated tubers in three successive days

Essential oils	First day	Second day	Third day	All three days
Wormwood	60.25±4.03^{b}	41.00±3.11^{b}	27.00±2.71^{b}	42.75±4.46^{b}
Yarrow	34.25±2.84^{c}	22.50±1.04^{c}	16.00±1.00^{c}	24.25±2.47^{c}
Tarragon	48.50±3.86^{bc}	31.75±2.69^{bc}	22.75±2.78^{bc}	34.33±3.61^{bc}
Control	85.50±2.90^{a}	70.25±1.44^{a}	50.25±2.66^{a}	68.67±4.53^{a}

Means in a column with the different letters are significantly different (P <0.05)

Results presented in Table 2 showed that the number of laid eggs was significantly higher in control compared with wormwood and yarrow. However, no significant difference was observed between control and tarragon (F= 8.99; df= 3, 89; P <0.01). A significant difference in the number of hatched eggs was observed between treatments and control. Also in between treatments, yarrow caused a significant reduction compared with tarragon (F= 12.43; df= 3, 89; P <0.01). In the female longevity, results showed that the value of this parameter was higher in control. However, no significant difference was observed between control and treatments (F= 1.04; df= 3, 89; P >0.05). The pre-oviposition was significantly higher in yarrow compared with two other essential oils and control (F= 4.40; df= 3, 89; P <0.01). In the oviposition was showed a significant reduction in treatments of wormwood and yarrow compared with control, but no significant difference was observed between tarragon and control in this parameter (F= 7.11; df= 3, 89; P <0.01). In the post-oviposition no significant difference was observed between treatments and control (F= 0.29; df= 3, 89; P >0.05). Also, in the sex ratio data indicated that sublethal concentration of yarrow can produce more males in the potato tuber moth population.

Table 2. The mean (±SE) of biological parameters of *P. operculella* in essential oils of wormwood, yarrow, tarragon and control

Essential oils	Number of laid eggs	Number of hatched eggs	Female longevity	Pre oviposition	Oviposition	Post oviposition	Sex ratio
Wormwood	70.27±7.18^{bc}	62.05±6.73^{bc}	11.00±0.47^{a}	1.91±0.16^{b}	2.95±0.24^{b}	6.14±0.54^{a}	45.60
Yarrow	55.40±5.67^{c}	45.52±5.63^{c}	11.68±0.45^{a}	2.64±0.20^{a}	3.04±0.23^{b}	6.00±0.42^{a}	44.94
Tarragon	85.90±7.40^{ab}	71.10±6.77^{b}	11.10±0.53^{a}	1.86±0.20^{b}	3.62±0.22^{ab}	5.62±0.49^{a}	50.00
Control	102.40±7.50^{a}	99.24±7.18^{a}	11.96±0.38^{a}	2.08±0.13^{b}	4.24±0.22^{a}	5.64±0.47^{a}	46.15

Means in a column with the different letters are significantly different (P <0.05)

Life expectancy of the pest (Figure 1) in the first day of egg stage in essential oils of wormwood, yarrow, tarragon and control were 21.61, 25.87, 21.81 and 26.17 days, respectively. These data show that in the beginning of life, life expectancy in control was more than treatments. Also in between treatments, the value of this parameter in wormwood was less than two other treatments. Life expectancy at the time of adults emergence in essential oils of wormwood, yarrow, tarragon and control were 10.50, 11.18, 10.60 and 11.46

days, respectively. These data show that the highest and the lowest life expectancy of adults were observed in control and wormwood, respectively. The results show that sublethal concentration of wormwood in the beginning of life and in the beginning of adults emergence caused reduction of life expectancy.

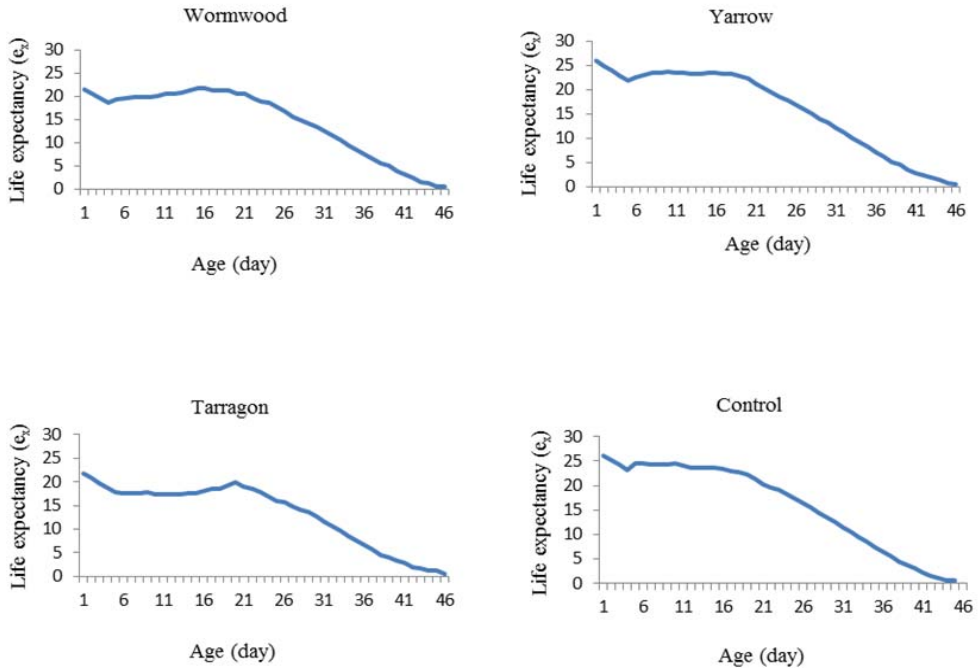

Figure1: Life expectancy (e_x) of *P. operculella* in essential oils of wormwood, yarrow, tarragon and control

Figure 2 shows that in all curves, the survival rate reduced with age increase. The survival reduction of potato tuber moth in wormwood and tarragon were more than yarrow and control.

According to Figure 3, the highest specific mortality in the egg stage was observed in control and wormwood. The value of this parameter at the end of larval stage and middle of pupa stage in tarragon was more than two other essential oils and control. The specific mortality in the early days of adult stage in essential oils and control were zero but gradually increased and at the end of this stage showed a sharp increase. The results show that treatments of wormwood and tarragon caused mortality increase of eggs and larvae of the pest, respectively.

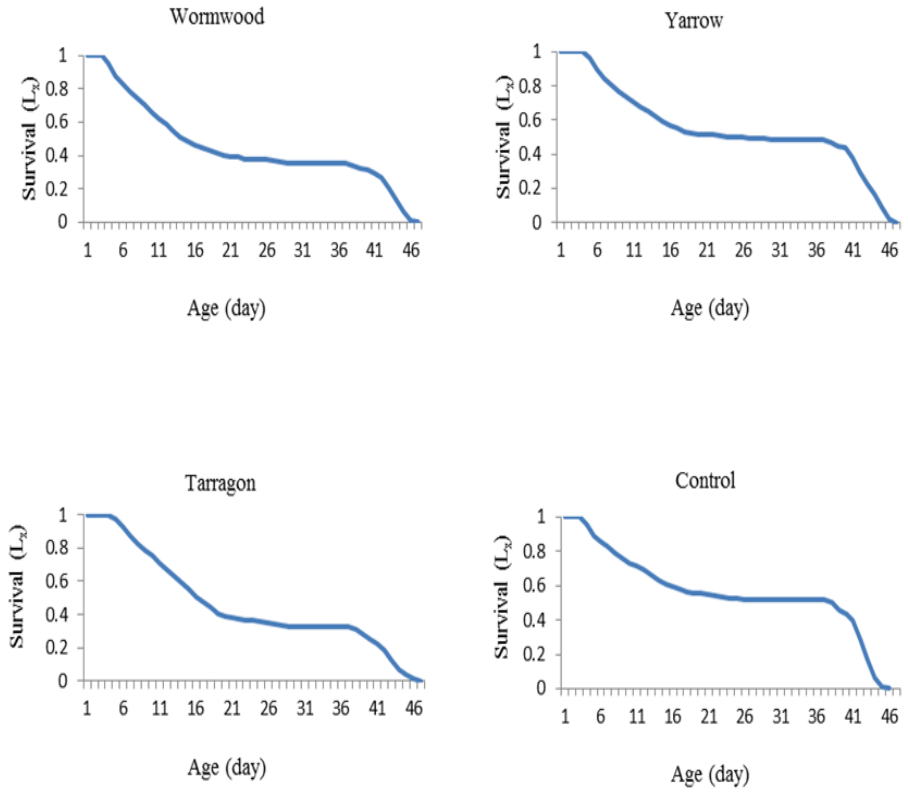

Figure2: Survival (L_x) of *P. operculella* in essential oils of wormwood, yarrow, tarragon and control

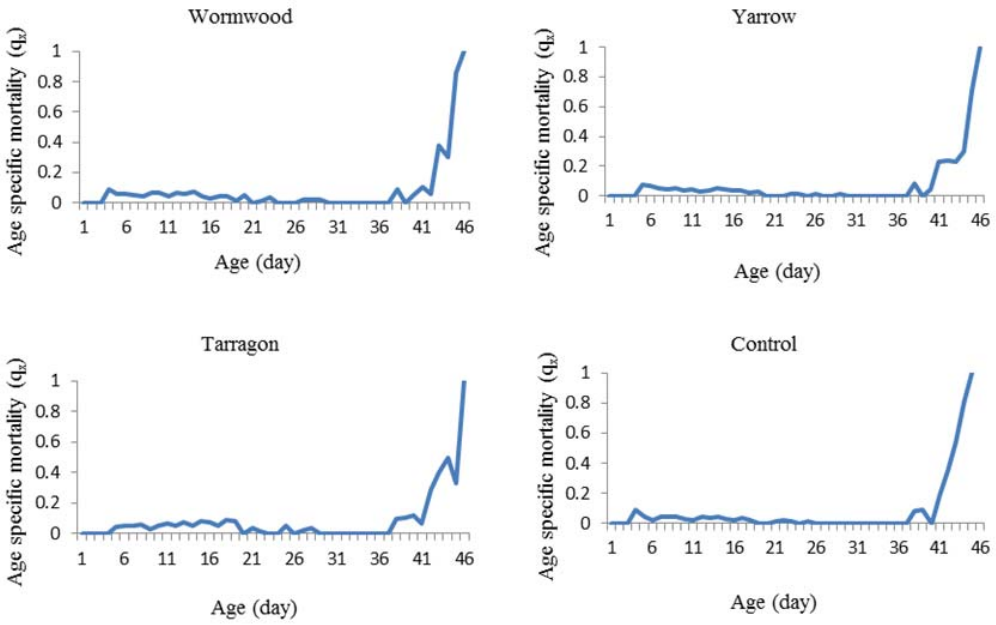

Figure3: Age-specific mortality (q_x) of *P. operculella* in essential oils of wormwood, yarrow, tarragon and control

DISCUSSION

The present study showed that the mean of number of laid eggs by females on treated tubers with yarrow were significantly less than treated tubers with wormwood. This show that essential oil of yarrow was more efficient as oviposition deterrent against the pest. In a study conducted by Khorrami (2012) the effect of methanolic extracts 5% of *Lavandula angustifolia* Mill. and *Origanum vulgare* L. was tested as oviposition deterrent of potato tuber moth and was showed a significant difference between extracts and control that with the results of the present study is similar. Although the results of a study conducted by Mona and El-Aziz (2011) showed that essential oil of *Majorana hortensis* Moench. on *P. operculella* had insignificant oviposition deterrent activity. In another study, Ajamhassani and Salehi (2004) examined the effect of leaf powder and 5% extract of *Sambucus ebulus* L., *Artemisia annua* L. and *Pterocarya fraxinifolia* Lam. on oviposition rate of potato tuber moth. They reported that either leaf powder or extracts of mentioned plants had deterrent activity but the extracts were more deterrent than their powder. Rafiee-Dastjerdi *et al*. (2013) investigated the oviposition preference activity of methanolic extracts 5% of fumitory (*Fumaria officinalis* L.), licorice (*Glycyrrhiza glabra* L.), lavender (*L. angustifolia*) and oregano (*O. vulgare*) on *P. operculella*. Their results showed that the most number of eggs were laid on control and fumitory with 28 and 10 eggs after three days, respectively.

The results presented in the present investigation showed that number of laid eggs in the essential oils of wormwood and yarrow were significantly less than control. Although in the number of hatched eggs was showed that all three essential oils caused significant reduction of this parameter compared with control. Khorrami (2012) reported that number of laid eggs and number of hatched eggs of *P. operculella* had a significant reduction in the sublethal concentration of essential oils of *L. angustifolia* and *O. vulgare* and their values were 23.30, 24.10 eggs and 15.10, 18.02 eggs, respectively.

According to our results it can be concluded that the use of essential oils of wormwood, yarrow and tarragon in the store environment can be useful for population management of PTM.

REFERENCES

Abdullah, M.D., Kandif, M.A., Farag, A.A. 1986. Bioactivity of plant extracts against *Sitophilus granarius* L. and *Tribolium castaneum* Hbst. ***Bull. Ent. Soc. Egypt. Econ. Ser.***, 15: 199-205.

Ajamhassani, M., Salehi, L. 2004. Effect of three non-cultivated plants on host preference oviposition rate of the potato tuber moth (*Phthorimaea operculella*). ***Journal of Agricultural Science of Iran***, 1(5): 112-119.

Bakali, F., Averbeck, S., Averbeck, D., Idaomar, M. 2008. Biological effects of essential oils, a review. ***Food Chemistry and Toxicology***, 46: 446-475.

Carey, J.R. 1993. **Applied Demography for Biologists with Special Emphasis on Insects**. Oxford University Press, New York, 211 pp.

Dikshit, A.K., Misra, S.S., Lal, L. 1985. Persistence of chlorpyrifos residues in potatoes and the effect of processing. ***Potato Research***, 28: 461-468.

El-Sinary, N.H. 1995. **Magnitude and applicability of gamma radiation and controlled atomospheres to minimize the hazards of potato tuber moth, *Phthorimaea operculella* Zeller (Lepidoptera:**

Gelechiidae). Ph.D. Thesis, Cario University, 187 pp.

Fallatah, S.A.B. 2003. **Bioactivity and histopathological effects of some plant products and microbial pesticides against the potato tuber moth *Phthorimaea operculella* (Zell.) (Lepidoptera: Gelechiidae)**. Ph.D. Thesis, Department of Zoology, Girls College of Science, Dammam, Saudi Arabia.

Haines, C.P., 1977. The potato tuber moth, *Phthorimaea operculella* Zell.: a bibliography of recent literature and a review of its biology and control on potatoes in the field and in store. ***Tropical Products Institute***, London.

Karamanoli, K. 2002. **Secondary metabolites as allelochemicals in plant defense against microorganisms of the phyllosphere**. Pp 277-288 in Reigosa M, Pedrol N (Eds). Allelopathy: from molecules to ecosystems. USA-Enfield (NH): Science Publishers Inc.

Karamanoli, K., Menkissoglu-Spiroudi, U., Bosabalidis, A.M., Vokou, D., Constantinidou, H.I.A. 2005. Bacterial colonization of the phyllosphere of nineteen plant species and antimicrobial activity of their leaf secondary metabolites against leaf associated bacteria. ***Chemoecology***, 15: 59-67.

Khorrami, F. 2012. **The effect of essential oils of *Lavandula angustifolia* and *Origanum vulgare* on some biological characteristics of *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae)**. M.Sc. Thesis, Faculty of Agricultural Sciences, University of Mohaghegh Ardabili, 49 pp.

Llanderal-Cazares, C., Lagunes-Tejada, A., Carrillo-Sanchez, J.L., Sosa-Moss, C., Vera-Graziano, J., Bravo-Mojica, H. 1996. Susceptibility of *Phthorimaea operculella* (Zeller) to insecticides. ***Journal of Entomological Science***, 31: 420-426.

Moawad, S.S. 2000. **Utilization of some natural materials for protection of the potato crop from insect infestation**. Ph.D. Thesis, Faculty of Science, Ain Shams University, 162 pp.

Moawad, S.S., Ebadah, I.A.M. 2007. Impact of some natural plant oils on some biological aspects of the potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae). ***Research Journal of Agriculture and Biological Sciences***, 3(2): 119-123.

Mona, F., El-Aziz, Abd. 2011. Bioactivities and biochemical effects of marjoram essential oil used against potato tuber moth *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae). ***Life Science Journal***, 8(1): 288-297.

Rafiee-Dastjerdi, H., Khorrami, F., Razmjou, J., Esmaielpour, B., Golizadeh, A., Hassanpour, M. 2013. The efficacy of some medicinal plant extracts and essential oils against potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae). ***Journal of Crop Protection***, 2(1): 93-99.

Raman, K.V., Palacios, M., 1982. Screening potato for resistance to potato tuber worm. ***Journal of Economic Entomology***, 75: 47-49.

Shelton, A.M., Wyman, J.A., Mayor, A.J. 1981. Effects of commonly used insecticides on the potato tuber worm and its associated parasites and predators in potatoes. ***Journal of Economic Entomology***, 74: 303-308.

SPSS, 2007. SPSS 16.0 for Windows®

تأثيرات الزيوت العطرية من *Artemisia absinthium* L. و*Achillea mellefolium* L. لمكافحة عثة درنات البطاطا *Phthorimea operculella* zeller (حرشفية الأجنحة – Gelectidae)

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ملخص

عثة درنات البطاطا Phthorimea operculella zeller آفة هامة لمحصول البطاطا Solanum tuberosum L. في الحقل والمخزن في المناطق الاستوائية وشبه الاستوائية. تم في هذه الدراسة إعاقة وضع البيض لهذه الآفة من زيوت الافسنثين (نب) والألفية وتراجون. أظهرت النتائج بأن عدد البيوض الموضوعة على الدرنات كانت أقل معنوياً من معاملة الشاهد. كذلك شملت الدراسة التأثير تحت السام للزيوت المختبرة على المقاييس البيولوجية وعلى جداول الحياة. أظهرت الدراسة بأن أعداد البيوض الموضوعة في معاملات الزيوت من الافسنثين (نب) والألفية كانت أقل معنوياً من الشاهد. كذلك أظهرت النتائج أن معاملات الزيوت الثلاثة تسببت في انخفاض معنوي في أعداد فقس البيض مقارنة بالشاهد. كذلك كان طول عمر الآفة في اليوم الأول من عمر البيضة وقت فقس البالغة من البيضة في معاملات الافسنثين (نب) والألفية وتراجون والشاهد كانت 21.61، 25.87، 21.81، 26.17 يوماً، و10.50، 11.18، 10.60، 11.46 يوماً، على التوالي. أظهرت النتائج أن الزيت من الافسنثين (نب) تسبب في تخفيض طول عمر فراشة درنات البطاطا، لذلك فإن استعمال الزيوت المذكورة في المخزن من الممكن أن تكون مفيدة في مكافحة عثة درنات البطاطا.

الكلمات الدالة: الزيوت العطرية، درنات البطاطا، حرشفية الأجنحة.

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