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STUDY OF POTATO TUBER MOTH BIOLOGY (*PHTHORIMAEA OPERCULELLA*), IN THE VEGETATION PERIOD, IN KORCA REGION

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ABSTRACT— Potato tuber moth (*Phthorimaea operculella*) [1] (Zeller), is a pest mainly of solanaceous plants, especially for potato crop. In the period of full potato germination, the adult insects after mating begin to lay eggs mainly in leaves or tubers throughout the vegetation. When there are soil cracks or potato seed is sown shallow, moths prefer to lay eggs near potato buds. In the leaves it forms galleries between the two epidermis of the leaf or in the stalk and in the tubule. The damage in the leaves does not turn out to cause major damage, but in potato tubers the damage can go up to 100% of production, both in the field and in the storage. Tubers are damaged by reducing the quantity and quality but also the values as planting material. During the vegetation, the potato crop is damaged by 4 generations of the pest, a fifth generation begins to develop during October in the potato waste left on the ground after harvest, in tobacco, tomatoes, sugar beets, weeds or in storage. Farmers find it very difficult to control the development of this pest, despite the chemical treatments carried out against this pest. Cultivation of resistant species, as well as the application of good agricultural practices such as frequent irrigation with reduced water rates, planting potato seeds at a depth of not less than 10 cm can ensure a good yield. Pest monitoring mainly through sexual pheromone use and the application of chemical treatments immediately after the first larvae hatching from the egg, reduce significantly yield damage in both quantity and quality.

KEYWORDS: Potato tuber moth, pest, generation, potato, tuber, pheromone, cultivar.

1. INTRODUCTION

The district of Korca lies in the southeast of Albania and is known for it's potato cultivation. The geographical position, the altitude of 850 m above sea level and the Mediterranean continental pre - mountainous climate, make this region very appropriate for it's cultivation. The area and production of potatoes in the last two years are shown in table no.1. Some potato cultivars are planted such as Fabula, Lucinda, Rashida, Canela, Jelly, Safari, Arizona and Agria. The largest planted area is occupied by the Fabula cultivar in 40% of the area. In recent years, Korca farmers which cultivate potatoes, among other problems, have faced a harmful pest such as the potato tuber moth (*Phthorimaea operculella*). This pest has been present but with a weak impact on production, in the coastal area of Albania. As for Korca region, this pest has not been known. The first signs of this pest appeared in 2018, causing minor damage. After this year the damages have been very serious. In 2019, about 400 ha were not been harvested because all potato yield was completely damaged. However, infested tubers may reduce marketability, and damage can be distinctive in storage, especially in non-refrigerated systems [2]. Moreover, P. operculella is responsible for about 20 – 30% infestation in the field, and 100% under storage. [3]. Concluded that the thicker periderm thickness of tubers was responsible to slowdown the penetration of larvae inside tubers. [4], [5] have indicated that the tuber flesh firmness negatively affects larval developmental.

The situation created in the field increased our attention to conduct a study on the life biology of this pest for the Korca region, mainly for the developmental stages of the pest during the vegetative period, to enable the control of this pest.

Table 1. Area and yield of potatoes in 2019 and 2020 in the Korca region

Name	Years 2019	2020
Surface (Ha)	1660	1370
Yield (Ton)	50 090	43 919

Phthorimaea operculella. *Zelta*, Order: *lepidoptera*, Family: *Gelechidae*, the pest originates from North America. The potato tuber moth, *Phthorimaea operculella* (*Lepidoptera*: *Gelechiidae*), is a cosmopolitan pest, distributed among tropical and subtropical countries in South, Central, and North America, Oceania, Africa, Australia, Europe, and Asia. [6], [7]. It is a highly adaptable insect, found in locations with very different climatic conditions [8]. It is very widespread in all Mediterranean countries. It was brought to our country with potato seeds in 1948 in Fier, Vlora, Durres, Elbasan and Lushnja. The larva infects the tail, leaves and tubers. After the plant withers the pest enters the tuber and begins to make galleries. Damage continues even in storage, damaging 30 – 70 – 100% of production. [9] studied potato lines, some of which exhibit promising results for controlling mines and number of larvae in potato tubers. She confirmed that tubers of the transgenic clone Spunta G2 were resistant to *P. operculella* damage. Spunta G2 was developed in the early 2000. Potatoes lose their commercial value and have an unpleasant smell. *Phthorimaea operculella* is an oligophagous pest (i.e., an insect feeding on a restricted range of food plants) of vegetable crops that belongs mainly to the family *Solanaceae*. Potato (*Solanum tuberosum L.*), tomato (Lycopersicon esculentum Mill.), and tobacco (*Nicotana tabacum L.*) are principal hosts; however, the pest also attacks eggplant (*Solanum melongena L.*), bell pepper (*Capsium annuum L.*), Cape gooseberry (*Physalis peruviana L.*), aubergine (*S. melongena L.*), and sugar beet (*Beta vulgaris L.*) of the family *Chenopodiaceae*. Further, wild species of the Solanaceae family, including important weeds (e.g., black night shade, *Solanum nigrum L.*), are reported hosts. In total, the host range comprises 60 species. [10].

Adult insect is a moth, 8 mm, with open wings 12 - 15 mm, gray-silver. Females with closed wings form the letter X on the front of the first wings. The front wings are gray, narrow with dark spots on the back. The back wings are smaller, yellow – violet in color. The size of the pest with open wings is 12 - 15 mm. However, recent studies have shown that they can fly for over 5 hours or up to 10 km nonstop indicated that *P. operculella* cannot fly at wind speeds in excess of about 5 – 6 m/s. Adults can live for 1 – 2 weeks. Adults are normally inactive during the day and oviposition occurs at night [11]. The eggs are smooth, oval, white and before hatching they turn yellow – brown in color. For instance, [12] indicated that in the field, females laid eggs singly and rarely in groups of 3 – 5 eggs on either side of the leaf but close to the mid-rib.

Incubation period could range from 5 to 34 days. [13] reported 36°C as the upper critical temperature at which no eggs were laid.

The caterpillar is white - yellow with green shades. Dark brown chitinous head. Length 10 - 12 mm. Pupa is 9 - 10 mm length, in yellow color then later gradually turns brown wrapped in a gray - silver blister. Size 9-10 mm. [14], reported 15–17 days for the larval period; [15] reported 13–33 days, and [16] reported 14 days. Larval density in foliage and tubers is higher at the margins of the field than in the center, a typical characteristic of pests that move from nearby areas. The longer tubers are left in the field after desiccation, the greater the likelihood of tuber infestation. The pupa develops for 10-30 days. [17], reported 6–9 days as

pupal period; [18] reported 13–33 days; and [19] observed 14–17 days. Studies in the western USA indicated that P. operculella adults can potentially emerge from soil at depths up to 10 cm. Once adults emerge, mating occurs, and within a few hours, females seek a potential host to lay their eggs. 24 hours after hatching, the female moth is paired and after 3 - 6 days lays eggs, on the back of the leaf, near the buds, potato cracks or on other materials in storage. The female lays 150-200 eggs in 4 days, at the dusk. [20] determined the average fecundity of females ranged from 45.3 eggs (at 16°C to 117.3 eggs (at 28°C); net reproductive rate (R0) ranged from 12.8 (at 16°C) to 43.2 (at 28°C); and mean generation time (T) decreased with increasing temperatures from 61.0 days (at 16°C) to 16.2 days (at 32°C). The life of moths lasts 7 - 14 days. Eggs are laid either one by one or in groups. After 3 - 10 days the larvae hatch. The larvae first feed on the parenchyma of the leaves, then enter in the tail and finally in the stalk, where they make galleries towards the ground. Near 55% of the mines are found in the upper third of the potato plants. The caterpillar developed inside a bladder laid in the ground for wintering. The caterpillar causes the greatest damage to the potato tubers both in the field and in the storage. The larval period lasts 5-16 days. The developed caterpillar passes into the ground or between dried leaves, for wintering inside a bladder. [21] reported 6 – 8 generations a year in tropical regions; [22] French reported 2 generations in Australia, first in the winter and the second one on stored tubers; [23] Graft, [24], [25] reported 3 – 4 generations in Chile and the southern USA; [26] reported 13 generations per year in India, and [27] reported 12 generations in Iraq.

Recently, pheromone trapping in Bologna, Italy, where researchers integrated temperature dependent developmental time models, showed that P. operculella completed two generations throughout the potato-growing season; the remaining generations developed in the noncrop season. This information suggests a correlation between geographical location, presence or absence of food source, and P. operculella generations per year. [28] determined that the lower temperature threshold and thermal constant of immature stage were estimated to be 11.6°C and 338.5 degree days. A degree day is a measurement of heat units over time calculated from daily maximum and minimum temperatures; California recommends a threshold of 15 – 20 moths per trap per night as a general threshold level and 8 moths per trap per night for Oregon. In sandy soils of Israel, pheromone traps caught almost twice as many moths than in loess fields. Foliar damage does not usually result in significant yield losses. Indicated that yield loss in storage could be up to 100% where no temperature and/or humidity control is possible. [29- 31] researches have shown that irrigating daily with 0.25 cm through a center irrigation system decreased P. operculella tuber damage. Since water closes soil cracks, reducing tuber access, P. operculella possibly perish from lack of oxygen in the soil. Chemical management of P. operculella is challenging because of the cryptic behavior of larvae and because this insect has developed resistance to many traditional organophosphate, carbamate, and pyrethroid insecticides [32].

Pest management practices are effective in controlling P. operculella but the effectiveness depends on the response time to pest infestation, resources available, and pest management practitioner experience [33].

2. MATERIALS AND METHODS

The pest was monitored on a farm in the village of Drithas, in three potato cultivars; Fabula, Lucinda, Rashida. The three cultivars were located about 500 m away from each other, with an area of 20 ha, 11 ha and 6 ha, respectively. Planting was carried out with potato planting machine at distances 75 cm - 30 cm in 10-12 cm depth. An average of 25 kv/ha of seed potatoes was used. Plantings were carried out from April 6 to 10. Potato seeds were not germinated in advance. All three plots of the experiment were previously planted with wheat. The soil composition was light sandy loam soils. Potato germination took place on May 11 - 15. Yield harvesting took place on September 15 until October 10. Throughout the vegetation, 9 rain irrigations were carried out, every 10 days, using an average of 300 - 350 m3/ha, water. Were carry out 5 chemical treatments with insecticides as Movento, Dursban, Minecto alpha, Abamectine. Econex pheromone traps were used to

monitor the adult moth. Sexual pheromones are species- specific and highly selective, and since they are not toxic and do not represent health risks to humans and animals, they are valuable tools in integrated pest control management. [34] Pheromones were placed in three pieces for each cultivar, before the start of the first generation, after June 15th. The pheromones were placed at a distance of 15 - 20 meters from each other, at a height of 0, at 30 cm and at 60 cm from the ground. The traps were activated after the pheromone diffuser was placed in the trap. Three pheromone traps were used for each generation and for each cultivar. Captured male adult moths were counted every two days. The pheromone diffuser lasts 40 days in field conditions.

Four days after the appearance of the first adult moth, a check was made for laying eggs under the middle leaves of the potato plant. After finding the eggs, the plants were labeled and the leaf together with 2 - 3 other different leaves was inserted inside a transparent experimental cloth. Thus, inside the transparent experimental cloth was carried out the monitoring of larval hatching, their development and the formation of pupae. Relevant records were kept for each stage of moth development and for each generation.

3. RESULTS AND DISCUSSIONS

The months of June, July, August and September for Korca region, have average temperatures above 10°C, which are also considered as normal temperatures for the development of potato moth [35]. While the amount of precipitation in these months is at the lowest levels of the year, the data recorded are presented in table 2.

Table 2. Average monthly temperatures and precipitation years 2019 and 2020 in the Korca region

Climatic factors	May	June	July	August	September
Average monthly temperatures (°C)	8	18	21	22	16.5
Precipitation (mm)	99	25	18	10	51

Table 3. Average of moths caught according to cultivars and trap height for 2019 and 2020

Nr	Cultivars	By months			
		June	July	August	September
1	Fabula	112	153	192	218
2	Lucinda	109	157	197	221
3	Rashida	108	155	196	214
	Levels				
1	Level 0 cm	45	86	140	166
2	30 cm	86	129	161	184
3	60 cm	198	250	284	303

The number of moths captured at the pheromone traps increases for each generation, reaching a maximum in the third generation. Even the maximum number of moths caught by pheromone traps is at a height of 60 cm from the ground, the data are shown in table number 3.

Table 4. Dates of beginning of each development phase per months and years

Years	Development phase	By months			
		June	July	August	September
2019	Pupa	-	11	10	7
	Moth	21	22	20	21
	Egg	24	25	23	25
	Larvae	29	29	26	29
2020	Pupa	-	9	8	8
	Moth	20	20	21	22
	Egg	24	23	24	25

	Larvae	28	26	28	29

From table no.4 we see that the appearance of the first moths occurred after June 20. While the hatching of the first larvae occurred almost at the end of each summer month. The table does not show even a fifth generation after the potato production harvest, but this generation has developed into other cultivated vegetation, spontaneously or developed in storage.

Table 5. The number of days per each development phase that potato tuber moth passes

Development phase	**Egg**	**Larvae**	**Pupa**	**Imago**
Number of days	4 - 5	11 - 14	7 - 15	8 - 14

Table 5 shows that the development of full generation requires from 30 to 38 days, depending on climatic conditions

Table 6. Comparative results for cultivars and pheromone traps placement height

FACTOR	**June**	**July**	**August**	**September**
Cultivar				
Fabula	112 a	153 a	192 a	218 a
Lucinda	109 a	157 a	197 a	221 a
Rashida	108 a	155 a	196 a	214 a
Level above ground				
Level 0 cm	45 a	86 a	140 a	166 a
30 cm	86 ab	129 ab	161 ab	184 ab
60 cm	198 b	250 b	284 b	303 b

Referring to the Tukey test for $\alpha = 0.05$, the results with the same letter do not represent statistically proven differences. While the results with different letters show statistically proven differences. Many studies show that some cultivars present higher resistance than some other cultivars. But in our case the difference between the three cultivars putted to the test does not represent statistically proven differences.

4. CONCLUSIONS

- The pest in Korca region, for the period of potato vegetation has four generations;
- The number of days for a generation varies from 30 to 38 days;
- There are no statistically proven differences between the three cultivars tested for $\alpha = 0.05$;
- For the number of moths captured by pheromones at different levels, there are statistically proven differences. The highest number of captured moths results in the level at 60 cm height and the lowest number of captured butterflies results in pheromones located at level 0;
- Pest management practices, such as soil moisture and good potato cover with soil, can keep the pest under control;
- In areas where the pest is widespread, potatoes should be planted deep below 10 cm and stuffed during hoeing process;
- For planting, it is effective to use resistant cultivars and clean seed;
- Elimination of weeds;
- After harvesting the potatoes, the production should not be left in the field because in the evening adult moths flies and lay eggs on the harvested yield.

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