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Araştırma Makalesi/Research Article

The Body Growth Rates on Different Foods and the Relationship between Egg-Body Sizes of Phthorimaea operculella (Zeller, 1873) (Lepidoptera: Gelechiidae)

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Abstract: The study investigated the impact of larval food on body growth in mature and immature stages of *Phthorimaea operculella* (Zeller, 1873) (Lepidoptera: Gelechiidae).To this end, eggplant, potato and tomato plants were used as well as potato tuber as larval food. With regards to larval weight, the highest larval body growth index (LBGI) between the first-second larval stages was observed at the larvae fed on potato plants by the rate of 5.00, but the highest LBGI between the second-third larval stages was seen at the larvae fed on potato tubers with 4.28 increase rates. Between the third-fourth larval stages, potato tuber caused the least increase in terms of growth indexes calculated on larval length and weight (0.26 and 0.84, respectively). Also, potato tuber showed the highest impact on pupal size and weight. It was seen that wingspan and length of the adults that fed on potato tuber during the larval stage were the longest. Additionally, eggs (0.17 mm²) laid by the adults that fed on potato tuber during the larval stage were the largest. Consequently, larval food had an important role on body growth in both of immature and mature stages of *P. operculella*. Also, both of pupal weight (R^2=0.48) and adult length (R^2=0.12) had a weak relationship with egg size. Therefore, it was understood that the selection of large individuals during mass production of the pest was not so important to increase the prospects of mass production.

Keywords: Eggplant, Correlation, Food, Tomato, The potato tuber moth

Phthorimaea operculella (Zeller, 1873) (Lepidoptera: Gelechiidae)'nın Farklı Besinlerdeki Vücut Gelişme Oranları ve Yumurta İle Vücut Büyüklüğü Arasındaki İlişki

Özet: Çalışmada, *Phthorimaea operculella* (Zeller, 1873) (Lepidoptera: Gelechiidae)'nın ergin ve ergin öncesi dönemlerinin vücut gelişimi üzerine farklı larva besinlerinin etkileri araştırılmıştır. Denemede, domates bitkisi, patates bitkisi, patlıcan bitkisi ve patates yumrusu olmak üzere dört farklı besin çeşidi kullanılmıştır. Birinci ve ikinci larva dönemleri arasında, larva ağırlığı bakımından en yüksek artış indeksi (5,00) patates bitkisinde beslenen larvalarda görülmüştür. Bu bireylerin ikinci ve üçüncü larva dönemleri arasında ise, gösterdiği larva ağırlık artış indeksi (4,28) bakımından, en yüksek artışa neden olan besin patates yumrusu olmuştur. Üçüncü ve dördüncü larva dönemleri arasında, larva boyunun (0,26) ve ağırlığının (0,84) artış indeksleri bakımından patates yumrusu en az artışa neden olan besin olmuştur. Pupa büyüklüğü ve ağırlığı bakımından da, en yüksek etki gösteren besinin patates yumrusu olduğu belirlenmiştir. Ergin bireylerin kanat açıklığının ve boyunun, larva döneminde patates yumrusu ile beslenen bireylerde, en uzun olduğu görülmüştür. Ayrıca, larva döneminde patates yumrusu ile beslenen ergin bireylerin bıraktıkları yumurtalar (0,17 mm²), diğer besinlerle beslenen ergin bireylerin bıraktıkları yumurtalara göre en iri yumurtalar olmuştur. Sonuç olarak, larva döneminde kullanılan besinin, *P. operculella*'nın hem ergin öncesi hem de ergin döneminde vücut gelişimi üzerine etkili olduğu belirlenmiştir. Ayrıca, pupa ağırlığının (R^2=0,48) ve ergin boyunun (R^2=0,12) yumurta büyüklüğü ile önemli seviyede bir ilişkisinin olmadığı saptanmıştır. Bu nedenle, zararlının kitle üretimi yapılırken iri bireylerin seçilmesinin üretim kalitesi açısından çok önemli olmadığı anlaşılmıştır.

Anahtar kelimeler: Patlıcan, Korelasyon,Besin, Domates, Patates güvesi

Introduction

The potato tuber moth, *Phthorimaea operculella* (Zeller, 1873) (Lepidoptera: Gelechiidae) has ca. 60 host plants particularly potato (*Solanum tuberosum*), including eggplant *(Solanum melongena),* tobacco *(Nicotina tobaccum),* tomato *(Lycopersicon esculentum),* pepper *(Capsicum spp.)* (Avidov and Harpaz, 1969, Alvarez et al., 2005). The pest can also feed on host plants from Scrophulariaceae, Boraginaceae, Rosaceae, Typhaceae, Compositae, Amaranthaceae, and Chenopodiaceae families as well as those from Solanaceae family (Das and Raman, 1992).

Eggs, larvae and pupae of *P. operculella* are present on host plants or in the soil after crop harvest. Larvae of the pest feed on leaves, petioles, stems and tubers of host plants in crop field and store (Zümreoğlu, 1987; Çalışkaner et al., 1989). A study of Zümreoğlu (1987) stated that *P. operculella* causes damage to leaves and stem of tobacco by carving, and forms the most important harmful on leaves of tobacco plant. Insects do not make a host-selection based on only odors and tastes of plants. At the same time, nutritional value of host plants is also highly effective on the selection (Kansu and Has, 1987). Herbivore insects deposit their eggs to host plants and parts thereof, whereon their offspring can develop successfully (Pehlivan, 1981, Renwick, 1989, Birgücü et al., 2014). Again according to statements by Kansu and Has (1987), various foods of insects have significantly different effects on their body development. Host plant quality in the larval stage of herbivore insects is an important factor in determining to have a healthy morphological structure.

Moreau et al. (2007) researched the effect of host plant in the larval stage of Lobesia botrana Den. & Schiff. (Lepidoptera: Tortricidae) on reproductive success. This study related to L. botrana demonstrated that foods consumed in the larval stage impacted in a different way on the mating successes and reproductive efficiencies of male and female adults. Weights of pupae obtained from larvae of L. botrana fed on different grape cultivars were also showed significant differences. In addition, it was stated that food consumed in the larval stage had an impact on egg efficiency, egg size and hatching success (Moreau et al., 2007).On the other hand, it was found out that there was also a direct correlation

between egg size and hatching success (Moreau et al., 2006).

A study of Fenemore (1977) indicated that there was no statistically significant relation among fecundity, pupal weight and adult lifespan of P. operculella. However, a positive correlation between the number of mature eggs in the ovaries immediately after emergence of adult female and pupal weight was asserted. Besides, it was determined that eggs laid by females after feeding and mating were more in number and better developed than these mature eggs in the ovaries (Fenemore, 1977). Therefore, it was also stated in the study that there might be significant effects of food consumed in the adult stage on the fertility. Apart from that, a study investigated the effect of pupal weight and adult food on egg-laying of P. operculella by Fenemore (1979) indicated that there was a positive correlation between pupal weight and fecundity, and host plant difference influenced selection of oviposition site and number of eggs laid by female. Nevertheless, Fenemore (1980) suggested that morphological features of host plants which could form physical barrier were decisive as priority in oviposition site preference of P. operculella adult females.

Determination of food preference in the larval stage of pests is an important topic to find a cost-effective and environmentally suitable solution to the problems encountered in the control of herbivore insects. This study investigated how host plant difference in the larval stage could affect body growth in immature and mature stages of P. operculella. Additionally, correlation and regression analyses were performed between pupal weight, adult length and egg size of individuals fed on different larval foods. For this purpose, It was examined the impact of eggplant, potato and tomato plants from Solanaceae family on larval weight and length, pupal weight and size, adult length and wingspan, and size of eggs laid by adult female.

Materials and Methods

Maintenance of plants and insect

Tomato (Solanum lycopersicum L.) (var. İskender F1) and eggplant (Solanum melongena L.) (var. Phaselis F1) seedlings, and potato (Solanum tuberosum L.) (var. Agria) tuber were sown in 1.5 l plastic pots containing a mixture of soil and peat (1:1v/v). Potato tubers contaminated with larvae of Phthorimaea operculella (Zeller, 1873)

(Lepidoptera: Gelechiidae) collected from a potato field made harvest were brought to laboratory within a culture plate. These contaminated potato tubers were placed on clean potato tubers in a 28×37.2×7.5 cm sizes pot, at the base of which positioned blotting paper, in a 30x50x60 cm sizes plexiglass cage, of which the upper and lateral sides covered by net, in order to increase pest population and ensure the continuity of the insect stock culture. Daily maintenance and control for the plant and insect stock culture were achieved regularly, and food supplement for the insect stock culture and irrigation for the plants were made if deemed necessary. No fertilizer and chemical control was performed against any pest or disease during plant production.

The production of P. operculella and all experiments were conducted in a climate room with 26±1ºC temperature, 60±5% relative humidity and darkness conditions. Plant production was also carried out in a climate room at the same temperature and relative humidity conditions; however, lighting regime was set to be 16 hours of light, followed by 8 hours of darkness.

Establishment of experiments on the larval and pupal stages

Peeled potato slices of 1 mm thickness and leafy twig parts in ca. 3 cm length of potato, tomato and eggplant plants were used as larval food in the experiment. These cutting leafy twig parts of plants were placed into 1.5 ml Eppendorf tubes containing distilled water to prevent drying of them in a short time. Ten eggs obtained from the stock insect culture were gently put by the tip of a fine paintbrush on the food in the culture plate with a dimension of 5x8x12 cm, at the base of which positioned blotting paper. Subsequently, length, weight and head capsule width of the first instar larvae hatched from these eggs were measured. During daily care of the experiment, food and water were added in the culture plate if deemed necessary. These measurements were performed only once for each of four larval stages of the pest, two days after molting. Additionally, measurements of width, length and weight of pupae pupated from these larvae were done, too.

Establishment of experiments on the adult and egg stages

Potato tuber were put into a 5×8×12 cm sizes plastic culture plate, at the base

of which disposed blotting paper, and upper side of this culture plate was closed by a net. As for tomato, eggplant and potato plants used as food, a round Styrofoam (ca. 22 cm diameter), in the middle of which existed a hole (ca. 1.5 cm diameter), was cut into two parts, and placed on the pot, so that stem of the plant passed through the hole in the middle of the Styrofoam. Afterwards, the above-ground part of the plant in the pot was closed by a 20 cm diameter and 30 cm height lightweight, transparent, and cylinder plastic container. There were three holes in ca. 3 cm diameter closed by net on the side surface of this container to allow air circulation.

Pupae, of which measurements were made, were put in these contrivances to be separately for each food type to obtain adult moths, and adult emergence was observed. Width and length measurements of eggs deposited by mated adult moths were done in millimeters. Later, length and wingspan measurements of these adults were performed.

Statistical evaluation

The experiment related to larval stage was replicated 6 times, including separately for each food type, and 10 larvae were used for each replication. The experiments related to pupal, adult and egg stages were performed on 60 individuals, assuming that each individual was a repetition. All experiments were arranged according to a completely randomized experimental design.

Larval body growth indexes between sequential larval stages "$LBGI=[(L_{(n+1)}-L_n)/L_n]$" were calculated on the length, head capsule width and weight measurements made in each larval stage. Where "L_n and $L_{(n+1)}$" are the average values measured in sequential larval stages. Additionally, sizes of pupae, and ellipsoidal eggs laid by adult moths were computed by multiplying width and length measurements of them.

To analyze the data, Tukey's HSD multiple range test (Tukey, 1949) ($P\leq0.05$) was applied after One-Way ANOVA and also, correlation and regression analyses ($P\leq0.01$) were performed to determine the relationship between pupal weight, adult length and egg size of P. operculella individuals fed on different larval foods. For statistical analyses, IBM® SPSS® Statistics (Version 20.0, August 2011, IBM Corp., Armonk, NY, USA.) and Microsoft® Excel 2010 package programs were used.

Results and Discussion

Larval body growth indexes between sequential larval stages of the pest were given in Table 1.

Length increase index between the first and second larval stages of Phthorimaea operculella was observed the most at the larvae fed on eggplant leafy twig, and the lowest length increase index between these larval stages of the pest was seen at the larvae fed on peeled potato slice. The differences between the larvae fed on tomato, potato and eggplant leafy twigs in terms of larval length were not found statistically significant; however, the larvae fed on peeled potato slice were located in a different statistical group. While the highest increase index with regard to head capsule width was at the larvae fed on eggplant leafy twig, the lowest increase index of head capsule width was seen at the larvae fed on peeled potato slice. As for larval weight, the highest increase index was at the larvae fed on potato leafy twig, the lowest increase index was also at the larvae fed on peeled potato slice (Table 1).

Increase indexes of larval length and head capsule width of these individuals between the second and third larval stages showed no statistically significant difference. Potato tuber caused the highest increase as a larval food in point of larval weight (Table 1).

Between the third and fourth larval stages, potato tuber was the larval food caused the lowest increase in recognition of increase indexes of larval length and weight, but potato plant was the larval food caused the highest increase and also, it was located in the same statistical group with tomato plant in respect to head capsule width, too (Table 1).

Size of P. operculella pupae computed by multiplying width and length measurements was seen the highest at the pupae pupated from larvae fed on peeled potato slice. Potato tuber was followed by eggplant leafy twig with regard to the impact of food differences on pupal size and both food types were included in the same statistical group. The food showed the highest effect in terms of pupal weight became potato tuber, and it was in the same statistical group with eggplant leafy twig (Table2).

Table 1. Larval body growth indexes between sequential larval stages of *Phthorimaea operculella* individuals fed on different larval foods*

Larval stage intervals	Foods	Larval length	Head capsule width	Larval weight
Growth indexes between the I. and II. larval stages	Tomato plant	1.83±0.29 a (1.13-2.68)	1.00±0.11 b (0.78-1.33)	4.97±1.27 a (0.97-7.20)
	Potato plant	2.07±0.12 a (1.72-2.40)	1.14±0.08 b (0.96-1.37)	5.00±0.17 a (4.47-5.31)
	Eggplant plant	2.37±0.14 a (1.86-2.72)	1.60±0.10 a (1.27-1.80)	3.11±0.29 ab (2.28-3.94)
	Potato tuber	0.38±0.19 b (0.04-1.11)	0.22±0.16 c (0.27-0.79)	0.73±0.37 b (0.15-1.93)
Growth indexes between the II. and III. larval stages	Tomato plant	0.57±0.16 a (0.24-1.06)	0.61±0.09 a (0.32-0.79)	2.71±0.48 ab (1.53-4.12)
	Potato plant	0.52±0.06 a (0.41-0.71)	0.43±0.08 a (0.24-0.69)	2.16±0.13 b (1.74-2.38)
	Eggplant plant	0.54±0.09 a (0.26-0.79)	0.45±0.06 a (0.28-0.65)	2.73±0.34 ab (1.77-3.89)
	Potato tuber	0.53±0.11 a (0.26-0.97)	0.46±0.12 a (0.14-1.00)	4.28±0.53 a (2.21-6.13)
Growth indexes between the III. and IV. larval stages	Tomato plant	0.62±0.09 a (0.41-0.88)	0.44±0.03 a (0.36-0.50)	1.75±0.13 a (1.39-2.12)
	Potato plant	0.63±0.04 a (0.50-0.73)	0.53±0.06 a (0.36-0.68)	2.10±0.07 a (1.87-2.26)
	Eggplant plant	0.49±0.04 a (0.28-0.57)	0.21±0.04 b (0.03-0.30)	2.04±0.26 a (0.92-2.79)
	Potato tuber	0.26±0.04 b (0.13-0.36)	0.10±0.03 b (0.01-0.21)	0.84±0.19 b (0.43-1.67)

*The means (±standard error) followed by the same letters within the same column for each larval stage interval do not differ significantly according to a Tukey's HSD test ($p \leq 0.05$, total 60 larvae for each larval food; $F_{length\_I\text{-}II}= 20.409$; df= 3, 20; P= 0.000; $F_{capsule\_I\text{-}II}= 25.415$; df= 3, 20; P= 0.000; $F_{weight\_I\text{-}II}= 8.748$; df= 3, 20; P= 0.001; $F_{length\_II\text{-}III}= 0.042$; df= 3, 20; P= 0.988; $F_{capsule\_II\text{-}III}= 0.756$; df= 3, 20; P= 0.532; $F_{weight\_II\text{-}III}= 5.152$; df= 3, 20; P= 0.008; $F_{length\_III\text{-}IV}= 9.215$; df= 3, 20; P= 0.000; $F_{capsule\_III\text{-}IV}= 24.775$; df= 3, 20; P= 0.000; $F_{weight\_III\text{-}IV}= 10.928$; df= 3, 20; P= 0.000).

Wingspan and body length of adult moths were the highest at the moths fed on peeled potato slice in the larval stages. As for the lowest wingspan and body length values, they were measured at the moths fed on tomato leafy twig in the larval stages (Table2).

Table 2. Pupal size, pupal weight, adult wingspan, adult length and egg size of *Phthorimaea operculella* individuals reared on different larval foods*

Foods	Pupal size (mm²)	Pupal weight (mg)	Adult wingspan (mm)	Adult length (mm)	Egg size (mm²)
Tomato plant	9.98±0.27 c (5.25-13.66)	5.85±0.17 c (3.00-8.00)	12.21±0.11 d (10.65-13.26)	6.17±0.07 c (5.02-6.95)	0.09±0.00 d (0.08-0.10)
Potato plant	11.85±0.19 b (7.69-14.03)	8.47±0.11 b (6.50-9.60)	14.00±0.07 c (12.76-14.94)	7.22±0.04 c (6.21-7.63)	0.11±0.00 c (0.10-0.16)
Eggplant plant	12.94±0.14 a (9.79-15.18)	10.52±0.10 a (8.90-12.00)	13.49±0.13 b (11.05-15.92)	6.37±0.11 b (4.20-7.51)	0.16±0.00 b (0.12-0.20)
Potato tuber	13.60±0.20 a (10.25-16.80)	10.60±0.25 a (6.30-15.40)	16.16±0.09 a (14.26-17.80)	8.00±0.06 a (6.63-8.99)	0.17±0.00 a (0.13-0.21)

*The means (±standard error) followed by the same letters within the same column do not differ significantly according to a Tukey test ($p \leq 0.05$; F_{pupal_size}= 60.336; df= 3, 236; P= 0.000; F_{pupal_weight}= 179.806; df= 3, 236; P= 0.000; $F_{wingspan}$= 258.125; df= 3, 236; P= 0.000; F_{adult_length}= 129.911; df= 3, 236; P= 0.000; F_{egg_size}= 300.014; df= 3, 236; P= 0.000).

As regards egg size calculated by multiplying width and length measurements of ellipsoidal eggs laid by mated adult moths, the largest egg size was determined at the eggs laid by adult moths that fed on peeled potato slice in the larval stage. Potato tuber was followed by eggplant and potato plants in respect to the effect of food difference on egg size. The smallest eggs were laid by adult moths that fed on tomato leafy twig in the larval stage. The differences between of the impacts of these larval foods were no statistically significant (Table 2).

Fischer et al. (2002) announced that the correlation between egg-body sizes of Bicyclus anynana Butler (Lepidoptera: Nymphalidae) was no significant. However, there was too much diversity among sizes of eggs laid and body sizes of adult moths were so different. Besides, Raguso et al. (2007) stated that feeding of Manduca sexta L. (Lepidoptera: Sphingidae) larvae influenced feeding behavior in the adult stage as well as the emergence time and size of adult moths. It has been demonstrated in several studies that adult feeding had an impact on fecundity rate (Fenemore, 1979; Hainsworth et al., 1991; Boggs and Ross, 1993; Boggs, 1997). In this case, it is a very realistic approach to think that larval feeding can also affect fecundity rate of adults. As for this present study, although both of larval length and weight showed no significant differences due to use of different foods in the larval stages, egg sizes of adults obtained from these larvae on different foods were statistically

different. Based on the data related to pupal weight and size, it was seen that effects of larval foods were significantly different. Considering these data, the larvae fed on tomato leafy twig had more water content. Therefore, they lost more water than other larvae fed on different foods while shading of into pupa, and thus, their weight were least than those of both the larvae fed on potato plant and the larvae fed on potato tuber. In parallel with this result, wingspan and length measurements were higher at the adults that fed on potato tuber during the larval stage. Also, it was determined that eggs laid by these adults were larger on average than others. However, in such a manner of the results of the study conducted by Fischer et al. (2002) to explain the relation between sizes of egg and body in butterflies by taking *B. anynana* as a model moth, it was understood that the correlations among weights of the pupae obtained from all larval groups fed on different foods and length of the adults emerged from these pupae, and size of eggs laid by these adults were no significant (Figure 1).

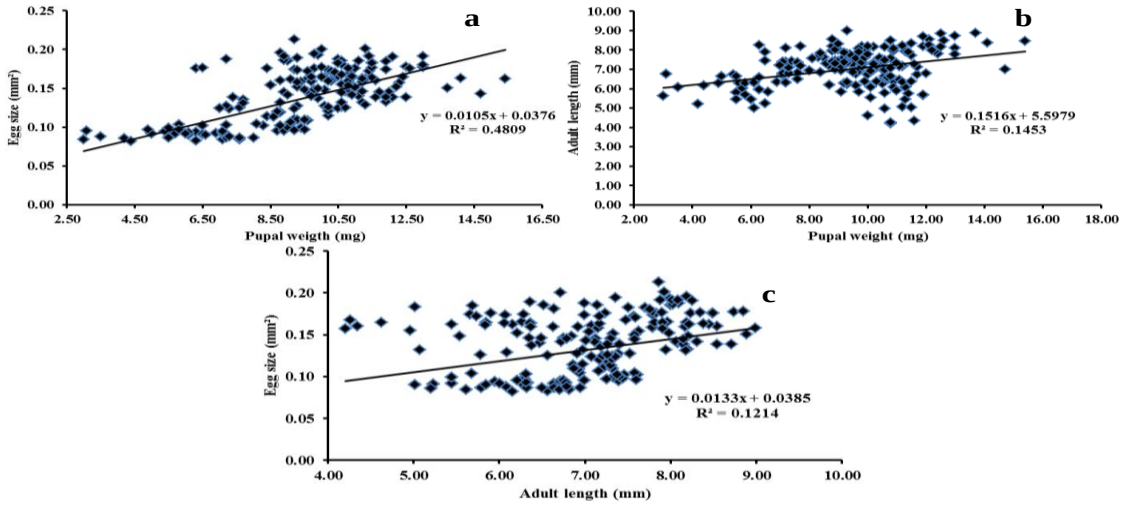

Figure 1. The correlations (n= 240, P≤0.01) among a) pupal weight-egg size, b) pupal weight-adult length, and c) adult length-egg size of *Phthorimaea operculella.*

Conclusions

The data obtained from the study demonstrated that length, head capsule width and weight of *P. operculella larvae* increased the least when rearing on potato tuber. It was thought that the body growth and weight increase indexes of these larvae were less than those of other larval groups, because thin potato slices cut from peeled potato tuber contain least amount of water and also, water content of them deplete more quickly when

compared with leafy twigs of all plants used as larval food in the experiment.

As regards the results obtained from length and weight measurements in the pupal stage, in contrast to measurements made in the larval stage, the increments of pupal size and weight were observed as the least at the pupae pupated from larvae fed on tomato leafy twig and the highest at the pupae pupated from larvae fed on peeled potato slice. Meanwhile, wingspan and length values in the adult stage were measured the least at the adults that fed on tomato leafy twig during the larval stage and the highest at the adults that fed on peeled potato slice during the larval stage.

Also in measurements made on eggs of the pest, the largest eggs were obtained from the adults that fed on peeled potato slice, and any significant correlation was not detected among pupal weight, adult length and egg size (Figure 1). During mass production of the pest, potato tuber is generally used as larval food (Maharjan and Jung, 2011). At the results of this study, it was understood that leafy twig parts of potato, tomato and eggplant plants could also be used as larval food if potato tuber is not exist or appropriate for experimental design. Additionally, it was concluded that the selection of large individuals of the pest was not so important in terms of mass production.

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