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Life Tables of the Olive Leaf Moth, *Palpita unionalis* (Hübner) (Lepidoptera: Pyralidae), on Different Host Plants

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ABSTRACT

The olive leaf moth, *Palpita unionalis* (Hübner), is an important pest on olives, and also feeds on other host plants from the Oleaceae family. In this study, the development, survival and reproduction of *P. unionalis* were evaluated in the laboratory at 25°C and photoperiod of L:D = 16:8 on three host plants: olive (*Olea europea* L., cv. Gemlik), ash (*Fraxinus angustifolia* Vahl.) and jasmine (*Jasminum fruticans* L.). Olive leaf moth larvae survived on all three host plants. The developmental time of immature stages ranged from 27.52 days on ash leaves to 30.00 days on olive leaves. Immature survival from egg to pupa was 72% on jasmine, 73% on olive and 74% on ash. The average number of eggs oviposited by adults from larvae reared on ash, jasmine and olive were 194.7, 321.8 and 390.3, respectively. The net reproductive rate of this species varied from 129.8 females/female on ash to 298.3 on olive. The intrinsic rate of population increase on ash, jasmine and olive was 0.148, 0.149 and 0.163 females/female/day, respectively. *Palpita unionalis* can complete its life cycle on all host plants, but ash was relatively less suitable because of the lower reproductive rate of the insects reared on it.

Keywords: *Palpita unionalis*; olive; ash; jasmine; life tables.

INTRODUCTION

The olive leaf moth *Palpita unionalis* (Hübner) is widespread in the tropical and mildly subtropical regions of the Old World. It originated in the Mediterranean region, where it is found from east to west, and south to the olive-growing regions of northern Africa, the Canary Islands and Madeira. Its distribution further extends to western and southern Africa, western and southern Asia, Japan, Australia and tropical America (Tzanakakis 2003).

The species is a serious pest on Oleaceae of the genera *Jasminum*, *Ligustrum*, *Oleae, Fraxinus* and *Phillyrea* (Tzanakakis 2003; Athanassiou et al 2004). In olive plantations, the moth generally has moderate population density; however, periodic outbreaks occur, causing severe damage to olive trees and nurseries (Kovancı and Kumral 2004; Kovancı et al 2006). Larvae attack tender leaves, particularly those of terminal twigs. Newly hatched larvae usually feed on the parenchyma of the lower surface of the leaves, drying the upper epidermis, which becomes brown. In nurseries, larvae may devour young leaves and apical buds, causing stunted growth of plants (Athanassiou et al 2004). As in the other polyphagous moths, the availability of different host plants plays an important role in population increase and spread (Hunter and McNeil 1997; Liu et al 2004). The larvae of the first generation appear in ash and jasmine plantations in May-June, grow rapidly and then the second generation larvae appear in olive plantations in June-July (Tzanakakis 2003; Kovancı and Kumral 2004; Kovancı et al 2006).

Different host plants are known to affect insect development, survival, reproduction and life table parameters (Richard 1961; Varley and Gradwell 1970; Greenberg et al 2001; Hansen et al 2004; Liu et al 2004). In the case of the olive leaf moth, a considerable amount of work has been done on the effect of temperature on development time on young olive foliage (El-Kifl et al 1974; Badawi et al 1976; El-Khawas, 2000; Shehata et al 2003; Antonelli and Rossi 2004). However, few biological observations of P. unionalis on several host plants of the family Oleaceae such as olive, privet, jasmine and lilac have been published (Avidov and Rosen 1961; Vassilaina-Alexopoulou and Santorini 1973; Arambourg 1986). The data from these studies include laboratory observations on the development time and fecundity of the olive leaf moth on different host plants. However, there is no information about life table parameters for P. unionalis on all host plants. Demographic data could help assess the potential of population increase on olive, as well as other host plants found around olive groves. Furthermore, tables could help explain why P. unionalis outbreaks occur in olive groves of the Bursa region. Therefore, the objective of this study was to determine the effect of host plants such as olive, ash and jasmine on the development, survival, reproduction and life table parameters of the olive leaf moth in the laboratory.

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MATERIALS AND METHODS

Laboratory Colony of Olive Leaf Moths. A laboratory population of *P. unionalis* from field-collected larvae from olive orchards in Gundogdu, Bursa-Turkiye, (40.321°N, 29.036°E) was used in this study. This culture was kept in 18 x 3 x 6 cm plastic rearing cages and covered with fine muslin. Pupae were transferred separately into 2 x 8 cm cups covered with fine muslin. Each pair of male and female moths was introduced into a laying container (2 x 8 cm) containing olive, ash or jasmine leaves. Eggs laid on olive, ash and jasmine leaves were kept in environment-controlled growth chambers in the laboratory at a constant temperature of 25 ±1 °C, relative humidity of 65 ± 5%, and a photoperiod of 18L: 6D.

Host Plant Sources. The young foliage of three plants was used in this study: olive (*Olea europea* L., cv. Gemlik), ash tree (*Fraxinus angustifolia* Vahl.) and jasmine (*Jasminum fruticans* L.). All foliage used in this laboratory experiment was collected from plants growing under field conditions without the use of any pesticides and fertilizers.

Development and Survival of Immature Stages. Ten female and ten male pupae were collected from larvae reared on the 3 host plants. When adults emerged, moths were provided with 10% sucrose solution and allowed to mate for 1-2 days in containers (18 x 3 x 6 cm). Mated moths were transferred to laying containers (2 x 2 x 8 cm). In the above mentioned laboratory conditions, thirty eggs laid on the same day by each pair were observed to determine the hatching rate (%) and the number of larvae emerging. Newly emerged larvae (30 from each experimental host plant) were transferred individually into 28 ml clear plastic cups containing young olive, ash or jasmine foliage. Fresh foliage was provided as required, and larvae were observed daily through pupation and adult emergence. Individual insects were checked twice daily for development and survival. Larval period (days from first instar to prepupation), prepupal period (days from prepupation to pupation) and pupal period (days from pupation to adult emergence) were recorded. Only individuals that survived to the adult stage were included in the analysis.

Adult Longevity and Reproduction. Emergent moths from larvae reared on each host plant were allowed to mate for 1-2 days and then transferred to a laying container (one pair per container with 10 replicates) and supplied with 10% sucrose solution. After mating, adult mortality and the number of eggs deposited were recorded daily until the death of each adult.

The Intrinsic Rate of Population Increase. Experimental data on the development times of immature individuals and reproduction were combined to create life tables that were used to calculate demographic parameters for *P. unionalis*. For each experiment, the following demographic parameters, as defined by Gotelli (1998), were calculated: the net reproductive rate, R_o, which represents the number of female descendants from an average female in one generation, and the generation time, T, which is equivalent to the mean period between the birth of parents and the birth of offspring. The intrinsic rate of population increase (r_m) for *P. unionalis* reared on different host plants was calculated, using the equation given by Gotelli (1998):

$$\sum e^{-rmx} l_x m_x = 1$$

where x is the age (as days), l_x is the age-specific survival, and m_x is the average number of female offspring of a female at age x.

Data Analysis. Differences in development time and reproduction of *P. unionalis* reared on different host plants were analyzed with analysis of variance (ANOVA), and means were separated with the Least Significant Difference (LSD) test (JMP, 2001).

RESULTS

Development. Table 1 shows the duration of different immature stages and total development time of *P. unionalis* reared on olive, ash and jasmine leaves under long day lighting, a constant temperature of 25 ºC and relative humidity of 65%. There were significant differences in the development times of immature stages among the three host plants (Table 1, F= 12.67; P< 0.001). In the other hands, no significantly a difference was found among plant species in term of egg hatching. As seen in Table 1, the differences in the duration of total development were predominantly due to larvae fed on ash leaves (F= 22.91; P< 0.001).

Larvae fed on ash leaves developed approximately 2-3 days faster than those on olive and jasmine. On the other hand, there was no significant difference in total development time between larvae fed on olive (17.44 ± 0.33 days) and jasmine (16.65 ± 0.30 days).

Table 1. Developmental period (days) (Mean ± SE) of immature stages of *Palpita unionalis* reared on three different host plants at 25 ºC.

Stage	Olive	Ash	Jasmine	df	*F*	Sig
Egg	3.71±0.09	3.69±0.07	3.74±0.07	2	0.13	0.8814
Larva	17.44±0.33a*	14.87±0.21b	16.65±0.30a	2	22.91	<0.0001
Prepupa	1.56±0.09a	1.00±0.00b	1.00±0.00b	2	43.68	<0.0001
Pupa	7.54±0.22b	8.26±0.11a	8.61±0.16a	2	11.06	<0.0001
Combined stage	30.00±0.49a	27.52±0.17b	29.89±0.39a	2	12.67	<0.0001

*Means in rows followed by different letters indicate significant differences among host plants tested at p≤ 5% (ANOVA).

Survival. Table 2 shows the survival of different immature stages and total development time of *P. unionalis* reared on the same host plants. Survival of immature stages was not different among plants (Table 2). Immature mortality generally was high in larval stages and mortality was low among instars 3-6 on all host plants (Figures 1, 2, and 3). Table 2 shows that the survival in immature stages was high; namely 73, 74 and 72% on olive, ash and jasmine, respectively.

Table 2. Within-stage survival (%) of immature stages of *Palpita unionalis* reared on three different host plants at 25ºC

Stage	Olive	Ash	Jasmine
Egg	94.0	96.0	96.0
Larva	82.7	81.3	79.2
Prepupa	97.5	100.0	97.4
Pupa	96.8	94.9	97.3
Egg to Adult	73.3	74.0	72.0

Adult Longevity, Fecundity and Oviposition. Host plant did not affect adult longevity (Table 3). Although adult females from larvae reared on olive lived longer than adults from larvae reared on jasmine and ash, there was no significant difference among them ($P = 0.1021$). Adult male longevity showed the same trend (Table 3). On the other hand, the mean total number of eggs produced was significantly affected by host plant ($F= 4.27$; $P=0.025$). Females from larvae reared on olive laid significantly more eggs than those from larvae reared on ash and jasmine (Table 3). There were no differences among the host plants in terms of pre-oviposition. However, the post-oviposition period, and especially the oviposition period of females from larvae reared on different hosts, was statistically significant (Table 3). In parallel with the results for fecundity, the oviposition period for females from larvae reared on olive was longer than for other plants ($F= 11.54$; $P<0.002$). On the three host plants, most of the eggs were laid a few days after the start of oviposition and the numbers decreased in the second half of oviposition. Females laid until the last few days of their lives. However, they did not lay every day, particularly towards the end of their lives.

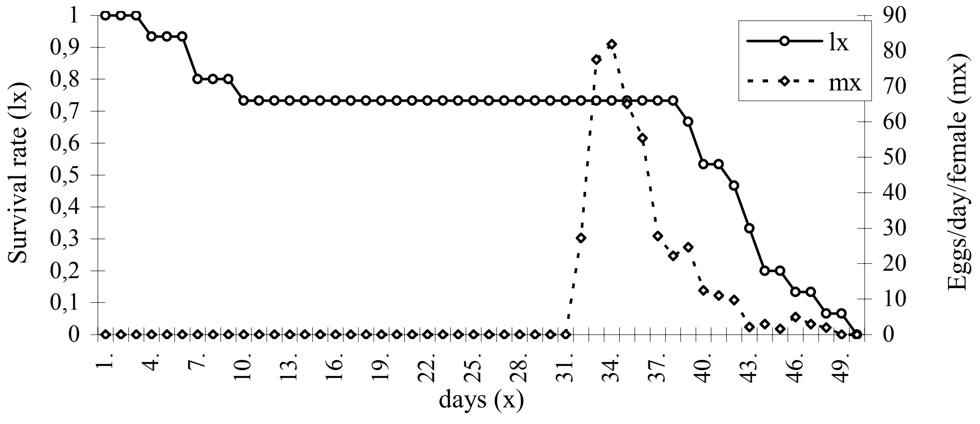

Figure 1. Survival and daily oviposition curves of *Palpita unionalis* females reared on olive foliage at 25 ºC.

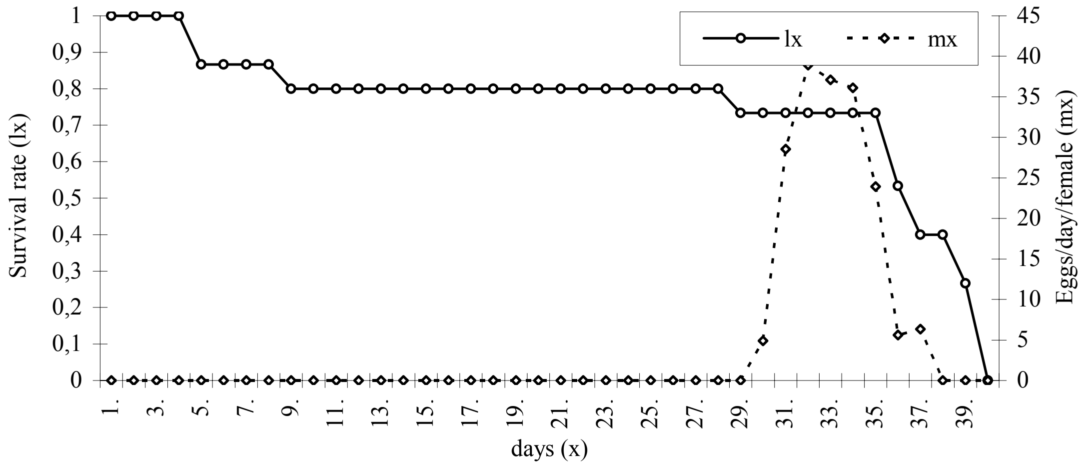

Figure 2. Survival and daily oviposition curves of *Palpita unionalis* females reared on ash foliage at 25 ºC.

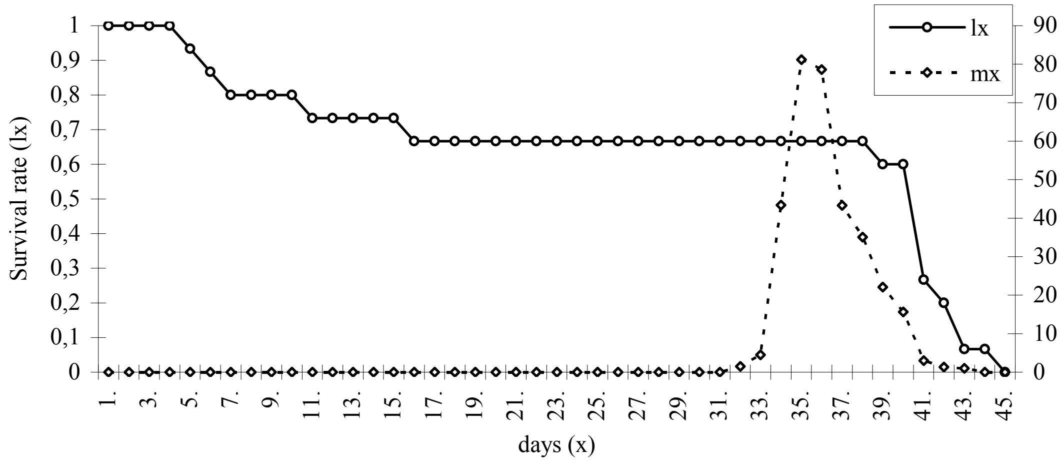

Figure 3. Survival and daily oviposition curves of *Palpita unionalis* females reared on jasmine foliage at 25 ºC.

Table 3. Longevity, fecundity and oviposition periods (Mean ± SE) of adult *Palpita unionalis* reared on three different host plants at 25 ºC.

Host	Longevity		Fecundity	Oviposition periods		
	Female	Male	No. of eggs/female	Pre-oviposition	Oviposition	Post-oviposition
Olive	11.64±0.57	10.57±0.43	390.30±52.21a*	2.75±0.32	9.15±0.74a	1.87±0.29ab
Ash	9.92±0.38	9.00±0.52	194.7±37.70b	2.35±0.32	5.60±0.34c	2.18±0.23a
Jasmine	10.70±0.45	9.20±1.06	321.80±52.68ab	2.62±0.30	7.77±0.19b	1.31±0.13b
F	2.41	1.65	4.27	0.42	11.54	3.30
df	2	2	2	2	2	2
P	0.1021	0.2044	0.0245	0.6609	0.002	0.0485

*Means in columns followed by different letters indicate significant differences among host plants tested at p≤ 5% (ANOVA).

Life Tables on Different Host Plants. The values for the different life table parameters of *P. unionalis* are shown in Table 4. Among life table parameters, the intrinsic rate of population increase (r_m) showed significant differences in terms of host plant (F=4159.9; P< 0.001). The net reproductive rate (R_o) of *P. unionalis* reared on olive was higher than on jasmine and ash. In contrast to the findings for net reproductive rate, the generation time (T) was relatively similar for olive and jasmine, but lower for ash.

Table 4. Life table statistics for *Palpita unionalis* reared on three different host plants at 25 ºC.

Parameter	Olive	Ash	Jasmine
r_m^a	0.163±0.001a	0.148±0.001c	0.149±0.001b
R_o^b	298.33	129.80	215.53
T^c	35.30	32.99	36.16

[a] Intrinsic rate of population increase (day^{-1}); [b] Net reproductive rate; [c] Generation time in days.

*Means in columns followed by different letters indicate significant differences among host plants tested at p≤ 5% (ANOVA)

DISCUSSION

This study showed that the mean total developmental period for *P. unionalis* reared on olive, ash and jasmine under long day lighting, a constant temperature (25 ºC) and relative humidity (65%) ranged from 27.52 days to 30.00 days (Table 1). This result was close to the value of 26 days reported for the species on olive at 26 ºC by Vassilaina-Alexopoulou and Santorini (1973) and of 27 days reported for the same species on olive at 25 ºC by Shehata et al (2003). El-Khawas (2000) stated that the duration of pre-imaginal development on young olive shoots ranged from 21 to 30 days at 27 ºC and 65% RH. However, Badawi et al (1976) and Arambourg (1986) reported that the duration of post-embryonic development varied from 29.2 to 32.0 days on different host plants including olive, jasmine and ash tree.

Adult longevity of *P. unionalis* reared on olive, ash and jasmine (9.92 to 11.64 days for female; 9.00 to 10.57 days for male) determined in the present work was similar to that on olive under the same laboratory conditions (11.4 days for female; 11.9 days for male) (Shehata et al 2003).

In this study, the mean numbers of eggs laid per female ranged from 194 to 390 at 25ºC, depending on the host plant. This is in agreement with the findings of Vassilaina-Alexopoulou and Santorini (1973) who reported the number of eggs laid per female varied between 86 and 515, with an average of 209. On the other hand, the current study's fecundity results were lower than the 463 at same temperature on olive established by Shehata et al (2003). Reproductive differences for *P. unionalis* females kept under the similar environmental conditions and on the same plant could be related to the cultivar Gemlik c.v. Characteristics such as leaf morphology, chemical composition or other interactions were not examined in this study (Vassilaina-Alexopoulou and Santorini 1973; Shehata et al 2003). The shorter oviposition duration (5.60 to 9.15 days) in our study, compared to the duration (10.5 days) reported by Shehata et al (2003) may have led to less laid eggs. However, our results for oviposition period confirmed the results of Shehata et al (2003) who reported that pre-oviposition and oviposition were 1.7 and 1.0 days, respectively.

According to the current study, there were significant differences in the developmental times of immature stages, especially total larval development, on each host plant species (Table 1). Larvae maintained on ash had comparatively shorter duration of immature stages. Despite the statistical differences, it is not fundamentally important that the larval development duration on ash was 1.5-2.5 days shorter than that on olive and jasmine. Developmental period provides an important clue concerning the ability of the host to support a complete insect life cycle, but this data should be linked to other parameters such as mortality, reproductive rate and intrinsic rate of population increase (Birch 1948; Varley and Gradwell 1970; Liu et al 2004). Therefore, there were not marked differences in survival of larvae among host plants (Table 2). This result confirmed that there were no differences among host plants in terms of the development of immature stages.

Another fitness indicator, the net reproductive rate, varied among hosts in different ways in this study. For example, the net reproductive rate of females from larvae reared on ash was less than that of females from larvae reared on olive and jasmine (Table 4). Thus, compared with olive and jasmine, ash was suboptimal for reproduction. The net reproductive rate is an important indicator of population dynamics (Richard 1961; Varley and Gradwell 1970). It is a key statistic that summarizes the physiological capability of an animal relative to its reproductive capacity. Comparison of net reproductive rate often provides considerable insight beyond that available from the independent analysis of individual life history parameters (Liu et al 2004). Also, the net reproductive rate may reflect the potential of host plants to contribute to olive leaf moth populations. These results are consistent with olive grove observations in Bursa (Kovancı et al 2006). In 2000 and 2001, the olive leaf moth caused large economic losses to olive trees and nurseries and this species is still a key pest of this crop. However, when the ash trees were examined, no or few olive leaf moth larvae were found on them (Kovancı et al 2006).

The intrinsic rate of population increase (r_m), the second life table parameter, was highest on olive, differing only slightly from that on ash and jasmine, although there were no significant differences among them. Similar to the results for the net reproductive rate, the intrinsic rate of population increase indicated that olive was more favourable than the other host plants. The intrinsic rate of population increase is a basic parameter which an ecologist may wish to establish for an insect population (Birch 1948). The value of r_m determines whether a population increases exponentially ($r_m > 0$), remains constant in size ($r_m = 0$), or declines to extinction ($r_m < 0$) (Gotelli 1998). Thus, the intrinsic rate of population increase indicated that *P. unionalis* reared on three host plants exhibited exponential population growth. These findings were consistent with those of Greenberg et al (2001) on *Spodoptera exigua* (Hübner) and Hansen et al (2004) on *Sitotroga cerealella* (Olivier).

In conclusion, demographic parameters obtained from *P. unionalis* reared on three host plants under laboratory conditions are useful for the assessment of host plant quality. Intrinsic rate of increase and mean generation time reflect the suitability of the host plant. In addition to other factors, survival and fecundity are affected by the host plant's nutritional value (Pereyra and Sanchez 2006). Meanwhile, this study provides a foundation regarding the host range of *P. unionalis*, and as such, will be useful to pest management. The host plants examined in this study are all suitable for the pre-imaginal development of *P. unionalis*, but the intrinsic rate of increase and the net reproductive rate mark the olive as the the most suitable host in terms of population increase.

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