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Effects of five different melon (*Cucumis melo* L.) cultivars on population growth of *Aphis gossypii*

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Abstract: In this study, population growth parameters of *Aphis gossypii* Glover (Hemiptera: Aphididae) on five different melons [*Cucumis melo* Linnaeus (Cucurbitaceae) cultivars (Balin, Çıtırex, 221 F1, Gediz, Yusufbey)], which are commonly grown in Turkey, were investigated in laboratory experiments. Life table parameters were estimated according to age-stage and two-sex life table theory. The results showed that *A. gossypii* developed more successfully on the Gediz cultivar due to the higher intrinsic rate of increase (0.5042 1/day), the finite rate of increase (1.6557 1/day) and the shorter mean generation time (8.161 days) than the other cultivars. Ecological pest control against aphids' use of resistance or less favourable host plant cultivars is considered one of the significant components of pest management. The findings obtained in this study can be used in the pest management program designed for the aphid.

Keywords: intrinsic rate of increase; life table; melon aphid; population growth simulation; population parameters

Cucumis melo Linnaeus, Cucurbitaceae, which can be used in different forms, is one of the most widely grown horticultural crops in the world due to its significance in international trade (Bezirganoglu 2018). Turkey is placed second in global melon production after China (FAOSTAT 2018). With broad melon cultivation in Turkey, locally, there are many cultivars encountered and richness concerning form. Galia-type melons are most common in Europe and Turkey, and it is the cultivar with the highest quality product from covered cultivation. Melon aphid [*Aphis gossypii* Glover (Hemiptera: Aphididae)] is a major pest of melons worldwide, especially for greenhouse plants (CAB International 1968; Blackman & Eastop 1984). In addition to the general aphid damage, melon aphids also transmit plant viral diseases and infect healthy plants (Düzgüneş & Tuatay 1956; Kishaba et al. 1992). The melon aphid is known to carry potyviruses in cucurbits (Blackman & Eastop 2000). Natural enemies, such as predators and parasitoids, can control melon aphids, but population outbreaks may occur because extensive pesticide applications reduce the populations of beneficial insects (Williamson & Griffin 2016). Although some insecticides can control *A. gossypii* at concentrations lower than the application doses, they may harm the parasitoid, and pesticide exposure routes should be evaluated using new approaches in line with the IPM approach (Ricupero et al. 2020). Moreover, the use of chemicals has caused this pest to develop resistance (Devonshire 1989; Kırışık 2020). Currently, management of the melon aphid sticks to the use of friendly methods because of the concerns on the health of humans and the environment. Thus, the integrated pest management approach seems to be a better approach within this context. One of the crucial steps in this approach is the use of resistant plants, which affects insects' the biology and development (Chen et al. 1996). The chemical, physical structure and biological traits of the host plants determine the reason for preference or makes the plant resistant to insects (Awmack & Leather 2002; Lee 2007). Hence, the selection of resistant plants or being not preferred in the selection

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of the product at the start of production is the first step to protect them from pests (Polat-Akköprü et al. 2015; Güncan & Gümüs 2017; Qayyum et al. 2018). Life table analysis is significant to investigate if the sensitivity of the host plant to the pest is possible by obtaining data about the biology and population parameters of the pest (Smith 2005). It is also an essential tool for assessing the performance and understanding of the ecology of an insect pest on its host plant. There are studies about the life cycles of *A. gossypii* on different host plants (Aldyhim & Khalil 1993; Polat-Akköprü 2018). To our knowledge, there has been no study on the effects of melon cultivars on the life table and population growth parameters of melon aphid.

This study aims to investigate the biology and population parameters using age–stage, two-sex life table theory of *A. gossypii* on melon cultivars widely cultivated in Turkey and reveal the susceptibility status of these cultivars against the pest.

MATERIAL AND METHOD

Cultivation of melon cultivars. In this study, Galia-type melon seeds (Balin, Çıtırex, 221 F1, Gediz, Yusufbey) were used that are grown in different regions of Turkey. All cultivars were grown in plastic pots (90 cm in diameter, 90 cm in height) and kept in a climate chamber set at 25 ± 1 °C, 60 ± 10% relative humidity (RH) and a photoperiod 16 : 8 (L : D) with watering at certain periods.

Insect rearing. *Aphis gossypii* adults were collected from melon growing areas in Van and reared in climate rooms at 25 ± 1 °C, 65 ± 5% RH and aphids were reared on two generations on potted of each melon cultivars under the same condition as a stock culture. Thus, the effects of the previous host experience were eliminated.

Life table of *Aphis gossypii*. Life table study was conducted at the climate room under controlled conditions (25 ± 1 °C, 60 ± 10% RH and 16 L : 8 D photoperiod). Concurrent adults were transferred onto a leaf individually and kept in a Plexiglas clip-cell (20 by 10 mm with their upper side covered by muslin). After 12 h, one newborn nymph was kept in each cell, and other newborn nymphs and adults were removed. On each plant, only three to four clip-cells were used.

The developmental stage and survival were observed daily, with the presence of exuviae used as evidence for molting to the next developmental stage. Once females reached adulthood, the duration of the adult pre-reproductive, reproductive, total pre-reproductive periods and total longevity were determined by daily observations until the death of each individual. During the reproductive period, all nymphs were removed from the test area after counting. In this study, 50 individuals were used on each melon cultivar, but only those individuals that survived to adulthood were included in the calculations of immature developmental time.

Data analysis. Raw data obtained as a result of observations were analyzed according to the age-stage, two-sex life table theory (Chi & Liu 1985; Chi 1988; Chi et al. 2020). The age-stage specific survival rate [s_{xj}; where: x – age in days; j – stage, the age-stage specific fecundity; f_{xj} – the age-specific survival rate l_x – the age-specific fecundity; m_x and the population parameters (r – the intrinsic rate of increase; λ – the finite rate of increase; $\lambda = e^r$; R_0 – the net reproductive rate; T – the mean generation time)] were calculated with TWOSEX-MSChart the computer program (version 2020.11.10) (Chi 2020b). The values were calculated according to the formulas in Polat-Akköprü's (2018) study. The bootstrap technique (Efron & Tibshirani 1993, Huang & Chi 2012) with 100.000 resamplings was used to estimate the variances and standard error (SE) of the population parameters.

The paired bootstrap test was used at a 5% significance level to compare the different treatments.

The paired bootstrap test was used to compare development rates, longevity, fecundity, mortality rates and life table parameters values of the different melon cultivars (Polat-Akköprü et al. 2015).

Population projection. On five different melon cultivars, 45 days- long, the population projection of *A. gossypii*, based on the data obtained from the life table studies of the pest, was made using the computer program TIMING-MSChart (version 2020.11.10) (Chi 2020a) according to the method devised by Chi (1990). The population size and stage structure were simulated by assuming an unlimited growth from an initial population of 10 newborn nymphs.

RESULTS

Development and production. The *Aphis gossypii* nymphs had the shortest total development time on the Gediz cultivar at 4.00 days, which was statistically different from the other four cultivars. There were no differences among Balin, 221-F1, Çıtırex and Yusufbey cultivars (Table 1).

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Table 1. Developmental time and preadult mortality of *Aphis gossypii* reared on five different melon cultivars (mean ± SE)

Durations of development (days)	Cultivars				
	221-F1	Balin	Çıtırex	Gediz	Yusuf Bey
1st instar	1.1 ± 0.1[ab]	1.0 ± 0.0[b]	1.2 ± 0.1[a]	1.0 ± 0.0[b]	1.0 ± 0.0[b]
2nd instar	1.1 ± 0.1[ab]	1.3 ± 0.1[a]	1.1 ± 0.1[b]	1.0 ± 0.0[c]	1.1 ± 0.1[ab]
3rd instar	1.2 ± 0.1[a]	1.3 ± 0.1[a]	1.1 ± 0.1[ab]	1.0 ± 0.0[b]	1.3 ± 0.1[a]
4th instar	1.1 ± 0.1[a]	1.0 ± 0.1[b]	1.1 ± 0.1[a]	1.0 ± 0.0[b]	1.0 ± 0.0[b]
Total preadult	4.6 ± 0.1[b]	4.6 ± 0.1[b]	4.5 ± 0.1[b]	4.0 ± 0.0[a]	4.5 ± 0.2[b]
n	29	27	27	25	28

Means within a row followed by the same letter are not significantly different ($P < 0.05$; paired bootstrap test); SE were estimated with 100 000 bootstrap resamplings

The age and stage survival rate (s_{xj}) suggest the possibility that a newly hatched nymph (N) will survive to x age and j period (Figure 1). The possibility of survival of a newly-lied nymph until the adult period was determined as 0.83, 1.00, 1.00, 1.00, and 0.96 for 221 F1, Balin, Çıtırex, Gediz and Yusufbey cultivars, respectively (Figure 1).

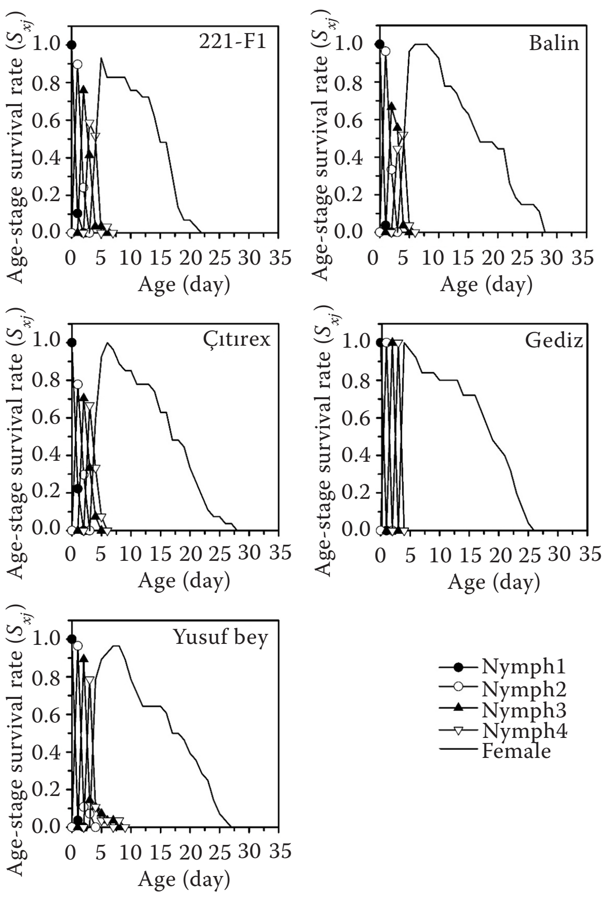

Figure. 1. The age-stage specific survival rate (S_{xj}) of *Aphis gossypii* reared on five different melon cultivars

The lowest adult longevity value was on 221 F1 cultivars (14.48 ± 0.875 days). No statistically significant difference was found between the other cultivars. The APRP (0.24 ± 0.0855) and TPRP (4.24 ± 0.0855) values for the Gediz cultivar were observed to be shorter than the other cultivars tested (Table 2). The reproductive days were shorter for the Balin cultivar (9.00 ± 0.653 days), with no difference between other cultivars. The highest fertility values for *A. gossypii* were on Yusufbey (72.14 ± 8.39 per nymph) and Balin (71.48 ± 6.01 per nymph), with the lowest value determined on the 221 F1 (52.14 ± 4.89 per nymph) cultivar (Table 2).

The survival rate (l_x) is the possibility of a newborn individual living until x age and is calculated by adding individuals dying in the pre-adult period to those surviving (Southwood 1971; Sharov 2012). The cultivar with the lowest survival rate l_x was determined as 221 F1. The term m_x is the number of female offspring produced by females of x age in unit time and refers to fecundity. The highest peaks for m_x and $l_x m_x$ were at 9.55 and 9.40 days and 7.15–7.92 days for Çıtırex and Gediz cultivars, respectively. Mean daily fecundity reduces in stages after these peaks (Figure 2).

Population parameters. The life table parameters of the melon pest *A. gossypii* were determined to display significant levels of change as a result of feeding on different melon cultivars (Table 3). The Gediz cultivar had a higher intrinsic rate of increase (0.504 1/day) and a finite rate of increase (1.655 1/day) than the other cultivars. However, it had a shorter mean generation time (8.16 days). While there was no statistically significant difference for other cultivars, the Yusufbey cultivar had a lower intrinsic rate of increase (0.413 1/day) and a finite rate of increase (1.512 1/day) than other cul-

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Table 2. The adult prereproductive period (*APRP*), the total prereproductive period (*TPRP*), reproductive days, fecundity, and longevity of *Aphis gossypii* reared on five different melon cultivars (mean ± SE)

	Cultivars				
	221-F1	Balin	Çıtırex	Gediz	Yusuf bey
APOP (d)	0.6 ± 0.1^{ab}	0.9 ± 0.1^{a}	0.9 ± 0.1^{a}	0.2 ± 0.1^{c}	1.1 ± 0.1^{a}
TPOP (d)	5.2 ± 0.1^{a}	5.4 ± 0.1^{a}	5.3 ± 0.1^{a}	4.2 ± 0.1^{b}	5.6 ± 0.2^{a}
Reproductive days (d)	9.0 ± 0.7^{b}	11.8 ± 0.9^{a}	11.3 ± 1.0^{a}	11.3 ± 0.9^{a}	11.1 ± 1.1^{a}
Fecundity (nymphs/female)	52.1 ± 4.9^{b}	71.5 ± 6.0^{a}	63.9 ± 6.9^{ab}	61.3 ± 5.5^{ab}	72.1 ± 8.4^{a}
Adult longevity (d)	14.5 ± 0.9^{b}	18.4 ± 1.2^{a}	17.4 ± 1.1^{a}	17.9 ± 1.1^{a}	17.6 ± 1.2^{a}

Means within a row followed by the same letter are not significantly different ($P < 0.05$; paired bootstrap test); SE were estimated with 100 000 bootstrap resamplings

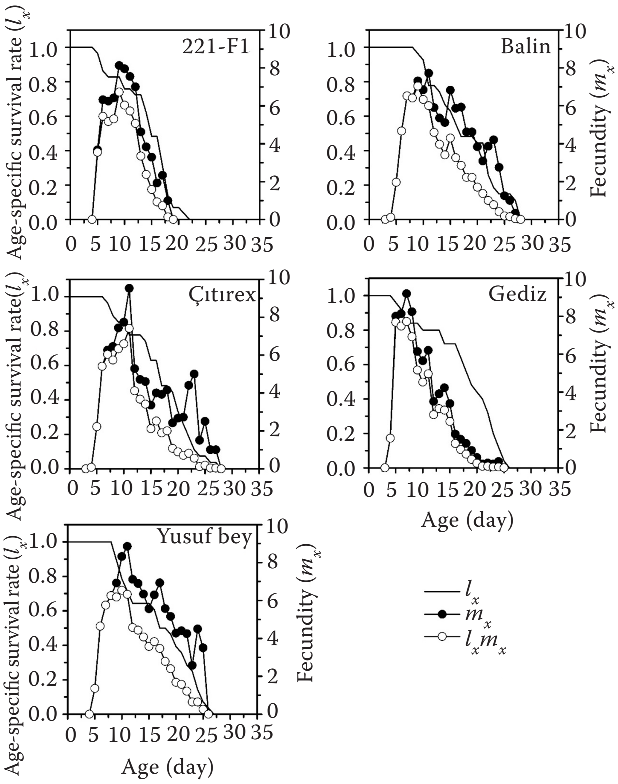

Figure 2. Age-specific survival rate (l_x), fecundity (m_x), and net maternity (l_xm_x) of *Aphis gossypii* reared on five different melon cultivars

tivars with a longer mean generation rate identified at 10.34 days (Table 3).

Life expectancy. The expected life duration gives the duration an organism with x age in the j period is expected to survive (Figure 3). The life expectancy of a newly born *A. gossypii* nymph was 14.48, 18.37, 17.40, 17.96 and 17.57 days on 221-F1, Balin, Çıtırex, Gediz and Yusufbey cultivars, respectively (Figure 3). The life expectancy of nymphs and adult *Aphis gossypii* was longer on Gediz and Balin cultivars than other cultivars (Figure 3).

Reproductive value. The reproductive value of a newborn individual is the same as the finite rate of increase (λ) in all senses (Chi and Su 2006) (Figure 4). All females developing on 221-F1, Balin, Çıtırex, Gediz and Yusufbey cultivars reached the adult period on the 4th day, and the highest reproductive values were on the 10th day ($v10 = 18.6$), 8th day ($v8 = 18.03$), 10th day ($v10 = 19.2$), 8th day ($v8 = 19.07$) and 11th day ($v11 = 20.3$). Aphids feeding on different nutritional sources may affect reproductive power (Huang & Chi 2012).

Population projection. At 45 d, the total population size was projected to be the highest on Gediz and the lowest on Yusufbey (Figure 5A). To investigate the variability of population growth, the

Table 3. Population parameters of *Aphis gossypii* reared on five different melon cultivars (mean ± SE)

	Cultivars				
	221-F1	Balin	Çıtırex	Gediz	Yusuf Bey
r (1/day)	0.4331 ± 0.011^{b}	0.4253 ± 0.006^{b}	0.4256 ± 0.009^{b}	0.5042 ± 0.009^{a}	0.4134 ± 0.007^{b}
λ (1/day)	1.5420 ± 0.017^{b}	1.5300 ± 0.009^{b}	1.5305 ± 0.014^{b}	1.6557 ± 0.015^{a}	1.5120 ± 0.011^{b}
R_0 (offspring/individual)	52.13 ± 4.803^{b}	71.48 ± 5.903^{a}	63.92 ± 6.843^{ab}	61.28 ± 5.430^{ab}	72.14 ± 8.261^{a}
T (d)	9.129 ± 0.158^{b}	10.038 ± 0.253^{a}	9.728 ± 0.181^{a}	8.161 ± 0.120^{c}	10.348 ± 0.285^{a}

Means within a row followed by the same letter are not significantly different ($P < 0.05$; paired bootstrap test); SE were estimated with 100 000 bootstrap resamplings; r – intrinsic rate of increase; λ – finite rate of increase; R_0 – net reproductive rate offspring/individual; T – mean generation time

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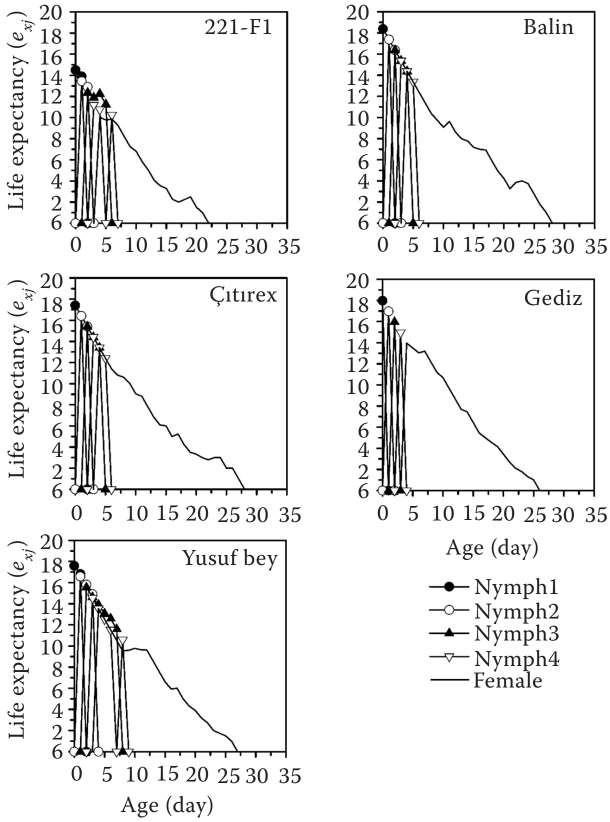

Figure 3. The age stage specific life expectancy (e_{xj}) of *Aphis gossypii* reared on five different melon cultivars

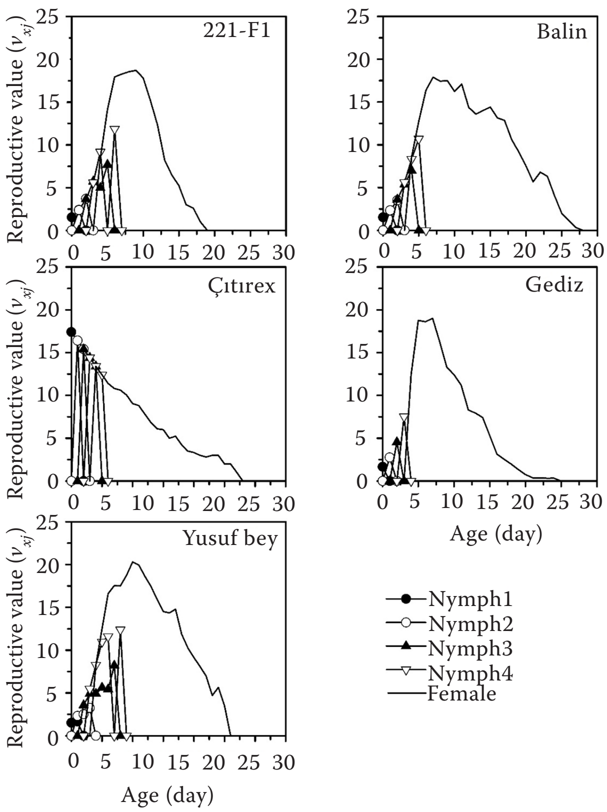

Figure 4. The age stage specific reproductive value (v_{xj}) of *Aphis gossypii* reared on five different melon cultivars

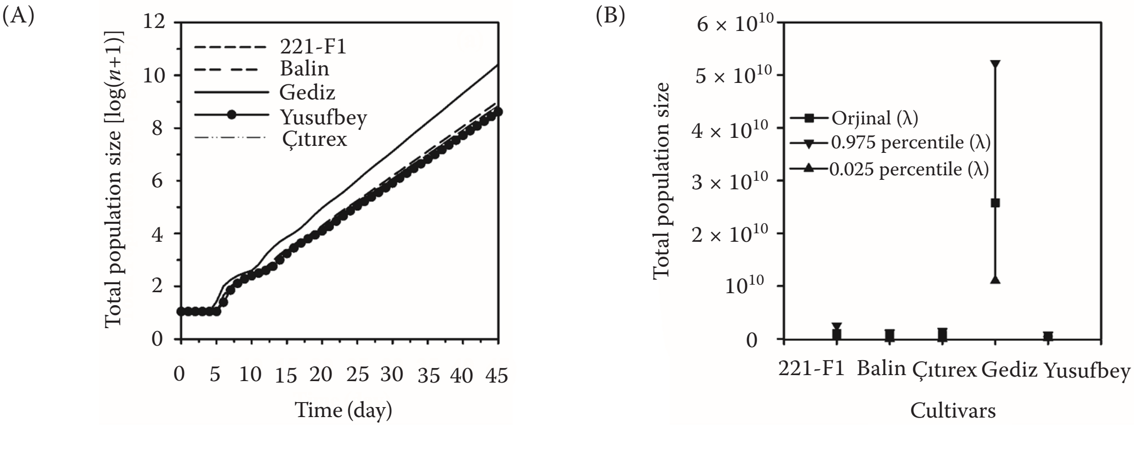

Figure 5. (A) Projection of population growth potential of *Aphis gossypii* reared on five different melon cultivars and (B) confidence interval of population growth at day 45

total population sizes of the original cohort and finite rate of increase based on the boot percentages of 0.025 and 0.975 are represented in Figure 5B. The variability of the projected population increase of 45 days showed that there was a high level of uncertainty in the population increase of aphids fed on the Gediz cultivar, unlike other cultivars (Figure 5B).

DISCUSSION

The use of insect-resistant cultivars can be useful in integrated pest management programs to minimize pesticide applications. Insect-resistant cultivars of plants will provide more yield than a sensitive cultivar in pest invasions and resistant crop cultivars suppress

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pest populations or elevate the tolerance of the plants to harm. McCreight et al. (1984) reported that resistant melon cultivars were used with limited commercial success against melon aphid. One of the most suitable tools to investigate whether the host's resistance to the harmful species is the life tables. The life table parameters are the good indications to investigate the effects of host plant on aphids (Atlıhan et al. 2017), especially the intrinsic rate of increase (*r*) that integrates all important parameters of insect population dynamics (Dent 1997), and intrinsic rate of increase (λ) (Goodarzi et al. 2015). It has been stated that fluctuations in the intrinsic rate of increase have considerable effects on populations of pests (Goundoudaki et al. 2003). Insects in different host plants have different life-history traits (Dogar et al. 2018; Milenovic et al. 2019).

In this study, the results suggest that the population growth rate of *A. gossypii* was affected by Galia melon cultivars. The pre-adult development period of the Gediz variety was shorter than other cultivars. Short development duration provides information about the high performance of the pest on the cultivars (Polat-Akköprü 2018).

It has been determined that the intrinsic rate of increase and finite rate of increase of the Gediz cultivar were higher than the other cultivars and due to the shorter mean generation time, it was more sensitive than the tested cultivars. There are many studies showing that the host plants, *A. gossypii*, affect the development, reproduction and population parameters (Alizadeh et al. 2016; Polat-Akköprü 2018)

The interaction of the relationship between insect and plant is linked to different resistance types like antibiosis (high death rate, short lifespan), antixenosis (effects on behavior and not selection or tolerance) [the ability of the plant to tolerate the pest (Li et al. 2004) (Smith 2005; Diaz-Montano et al. 2006; Teetes 2019)].

Many factors that arise from plants affect the performance of the pest. The characteristics of the host plant, such as its biochemical content (secondary metabolites, jasmonic acid, abscisic acid and salicylic acid), morphological and physical structure (tissue hardness, trichomes and cell wall thickness, color) and nutrient quantity, affect the population parameters of the pest (Wilkinson & Douglas 2003; Smith 2005; Saska et al. 2020). Polat-Akköprü et al. (2015) stated that plant fitness often depends on the biochemical content of the host plants can help explain the factors affecting the population growth of the pests.

Gossypol and tannins content in cotton have an antibiosis effect against *A. gossypii* proven in some studies on cotton (Du et al. 2004). Delafuente et al. (2020) stated that salicylic acid application in the melon caused a decrease in the intrinsic rate of increase of melon aphid

The Vat gene has been identified in melon lines that confer both antibiotic and antixenosis melon resistance to *A. gossypii* and known to inhibit aphid colonization in melon and virus transmission of aphids (Sarria et al. 2008), has been identified, and this gene has been used in melon breeding to develop aphid-resistant varieties in several melon lines (PI 161375, PI 414723 and TGR-1551). Among these genotypes, TGR-1551 melon genotypes have a resistance mechanism that prevents *A. gossypii* from feeding on phloem (Garzo et al. 2002) and aphids are prevented from settling (Sarria et al. 2010). Moreover, trichome density in cotton and cucurbit genotypes negatively affects the pest's performance (Zarpas et al. 2006; Mansouri et al. 2013). Saria et al. (2010), in their study of *Cucumis melo* genotypes, stated that high density glandular trichomes and the chemicals secreted by them deter *A. gossypii.* However, more studies are needed to understand the resistance mechanism of Galia melon cultivars melon (antibiosis, antixenosis or tolerance) to *Aphis gossypii*.

As a result, melon producers are recommended to cultivate other cultivars (221-F1, Balin, Çıtırex & Yusufbey) used in this study instead of Gediz to prevent aphid damage. Thus, in the first stage, yield losses formed of *A. gossypii* feeding on melon leaves will be reduced to the least due to the cultivation of cultivars that are not selected by aphids (221-F1, Balin, Çıtırex & Yusufbey). Additionally, it is crucial in terms of having an easy application, being economical and reliable compared to other management methods, reducing the use of pesticides required for management and preserving the natural balance. As an alternative to synthetic pesticides for aphid control, as well as many nature-friendly methods, such as the use of biopesticides (Milner 1997), nanoformulations (Campolo et al. 2017) and biological management, the use of resistant varieties can be successful in integrated pest management programs.

In addition to preserving the natural balance, due to increased species variegation in the agroecosystem, it will contribute to the formation of a more sustainable system causing less pollution and less harm to natural resources. Moreover, using such sensitive cultures to breed aphids would benefit both laboratory research and natural enemy mass production.

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