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# Life Table and Development Parameters of *Aphis fabae* (Scopoli) (Hemiptera: Aphididae) on Two Different Broad Bean (*Vicia faba* L.) Cultivars

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## ABSTRACT

**In this study, reproduction, life table, population, and development parameters of the black bean aphid, *Aphis fabae* (Scopoli) (Hemiptera: Aphididae), which causes significant losses in broad bean (*Vicia faba* L.) plants, were determined according to the age-stage, two-sex life table. The experiment was conducted in a climate room with a temperature of 25±1ºC, 60±5% relative humidity, and 16:8 hours light:dark conditions. All raw data were analyzed by using the age-stage, two-sex life table program. As a result of the analysis, the performance of *A. fabae* on the two different cultivars; performance on the Salkım cultivar according to the life table parameters was better than the Filiz-99 cultivar. According to the results obtained, it was concluded that the Filiz-99 cultivar was more resistant than the Salkım cultivar to the pest. Based on the data received at the end of the study, it can be said that the Filiz-99 cultivar can be planted in places where the pest will form high populations, and the control costs can be reduced.**

**Keywords:** *Vicia faba*, *Aphis fabae*, population projection, age-stage, two-sex life table.

## INTRODUCTION

The broad bean (*Vicia faba* L.), which is in the Fabaceae family, has an important place in human and animal nutrition. The broad bean plant is used as fresh, conserved, and fodder plants. Broad bean seeds are among the plants with high nutritional value with a protein content of 25-35%. Broad bean plant, is one of the plants that provide organic matter and nitrogen to the soil in crop rotation systems. It is also used as a green fertilizer with both root and stem structures. With the features mentioned above and high nutritional value, it attracts many harmful insects, especially aphids (Akçin, 1988; Nachi and Guen, 1996; Vural et al., 2000).

In addition to being global pests of many crops, aphids are characterized by their high reproductive rate and rapid growth, while their short life cycle and parthenogenetic reproduction cause serious damage to many crops by rapidly establishing populations (Leather et al., 1983). Aphids, which cause significant yield losses in many crops worldwide, not only cause series losses by causing fruit and leaf deformations, necrosis, and gal formations as a result of their feeding by stinging and sucking plants, but also by preventing photosynthesis of leaves with the sweetish substances they emit, but they also cause damage as the main vectors of many plant pathogens (Dedryver et al., 2010). The black bean aphid, *Aphis fabae* (Scopoli) (Hemiptera: Aphididae), is one of the most important pests of many cultivated crops such as broad beans, beans, tomatoes, potatoes, and tobacco, and also has a wide range of hosts, including many wild and ornamental plant species, with more than 200 host plant species worldwide (Völkl and Stechmann, 1998; Barnea et al., 2005). *A. fabae* is one of the most important pests attacking broad bean, *V. faba*, wherever it is cultivated (Basedow et al., 2006). *A. fabae*, one of the 14 most important pests of crops, is known as the most important pest of broad beans worldwide and is the vector of more than 30 plant viruses (Blackman and Eastop, 2007).

The main purpose of agricultural practices is to grow products sensitive to the health of the environment, humans, and other living things by sustainable agricultural methods, as well as to obtain a large amount of product

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from a unit area. For this reason, the concept of "Sustainable Agriculture", which meets food, energy, and natural resource needs while protecting nature and living things, has gained importance (Menalled et al., 2008). In sustainable agricultural activities, "Integrated Pest Management" (IPM) has started to be preferred for pest control as a management system that covers all the features above and ensures the use of all control methods harmoniously and healthily way and biological control practices have been shown as one of the most important elements of this management system and population estimation and life table parameters provide useful information in pest control (Akbaş, 2019).

Life tables, a research tool used in many fields such as demography and community ecology, form the basis of comprehensive studies in many fields such as pest management, pesticide resistance, prey-predator relationships, biological control, mass production of insects, and taking into account the raw data of parthenogenetically reproducing insects such as aphids, it allows data such as morphology, physiology, survival rates, fecundity, predation parameters, period differentiation to be obtained with appropriate and accurate analysis (Chi, 1988). Since traditional female age-specific life tables neglect male individuals and thus fail to describe the period differentiation of insects, leading to erroneous analyses and limiting practical applications, the "age-stage, two-sex life table" offers useful practices with more reliable results by considering each sex and period in detail (Chi et al., 2020). In the study, simultaneously obtained life table parameters, the development, survival, reproduction data, and population projection of *A. fabae* on two different broad bean cultivars were used together to estimate the population dynamics, and the population sizes they can reach in a certain initial population. We analyzed the raw data using the age-stage, two-sex life table (Chi and Liu, 1985; Chi, 1988). Results obtained in this study will be applicable in managing *A. fabae* in broad bean growing areas. In the study, we collected the development, reproduction, and development parameters of *A. fabae* on two different broad bean cultivars. The study aimed to reveal which cultivars are susceptible and resistant to the pest. It is thought that the results obtained will provide useful information for integrated pest management (IPM) within the scope of sustainable agriculture.

## MATERIAL AND METHODS

### Plant and aphid culture

The study's materials consisted of broad bean plant (*V. faba*) cultivars and aphid (*A. fabae)*. "Salkım" and "Filiz-99" broad bean seeds used in the experiment were obtained from 'Aegean Agricultural Research Institute-İzmir, Turkey'. "Salkım" and "Filiz-99" broad bean seeds were used in the experiment. Broad bean seeds were sown in 4-liter pots containing a 1:1:1 (soil: peat: perlite) mixture. The plants were kept in climate rooms with a temperature of 25±1°C, 60±5% relative humidity, and 16:8 light:dark conditions until the experiment was established. Aphids collected from bean cultivation areas in Van and its districts were grown on broad bean plants in a climate room with a temperature of 25±1°C, 60±5% relative humidity, and 16:8 light:dark conditions until the experiment was established.

### Life table study and analysis

In the climate chamber, mass-produced aphid adults were placed in a Plexiglas cell (2 cm diameter - 2 cm height) attached to the leaves and only one of the nymphs left by the adults was left in the cell and the other nymphs and adults were removed. Experiments were conducted for every cultivar starting with 50 newly born aphids. The experiments were set up with one Plexiglas cell per leaf and one individual in the cell. Biological changes were recorded daily.

The raw data obtained in the study were analyzed with TWOSEX-MSChart (Chi, 2022a) and TIMING-MSChart programs (Chi, 2022b) according to the age-stage-two-sex life table. With the help of this computer program, raw data of sexual insects can be analyzed, while at the same time, detailed analysis can be performed for parthenogenetic reproducing insects such as aphids. According to the aforementioned method, age-stage, dependent survival rate (*sxj*) (*x* = age, *j* = period), age-specific survival rate (*lx*), female age-specific fecundity (*mx*) were determined and population parameters (*R0*, the net reproductive rate; *r*, the intrinsic rate of increase; *λ*, the finite rate of increase; *T*, the mean generation time; life expectancy, *exj* and reproductive value *vxj*) were calculated.

The net reproductive rate ($R_0$) was calculated as follows.

$$R_0 = \sum_{x=0}^{\infty}\sum_{j=1}^{m} s_{xj} f_{xj} = \sum_{x=0}^{\infty} l_x m_x$$

The iterative bisection method calculated the intrinsic rate of increase (r) according to the Euler-Lotka formula starting from age 0 (Goodman, 1982; Chi and Liu, 1985) as follows.

$$\sum_{x=0}^{\infty}\left(e^{-r(x+1)}\sum_{j=1}^{m} s_{xj} f_{xj}\right) = \sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

The finite rate of increase (*λ*) was calculated with the formula below.

$$\lambda = e^{r}$$

Mean generation time (*T*) is defined as the length of time needed to increase the size of a population by the net reproductive output ($R_0$) and is calculated as follows.

$$T = (\ln R_0) / r$$

The life expectancy ($e_{xj}$) and reproductive value ($v_{xj}$) (*x* = age, *j* = period) parameters of aphids were calculated based on Chi and Su (2006).

The life expectancy ($e_{xj}$) is the life expectancy of an individual at age '*x*' and period '*j*' and was calculated as follows.

$$e_{xj} = \sum_{i=x}^{\infty}\sum_{y=j}^{\beta} s'_{iy}$$

Reproductive value ($v_{xj}$) is the contribution of an individual of age *'x'* and period '*j'* to the population and is calculated as follows.

$$v_{xj} = \frac{e^{r(x+1)}}{s_{xj}} \sum_{i=x}^{\infty} e^{-r(i+1)} \sum_{y=j}^{\beta} s'_{iy} f_{iy}$$

The "Bootstrap" method (Huang and Chi, 2012) was used to obtain the variance and standard errors of the data on the development, reproduction, and lifespan of the aphids, and the variance and standard errors of the population parameters. The same method was used for comparisons with the "Two-Sex-MSChart" program (Chi, 2022a).

**Population projection (Timing)**

The computer program "TIMING-MSChart" developed by Chi and Liu (1985) was used to estimate the population size of 10 nymphs at the end of 60 days according to the life table parameters (Chi, 2022b).

*P(t)*: Population projection of insect as follow formula.

$$P(t) = \sum_{j=1}^{m}\left(\sum_{x=0}^{\infty} c_{xj} n_{xj,t}\right)$$

## RESULTS AND DISCUSSION

**Development, survival, and reproduction parameters**

The development times, reproductive parameters, and longevity of *A. fabae* on two different broad bean cultivars are shown in Table 1. As a result of the feeding of *A. fabae* on Salkım and Filiz-99 cultivars, the development times of the 4 nymphal stages were 1.86-2.08, 2.04-2.29, 2.00-2.00, and 1.47-2.22 days, respectively, and the total development times were 7.31-8.50 days. The difference between nymph-1 and nymph-4 stages was found to be statistically significant. When the total pre-adult development of aphids was analyzed, it showed a better development on the Salkım cultivar. Adult longevity of *A. fabae* on cultivars was 20.59 days on the Salkım and 10.84 days on Filiz-99, respectively (Table 1). Survival rates, reproductive period, fecundity, APRP, and TPRP were; %64-%36, 9.44-6.45 days, 18.14-7.78 nymph/female, 0.12-0.75 days, and 7.44-8. 62 days, respectively (Table 1).

*Table 1*. Developmental times, longevity, survival rate and reproductive parameters of Aphis fabae on Salkım and Filiz-99 cultivars

| Stages and parameters | n | Salkım | n | Filiz-99 |
|---|---|---|---|---|
| | | Mean±SE | | Mean±SE |
| Nimf 1 | 50 | 1.86±0.05[b] | 50 | 2.08±0.06[a] |
| Nimf 2 | 49 | 2.04±0.09[a] | 42 | 2.29±0.10[a] |
| Nimf 3 | 47 | 2.00±0.13[a] | 35 | 2.00±0.12[a] |
| Nimf 4 | 32 | 1.47±0.13[b] | 18 | 2.22±0.19[a] |
| Preadult time | 32 | 7.31±0.16[b] | 18 | 8.50±0.32[a] |
| Survival rate (%) | 50 | 64[a] | 50 | 36[b] |
| Longevity | 32 | 20.59±1.33[a] | 18 | 10.84±1.00[b] |
| Reproductive period | 32 | 9.44±.1.07[a] | 18 | 6.15±1.35[b] |
| Fecundity | 32 | 18.34±2.26[a] | 18 | 7.78±2.16[b] |
| APRP* | 32 | 0.12±0.07[b] | 18 | 0.75±0.13[a] |
| TPRP** | 32 | 7.44±0.19[b] | 18 | 8.62±0.40[a] |

n: number of individual, APRP*: adult pre-reproductive period, TPRP**: total pre-reproductive period. *means in the same line fallowed by the same letter represent no significant difference between parameters (Bootstrap, P<0.05).

**Life table parameters**

The parameters were calculated according to the age-stage, two-sex life table program. The life table parameters of *A. fabae* on Salkım and Filiz-99 broad bean cultivars; the intrinsic rate of increase of (*r*), the finite rate of increase ($\lambda$), the net reproductive rate ($R_0$) and the mean generation time (*T*) were 0.20- 0.07 day$^{-1}$, 1.22-1.07 day$^{-1}$, 11.74-2.80 individuals/fertile, and 12.41-13.89 days, respectively (Table 2).

*Table 2*. Life table of *Aphis fabae* on Salkım and Filiz-99 cultivars

| Parameters | Salkım | Filiz-99 |
|---|---|---|
| | Mean±SE | Mean±SE |
| *r* (day$^{-1}$) | 0.20±0.01[a] | 0.07±0.03[b] |
| $\lambda$ (day$^{-1}$) | 1.22±0.02[a] | 1.07±0.03[b] |
| $R_0$ (individual) | 11.74±1.90[a] | 2.80±0.93[b] |
| *T* (day) | 12.41±0.26[b] | 13.89±1.23[a] |

n: number of individual, *r*: intrinsic rate of increase, $\lambda$: finite rate of increase, $R_0$: net reproductive rate, *T*: mean generation time. * means in the same line fallowed by the same letter represent no significant difference between parameters (Bootstrap, P<0.05).

The age and stage-dependent survival rate ($s_{xj}$) curves show the probability of a newly born nymph surviving to age '*x*' and stage '*j*'. The probability of a newly released *A. fabae* nymph surviving to the adult stage was shown on Salkım and Filiz-99 cultivars (Figure 1). In the graph given in Figure 1, the survival rates of each period can be observed from the raw data obtained from the “age-stage, two-sex life table” program, and the survival rate of each pre-adult period can be observed.

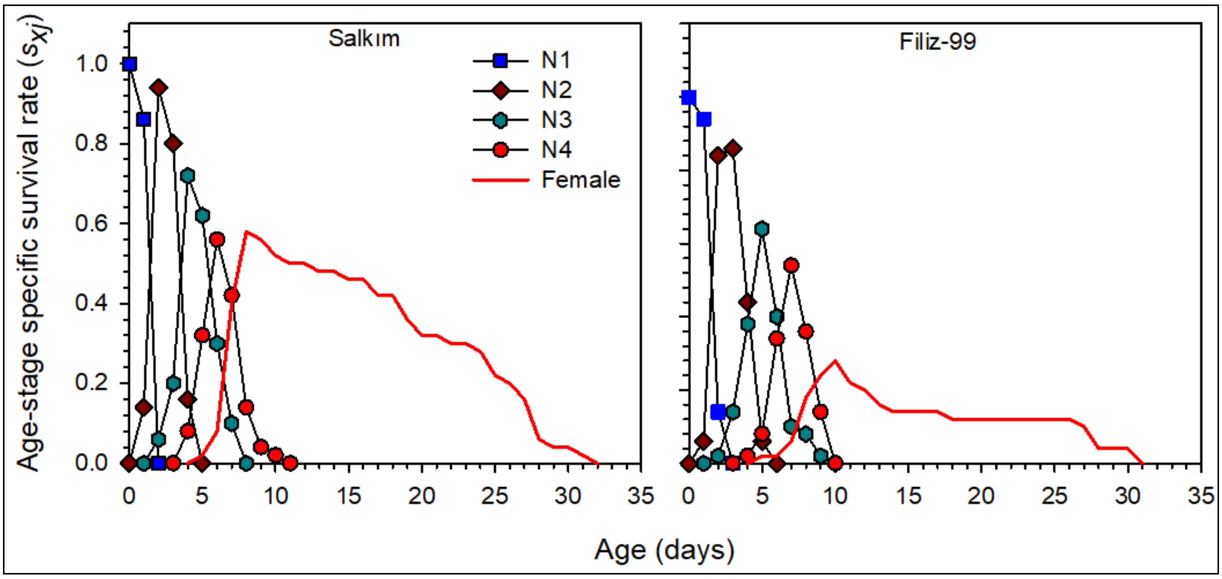


*Figure 1.* Age-stage specific survival rate of *Aphis fabae* on Salkım and Filiz-99 cultivars ($s_{xj}$)

The age-dependent survival rates ($l_x$), reproduction rate ($m_x$), and reproduction under the influence of maternity rates ($l_xm_x$) curves of all stages of *A. fabae* on Salkım and Filiz-99 cultivars are shown in detail in Figure 2. When the total age-dependent survival rate ($l_x$) of the pest is analyzed, it is observed that the age-dependent survival rate ($l_x$) of *A. fabae* decreases dramatically from day 5, on Salkım cultivar. When the maternity curve ($l_xm_x$) and fecundity curve ($m_x$) were analyzed, it was observed that the pest reached its highest levels between days 10 and 15 (Figure 2).

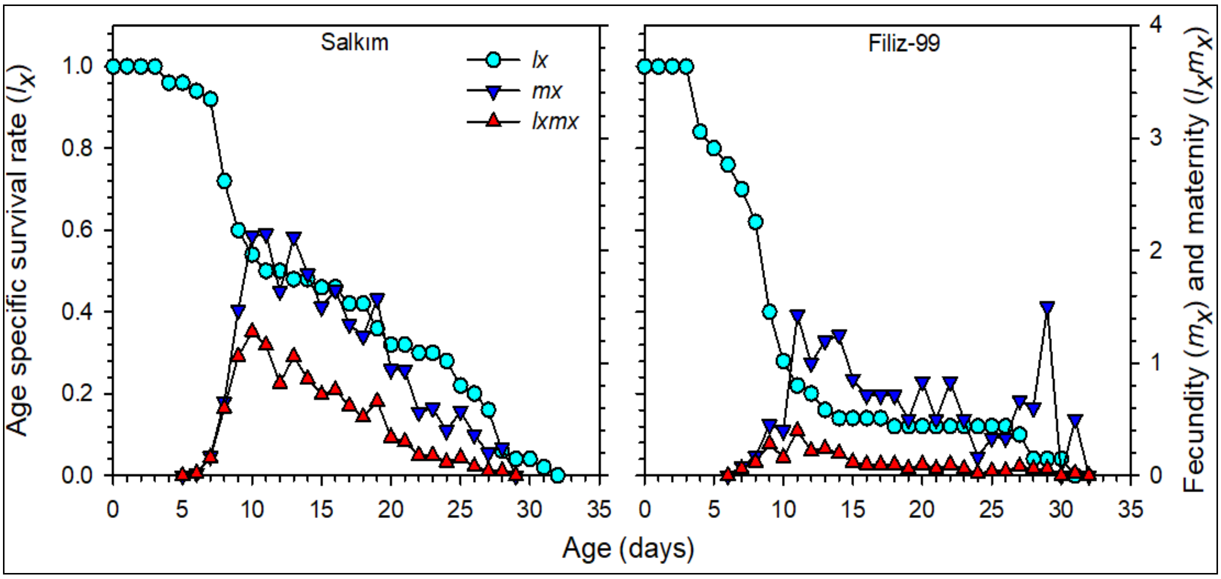


*Figure 2.* Age-specific survival rate ($l_x$), fecundity ($m_x$) and maternity ($l_xm_x$) of *Aphis fabae* on Salkım and Filiz-99 cultivars

The life expectancy curves ($e_{xj}$) calculated as a function of the survival rate are shown in detail in Figure 3 for the pre-adult and adult stages of the pest. It has been reported that the age, period, and sex of individuals affect the life expectancy curves, and that age-stage, two-sex life tables play an important role in revealing these differences and provide more effective results than traditional life tables based on female age (Huang and Chi, 2011).

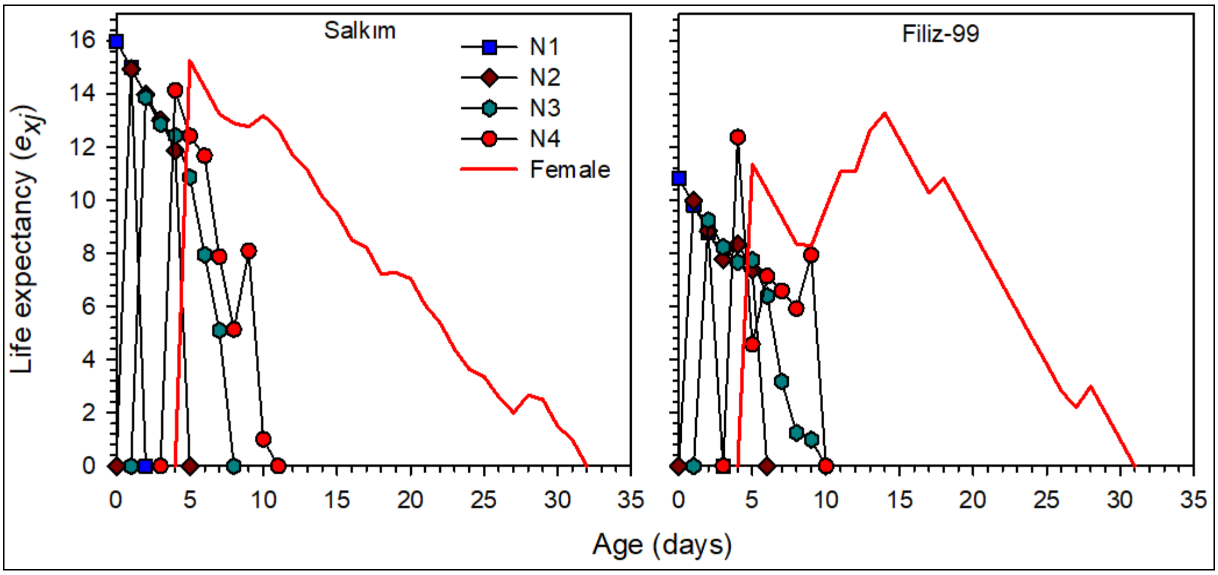


*Figure 3.* Age-stage specific life expectancy ($e_{xj}$) of *Aphis fabae* on Salkım and Filiz-99 cultivars

The reproductive value curves ($v_{xj}$), which reflect the contribution of the pest to the future population at any age and any period, varying as a function of survival rate, the intrinsic rate of increase, and daily reproduction, are shown in Figure 4 for the pre-adult and adult stages of *A. fabae* on Salkım and Filiz-99 cultivars. The highest contribution to the population was made by adult female individuals (Figure 4).

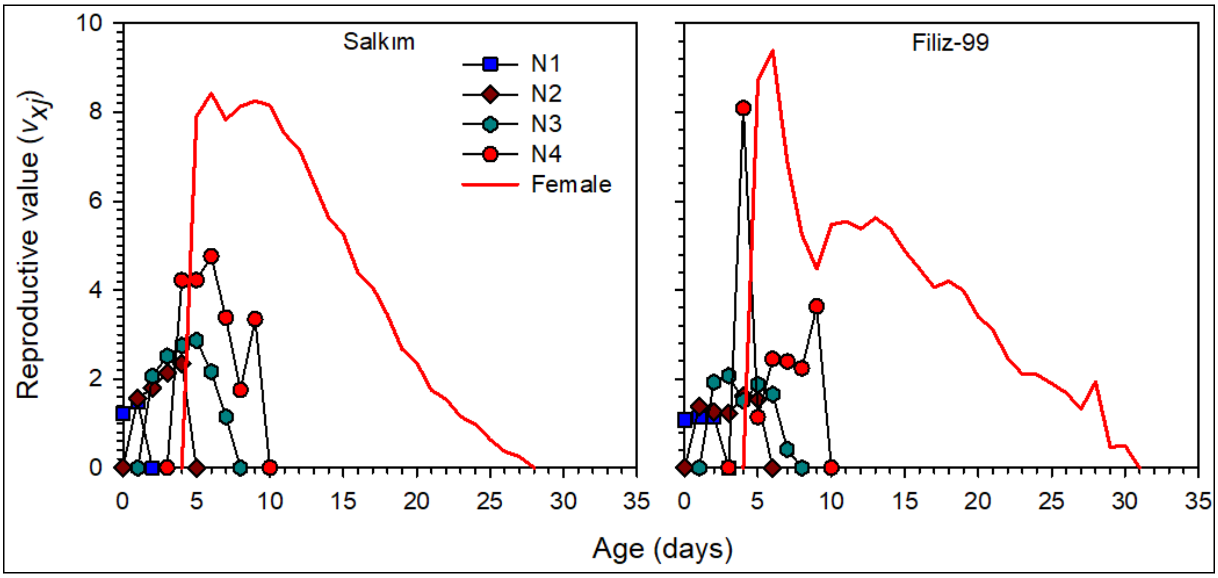


*Figure 4.* Age-stage specific reproductive value ($v_{xj}$) of *Aphis fabae* on Salkım and Filiz-99 cultivars

The number of individuals that 10 nymphs of *A. fabae* could reach at the end of 60 days was estimated for each biological period by Timing package program and the results are given in Figure 5.

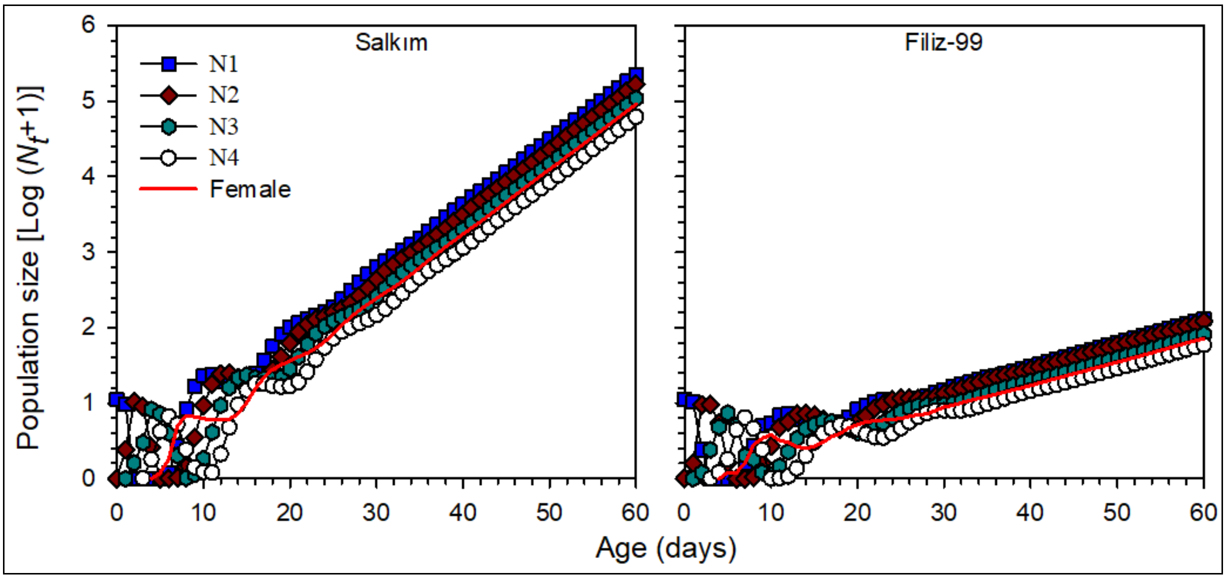


*Figure 5.* Population projection of *Aphis fabae* on cultivars (all stages) (log+1)

Different species or different cultivars of the same species affect the parameters of the insects such as development time, survival, and total development. The performance of insects may vary under different host and environmental conditions. Host preference and acceptance by aphids are directly related to the morphological, nutritional, and biochemical characteristics of plants (Thompson, 1988; Bernays and Chapman, 1994; Dixon, 1998). A plant reacts to an insect attack by increasing protein synthesis and gene expression which results in the activation of the plant's defensive mechanisms (Smith, 2005). In some cultivars that are less suitable for the pest, the attacked plant may increase the production of chlorophyll or protein to overcome the losses caused by the pest attack, triggering the processes of resistance (Bernardi et al., 2012). The performance of insects on plants is strongly affected by the mechanisms used by the plant against the insect, such as antibiosis, antixenosis, and tolerance (Painter, 1951; Horber, 1982; Emden, 2002). Antibiosis negatively affects the development, reproduction, and survival parameters of an insect, reducing the population growth rate in a resistant plant, while antixenosis negatively affects the activities of an insect such as feeding and oviposition in a resistant plant compared to a susceptible plant, and is also defined as non-preference (Hesler and Dashiell, 2011; Sulistyo and Inayati, 2016). There was a statistical difference between the total pre-adult development time, reproduction, survival rate, and longevity of the pest on the cultivars (Table 1). Significant statistical differences were observed especially in fecundity, survival rate, and longevity of *A. fabae* on the cultivars and these differences were almost doubled. (Table 1). Reproduction, development, and life table parameters affect the performance of insects, especially even a small reduction in the life table parameters can ultimately cause considerable change in a pest's population size (Goundoudaki et al., 2003). Ayvaz (2014) examined the reproduction, development, and life table parameters of *A. fabae* on 4 different bean cultivars (Alman ayşe, Balkız, Gina, and Öz ayşe) and reported that the total development time of *A. fabae* was 6.31, 5.84, 6.58 and 6.29 days, respectively, and statistically the lowest development time was observed in Balkız cultivar with 5.48 days and that the cultivars affected the development time of the pest. It is thought that the reason why the total development time we found in our study is different from this study is due to the different hosts used in our study. Akça et al. (2015) used four different constant temperatures (15, 20, 25, and 30°C) and 70% humidity- 16:8 light:dark conditions on broad bean 'Sevilla' cultivar to calculate the development, survival and reproduction parameters of *A. fabae* nymph: 1.49, 2nd nymph: 1.23, 3rd nymph: 1.21 and 4th nymph: 1.34 days, while the total pre-adult development time was calculated as 5.28 days. In our study, the pre-adult period and total development time at 25°C were 1.86, 2.04, 2.00, 1.47, and 7.31 days, respectively. Although the temperatures and pests were the same, different cultivars of broad bean plants were used in the two studies. It is thought that these differences are due to the different cultivars. Pre-oviposition period, oviposition period, post-oviposition period, reproduction rate, and longevity of *A. fabae* on cultivars are given in Table 1.

Generally, the biological parameters and performances of the pest were compared by using different temperatures and different cultivars in the studies. Ayvaz (2014) reported that the highest life span of *A. fabae* was 21.84 days in the “Balkız” cultivar and associated this difference with the cultivar difference due to the same climatic conditions. In our study, the life span of the pest was found to be 15.98 days, which is lower than the above-mentioned study, which can be explained by the cultivar difference. Especially in pests with more than 200 hosts such as *A. fabae*, such differences are explained by reasons such as host differences (Hodjat, 1986). Evaluation of pre-adult and adult survival rates of pests is of great importance in terms of control. Information such as which pest control measures or which period of the pest will be affected more by these measures can enable more effective control (Chi, 1988). Ayvaz (2014) reported that the survival rates of the pre-adult stages of *A. fabae* were different from each other. In our study, it was observed that the survival rates of each pre-adult stage of *A. fabae* were different from each other. In light of these data, it can be said that differences such as host, temperature, and cultivar affect the survival rates of the pest. In this study conducted by Razmjou and Fallahi (2009) to evaluate the development and reproductive parameters of *A. fabae* on 6 different sugar beet cultivars (BR1, Zarghan, 7233, PP22, PP36, and Polyrave), it was reported that the survival rates of the pre-adult stage were different in all cultivars. Golizadeh et al. (2016) reported that the pre-adult survival rates of *A. fabae* varied between 67.5% and 90%. In our study survival rates were 64% and 36% on Salkım and Filiz-99 cultivars, respectively.

When the life table parameters of the pest on two different cultivars were examined; a statistical difference was observed between all parameters (Table 2). The life table parameters of *A. fabae* on different cultivars of the same plant and different host plants may be similar or different. In a study using different faba bean cultivars (1, 4, 12, 3, 14), the intrinsic rate of increase (*r*) of *A. fabae* on cultivars was found to be 0.22±0.01, 0.23±0.02, 0.23±0.01, 0.22±0.01 and 0.24±0.01 day$^{-1}$, respectively, and was reported to be statistically indistinguishable (Meradsi and Laamari, 2016). In our study, the intrinsic rate of increase (*r*) was found to be 0.20±0.01 day$^{-1}$ and 0.07±0.03 day$^{-1}$ on Salkım and Filiz-99 cultivars which is close to the reported study, and it is thought that the reason for the close performance of *A. fabae* on the Salkım cultivar that it is the same plant.

Ayvaz (2014), using different bean cultivars, determined the intrinsic rate of increase (*r*) values of *A. fabae* as 0.39, 0.37, 0.33 and 0.33 day$^{-1}$, respectively. While the values of the intrinsic rate of increase in the aforementioned study were different from our study, this difference is thought to be due to host differences. In the 25°C experimental group of this study, the life table parameters were *r*: 0.44 day$^{-1}$, $R_0$: 77.46 nymph/female, $\lambda$: 1.54 day$^{-1}$ and *T*: 10.01 days (Akça et al., 2015) and these values were higher than the values in our study on cultivars. These life table parameters, which are higher than our study, may give us information about which cultivar is more susceptible or resistant. The fact that the life table parameters in this study are higher than our study indicates that the performance of the pest on the cultivar in this study is better, while the faba bean cultivar we used in our study is more resistant. The intrinsic rate of increase (*r*) is considered to be the most important parameter of life tables as it summarizes all parameters such as development, reproduction, and sex ratios (Birch, 1948; Carey, 1993). For this reason, evaluations are generally based on the intrinsic rate of increase. Golizadeh et al. (2016) evaluated the life table parameters of *A. fabae* on 5 different sugar beet cultivars (Doroti, Perimer, Pershia, Rozier, and 006). The intrinsic rate of increase (*rm*), the net reproductive rate ($R_0$), the finite rate of increase (λ), population doubling time (*DT*) and mean generation time (*T*) of *A. fabae* varied among cultivars and the highest intrinsic rate of increase value (*r*) was observed in "Pershia" cultivar with 0.45 day$^{-1}$ while the lowest value was 0.36 day$^{-1}$ in "Perimer" cultivar. As seen in the above-mentioned study, variables such as host plant and cultivar differences cause differences between the life table parameters of the pest.

When we look at the population size estimation of the pest on the varieties, it is seen that the pest can reach a much larger population on the Salkım variety compared to the Filiz-99 variety (Figure 6).

In our study, it was observed that reproductive performance decreased with increasing adult age. Akça et al (2014) found the highest age-specific reproduction rate ($m_x$) at 25°C to be approximately 5, while it was found between 2-3 on the Salkım cultivar in our study. It is thought that the difference between the comparative study and our study is due to the difference in cultivars. Akça et al. (2014) reported that life expectancy decreased in parallel with aging in their study using different temperatures. At 25°C, where we conducted our experiment, it was observed that the life expectancy curve did not decrease smoothly.

Akça et al. (2014) reported that *A.fabae* population does not show a stable distribution and the intrinsic rate of increase and reproductive rate are not sufficient parameters for population estimation. Similarly, population simulations based on the life table have been reported to provide advantages in biological control and pest damage level estimation (Yu et al., 2013; Tuan et al., 2014).

When both the cultivars in our study and the aforementioned studies were examined; the weakest performance of the pest in terms of reproduction, development, survival, and life table parameters was observed on the Filiz-99 cultivars (Table 1 - Table 2).

## CONCLUSIONS

To meet the food needs of the increasing World population, pesticides are used quite a lot in agricultural production. To prevent this and to make a healthier and more sustainable production in agriculture, the control methods to be chosen are of great importance. By trying different cultivars in the control of pests, by revealing the sensitivity and resistance of pests on these cultivars; it can be ensured that the use of chemicals is reduced or not used at all thanks to some cultivars. In our study, information that is thought to contribute to sustainable agriculture has been obtained with the data obtained in this direction, and comparisons and evaluations made. As a result, different cultivars, temperatures, and other conditions affect the reproduction, development, and life table parameters of the pest. A healthier control can be done by minimizing the damage caused by pests such as aphids by selecting resistant cultivars, especially without the need for chemical control. Knowing the performance of a pest on cultivars can help the producer to produce healthy and plenty of products.

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