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Effect of different Citrus host plants and temperatures on development rate and fecundity of apterous ***Aphis gossypii*** Glover (Homoptera: Aphididae)

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Summary

The developmental time, survivorship, and reproduction of the cotton aphid, ***Aphis gossypii*** Glover (Homoptera: Aphididae), were evaluated on detached citrus leaves of four citrus species (grapefruit cv. Star ruby, lemon cv. Interdonato, Satsuma mandarin cv. Okitsu, sweet orange cv. Washington navel) at constant 25 °C. In addition, the same parameters were assessed on excised grapefruit leaves (cv. Star ruby) at two constant temperatures (20 and 30 °C). All experiments were conducted in temperature cabinets in the laboratory at 5000 Lux light intensity.

A. gosspyii showed a better performance on grapefruit than on sweet orange, mandarin or lemon. This was mainly due to a short developmental period (6.4 days) and high fecundity (14.1 nymphs/female) resulting in a comparable short mean generation time (T_0= 11.3 days) and a high net reproduction rate (R_0= 14.5 females/female). The highest intrinsic rate of increase was determined on grapefruit (r_m= 0.3024 ♀♀/♀/day), the lowest one was observed on lemon (0.1244 ♀♀/♀/day).

Developmental periods of immature stages of ***A. gossypii*** varied from 7.4 days at 20 °C to 5.9 days at 30 °C. The average longevity of adult females was reduced from 28.8 days at 20 °C to 12.7 days at 30 °C. Mean generation time of the population ranged from 9.1 days at 30 °C to 13.2 days 20 °C. The net reproduction rate per female was 9.0 ♀♀/♀/day at 20 °C, 14.5 at 25 °C and 1.5 at 30 °C. The highest intrinsic rate of increase occurred at 25 °C (r_m= 0.3024 ♀♀/♀/day), the lowest at 30 °C (r_m= 0.0455 ♀♀/♀/day).

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Grapefruit was the superior citrus host plant of ***A. gossypii*** and the optimal range of temperature for population growth on citrus was 25 °C.

Key words: ***Aphis gossypii,*** developmental time, longevity, fecundity, citrus
Anahtar sözcükler: ***Aphis gossypii,*** gelişme süresi, ömür, üreme gücü, turunçgil

Introduction

Aphis gossypii Glover (Homoptera: Aphididae) is a cosmopolitan, polyphagous species widely distributed in tropical, subtropical and temperate regions. The cotton aphid is a pest of cotton, cucurbits and citrus, and in temperate zones principally attacks vegetables and ornamentals in field and greenhouses (Leclant and Deguine, 1994). ***A. gossypii*** causes direct damage, resulting from search of food that may induce plant deformation and indirect damage caused either by honeydew or by transmission of viruses. This aphid is the vector of 76 virus diseases in a very large range of plants (Chan et al., 1991) of which citrus tristeza virus (CTV), causing quick decline in citrus is a most important threat to the Turkish citrus industry (Çınar et al., 1993).

A. gossypii was long considered as a minor pest on citrus in the east Mediterranean region of Turkey (Dolar, 1976; Soylu and Ürel, 1977; Kansu and Uygun, 1980; Uygun and Şekeroğlu, 1981). However, in recent years the cotton aphid has emerged as one of the main aphid species attacking citrus (Yumruktepe and Uygun, 1994). Besides appearance of insecticide resistance (Takada and Murakami, 1988; O'Brein and Graves, 1992; Yumruktepe, 1993) and the elimination of benefical insects, changes in nutritional and bioclimatic factors may result in conditions more favorable to ***A. gossypii***, which in consequence may account for the increasing pressure on citrus. Despite the worldwide importance of ***A. gossypii*** as a pest of citrus and as vector of CTV, very few studies on its biological parameters on citrus have been reported in literature (Komazaki, 1982; Roistacher et al., 1984).

Published data on temperature depended development and fecundity of the cotton aphid signify important differences with regard to temperature, host plant and geographical region (Isely, 1946; Komazaki, 1982; Liu and Perng, 1987; Akey and Butler, 1989; Aldyhim and Khalil, 1993; Kocourek et al., 1994; van Steenis and El-Khawass, 1995, Kersting et al., 1998). Furthermore, more recent studies provided strong evidence that genetically distinct host races exist in ***A. gossypii***. Cotton aphid clones from cucumber badly performed on chrysanthemum and vice versa those from chrysanthemum poorly developed on cucumber (Guldemond et al., 1994). Host incompatibility was also reported for ***A. gossypii*** from cotton that did not survive on melon or eggplant (Deguine, 1992).

Thus, developmental and fecundity data for ***A. gossypii*** on one crop and from one region should be used with caution if applied to different crops and regions (Akey and Butler, 1989).

The present study was designed to provide primarily data on developmental rate and fecundity of a local citrus population of ***A. gossypii*** on different citrus species and at different constant temperatures in the laboratory. This knowledge may prove useful in understanding the population dynamics of ***A. gossypii*** on citrus in the east Mediterranean region of Turkey and the epidemiology of the viruses it transmits.

Materials and Methods

A. gossypii were obtained from sour orange trees near Adana in the east Mediterranean region of Turkey in March 1997 and colonized on detached grapefruit leaves cultivar Star ruby at 25±1 °C, 65±10 %r.h. and 16 h of artificial light of about 5.000 Lux in a temperature cabinet. Aphids had been reared in laboratory for two to four generations before individuals were used in the experiments.

Randomly selected apterous females from the stock culture were transferred onto excised citrus leaf disks placed upside down on wet cotton in Petri dishes (ø 5 cm). Offspring born within 24 h was confined individually on cotton leaf disks in Petri dishes. All replications in which nymphs died within 24 h after transfer were omited. The cotton in Petri dishes was wetted daily and every 3-5 days aphids were transferred to new citrus leaf disks. Young and soft, but fully expanded leaves used in the experiments were obtained from greenhouse-grown citrus plants that were between 1-2 years of age.

Experiments were conducted on four different citrus species: grapefruit cultivar Star ruby, lemon cultivar Interdonato, Satsuma mandarin cultivar Okitsu, and sweet orange cultivar Washington navel at a constant temperatures of 25±1 °C. In addition, temperature experiments were carried out at two different temperatures (20 and 30±1 °C) on grapefruit leaf disks cultivar Star ruby. All experiments were done in temperature cabinets set at 60±5 %r.h. and 16 h of artifical light (5000 Lux). ***A. gossypii*** immature stages and adults were observed daily on all citrus host plants and at all temperatures and their survivorship recorded. The exuviae were used to determine molting time; new born larvae were removed after counting.

Differences in developmental time, longevity, and fecundity were tested by analysis of variance (ANOVA). If significant differences were detected, multiple

comparisons were made using LSD test (α= 0.05). Each of the analysis were conducted using Statgraphics software package (Anonymous, 1988).

Mean generation times, net reproduction rates, and population growth rates were calculated from the equations of Lotka (Birch 1948):

$$T_0 = \Sigma (x * 1_x * m_x) / \Sigma 1_x * m_x \quad (1)$$

$$R_0 = \Sigma 1_x * m_x \quad (2)$$

$$1 = \Sigma e^{-r*x} 1_x * m_x \quad (3)$$

in which: x= age in days (including immature stages), r= intrinsic rate of increase, 1_x= age specific survival (including immature mortality), m_x= age specific number of female offspring.

Results

Effect of citrus host plant

A. gossypii-nymphs developed significantly faster on grapefruit (6.4 days) and sweet orange (6.6 days) than on lemon (7.7 days) or mandarin (7.4 days) (Table 1). The four different citrus varieties tested showed only little influence on longevity (from first nymphal stage till death) ranging between 22.0 and 24.4 days ***A. gossypii*** confined to lemon displayed a significant lower fecundity (4.0 nymphs/female) than those enclosed either with grapefruit, mandarin or sweet orange.

Table 1. Developmental time, longevity and fecundity of ***Aphis gossypii*** on excised citrus leaf disks of four different citrus species at 25 °C in the laboratory

Citrus host plant	n	Developmental time (days) (mean±SEM)	Longevity (days) (mean±SEM)	Total number of offspring (mean±SEM)
Grapefruit	24	6.4±0.23a	23.9±1.77a	14.1±2.00a
Lemon	21	7.7±0.35b	22.0±1.81a	4.0±1.04b
Mandarin	26	7.4±0.33b	24.4±2.05a	17.0±2.65a
Sw. orange	28	6.6±0.33a	23.2±1.76a	14.6±1.93a

Means in columns followed by the same letter are not significantly different by LSD test (α= 0.05)

Survival rates (1_x) of ***A. gossypii*** on the four different citrus species were mainly affected by age and only slightly influenced by the host plant (Fig. 1). Aphids confined to grapefruit and sweet orange showed a distinct peak in nymph

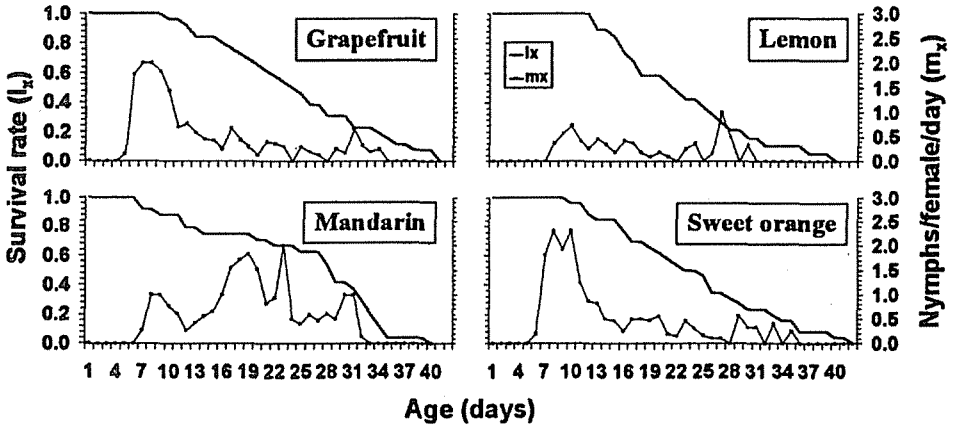

Figure 1. Age-specific survival rate (lx) and age-specific fecundity (m_x) of ***Aphis gossypii*** on excised citrus leaf discs of four different citrus species at 25 °C in the laboratory.

production (m_x) between the 7th and 12th day, valuing 2.0 and 2.3 nymphs/female/day, respectively. In contrast no discrete peak in reproduction was observed on lemon. On mandarin, the maximum number of nymphs/female/day was produced between day 19 and 25 and thus, much later than on any other citrus host plant.

The longest mean generation time (T_0) occurred on mandarin with 18.2 days, followed by lemon wih 14.4 days. Only slight differences were observed between grapefruit and sweet orange (Table 2). Net reproductive rate (R_0) of ***A. gossypii*** on lemon was as less as 4.9 ♀♀/♀, whereas only slight differences were found among the three other host plants ranging from 14.5 to 15.5 ♀♀/♀. Aphids enclosed with grapefruit leaves had the highest intrinsic rate of increase (r_m) (0.3024 ♀♀/♀/day) while ***A. gossypii*** on lemon displayed the lowest (0.1244 ♀♀/♀/day).

Table 2. Mean generation time (T_0), net reproductive rate (R_0), and intrinsic rate of increase (r_m) of ***Aphis gossypii*** on excised citrus leaf disks of four different citrus species at 25 °C in the laboratory

Citrus host plant	Mean generation time (T_0) (days)	Net reproduction rate (R_0) (♀♀/♀)	Intrinsic rate of increase (r_m) (♀♀/♀/day)
Grapefruit	11.3	14.5	0.3024
Lemon	14.4	4.9	0.1244
Mandarin	18.2	15.5	0.1846
Sw. orange	11.8	14.6	0.2743

Effect of temperature

The developmental time of ***A. gossypii*** on grapefruit significantly decreased with increasing constant temperatures ranging from 5.9 days at 30 °C to 7.4 days at 20 °C (Table 3). The shortest longevity (from first nymphal stage till death) occurred at 30 °C averaging 12.7 days, whereas aphids in the two other treatments survived 23.9 and 28.8 days. Fecundity of ***A. gossypii*** on citrus strongly depended on temperature, being significantly highest at 25 °C with 14.1 nymphs/female and lowest at 30 °C with on average only 2.0 nymphs/female.

Table 3. Developmental time, longevity, and fecundity of ***Aphis gossypii*** on excised grapefruit leaves at three different constant temperatures in the laboratory

Temperature (°C)	n	Developmental time (days) (mean±SEM)	Longevity (days) (mean±SEM)	Total number of offspring (mean±SEM)
20±1	31	7.4±0.14c	28.8±1.98b	9.2±0.94b
25±1	24	6.4±0.23b	23.9±1.77b	14.1±2.00c
30±1	20	5.9±0.39a	12.7±1.46a	2.0±0.47a

Means in columns followed by the same letter are not significantly different by LSD test (α= 0.05)

The maximum number of nymphs/day was produced at 25 °C with on average 2.0 nymphs/female/day at the 11th day, the lowest number at 30 °C with as less 0.6 nymphs/female/day at the 9th day (Fig. 2). Warmer temperature had a detrimental effect on the survival rate of ***A. gossypii*** on grapefruit. At 30 °C already 30 % of the aphids were dead before aphids started to reproduce whereas no or very few mortality occurred at 25 and 20 °C till the maximum of nymph production passed.

Increasing temperatures resulted in shorter mean generation times of ***A. gossypii*** on citrus with 13.2 days at 20 °C and 9.1 days at 30 °C (Table 4). The

Table 4. Mean generation time (T_0), net reproductive rate (R_0), and intrinsic rate of increase (r_m) of ***Aphis gossypii*** on excised grapefruit leaves at three different constant temperatures in the laboratory

Temperature (°C)	Mean generation time (T_0) (days)	Net reproduction rate (R_0) (♀♀/♀)	Intrinsic rate of increase (r_m) (♀♀/♀/day)
20±1	13.2	9.0	0.1840
25±1	11.3	14.5	0.3024
30±1	9.1	1.5	0.0455

net reproductive rate was highest at 25 °C (14.5 ♀♀/♀) and lowest at 30 °C with as less as 1.5 ♀♀/♀. ***A. gossypii***-populations kept at 25 °C showed the highest per capita rates of population growth (r_m= 0.3024 ♀♀/♀/day). The 20 °C and 30 °C treatments resulted in a sharp reduction of the per capita growth rate of the cotton aphid on grapefruit.

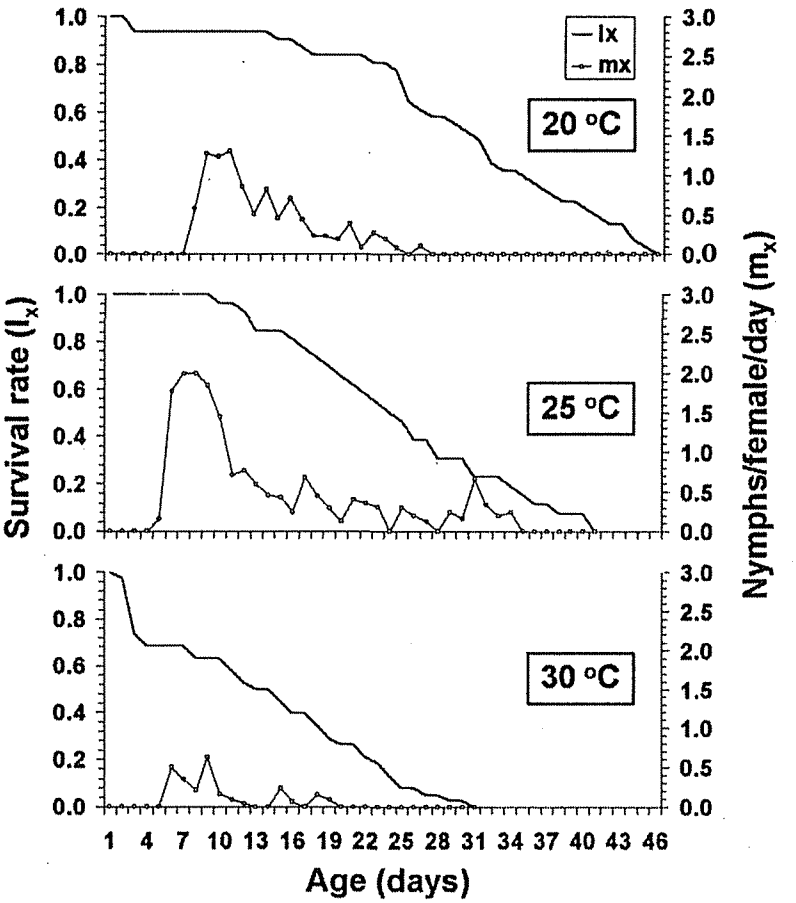

Figure 2. Age-specific survival rate (l_x) and age-specific fecundity (m_x) of ***Aphis gossypii*** on excised grapefruit leaves at three different constant temperatures in the laboratory.

Discussion

A. gossypii developed better on grapefruit than on sweet orange, mandarin or lemon. In particular, the bad performance on lemon was due to a significantly prolonged developmental time and a strongly reduced fecundity. On

mandarin, a long mean generation time resulted in a low per capita growth rate of the cotton aphid. The unsuitability of lemon as host plant for the cotton aphid is supported by the results of Yumruktepe and Uygun (1994), who found less ***A. gossypii*** on citrus in regions where mostly lemon trees are grown (İçel) compared to those areas where sweet orange and grapefruit are the predominant citrus species (Adana). Furthermore, the widespread cultivation of lemon does not only affect the abundance of ***A. gossypii*** in an area but also act upon the spread of CTV by its vector insect. In Spain, the field transmission of CTV was significant lower in areas with a high portion of lemon trees than in areas where mostly sweet orange was grown (Hermoso de Mendoza et al., 1988). In coincidence with these field results, Roistacher et al. (1984) reported that ***A. gossypii*** significantly preferred grapefruit and sweet orange over lemon in host-plant-choice experiments in the laboratory.

Despite insects are not subjected to constant temperatures in nature, controlled laboratory studies can provide a valuable insight of the population dynamics of aphids. Our results reported here clearly show the effects of temperature on the developmental time, longevity and fecundity of ***A. gossypii*** on citrus.

Optimum temperature for nymphal development of ***A. gossypii*** on citrus was 30 °C and thus, essential the same than the 29.7 °C observed for this species on Satsuma mandarin in Japan (Komazaki, 1982) and for a Turkish cotton population on cotton (Kersting et al., 1998). The optimum temperature of 25 °C for maximal production of nymphs per day in this study was lower than those determined by Akey and Butler (1989) (27.5 °C) on cotton and Liu and Perng (1987) on bottle guard cucurbit (27 °C), but much higher than the 20 °C reported by Komazaki (1982) for a Japanese cotton aphid colony obtained from citrus.

The intrinsic rate of natural increase (r_m) is a good indicator of the temperature at which the growth of population is most favorable, because it reflects the overall effects of temperature on development, reproduction, and survival characteristics of a population. ***A. gossypii*** kept at 25 °C had the highest r_m-value among all temperatures (r_m= 0.3024 ♀♀/♀/day), because of its faster development and the high daily rate of progeny. In contrast, the population exposed to 20 °C had a prolonged developmental time and a low number of progeny, resulting in a much smaller intrinsic rate of increase.

The intrinsic rate of increase of ***A. gossypii*** on citrus was considerably lower than those computed for the cotton aphid on cotton, cucumber and squash at comparable temperatures (Aldyhim and Khalil, 1993; Kocourek et al., 1994; van Steenis and El-Khawass, 1995; Kersting et al., 1998). Komazaki (1982)

showed that the highest population growth rate ($r_m \approx$ 0.32 ♀♀/♀/day) of a citrus population of ***A. gossypii*** occurred at 19.8 °C. Different climates in the Japanese citrus-growing areas (winter-cold) and the east Mediterranean region of Turkey (mediterranean-subtropical climate) may account for the large differences in performance of both citrus population of ***A. gossypii*** at the same temperature.

Özet

Değişik turunçgil türlerinin ve sıcaklıkların kanatsız *Aphis gossypii* Glover (Homoptera: Aphididae)'nin gelişme süresi ve üreme gücüne etkisi

Pamuk yaprakbiti, ***Aphis gossypii*** Glover (Homóptera: Aphididae)'nin gelişme süresi, yaşam oranı ve üreme kapasitesi dört farklı turunçgil türünden (altıntop (Star ruby), limon (Interdonato), Satsuma mandarin (Okitsu), portakal (Washington navel)) kesilmiş yapraklar üzerinde 25 °C sabit sıcaklıkta araştırılmıştır. Bunun yanında ayrıca farklı iki sabit sıcaklıkta (20 ve 30 °C) kesilmiş altıntop (Star ruby) yaprakları üzerinde aynı parametreler araştırılmıştır. Tüm denemeler laboratuvarda bulunan 5000 lux ışık yoğunluğuna sahip iklim dolaplarında yürütülmüştür.

A. gossypii altıntop üzerinde portakal, mandarin ve limona göre daha iyi bir gelişme göstermiştir. Bunun esas nedeni, kısa gelişme süresi (6.4 gün), ömür boyu verdiği yüksek yavru sayısı (14.1 nimf/dişi), kısa ortalama döl süresi (T_0= 11.3 gün) ve yüksek net üreme gücü (R_0= 14.5 ♀♀/♀/gün)'dür. En yüksek kalıtsal üreme yeteneği altıntopta (r_m= 0.3024 ♀♀/♀/gün) beklenirken, en düşük olarak ise limonda (0.1244 ♀♀/♀/gün) saptanmıştır.

A. gossypii'nin gelişme süresi 20 °C'de 7.4 gün iken 30 °C'de 5.9 gün olmuştur. Ergin dişilerin ortalama yaşam süreleri 20 °C'de 28.8 gün olurken, 30 °C'ye doğru bir azalma göstererek 12.7 güne düşmüştür. Ortalama döl süresi ise 30 °C'de 9.1 gün, 20 °C'de ise 13.2 gün olmuştur. Net üreme gücü 20 °C'de 9.0, 25 °C'de 14.5 ve 30 °C'de ise 1.5 ♀♀/♀ olarak saptanmıştır. En yüksek kalıtsal üreme yeteneği 25 °C'de (r_m= 0.0455 ♀♀/♀/gün) gerçekleşmiştir.

Denemeye alınan turunçgil türleri arasında altıntop ***A. gossypii***'nin en iyi konukçusu olarak bulunurken, populasyon gelişmesi için en uygun sıcaklığın ise 25 °C olduğu ortaya çıkarılmıştır.

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