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Development and Fecundity of *Aphis Gossypii* Glover (Homoptera: Aphididae) on Three Malvaceae Hosts

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Abstract: *Aphis gossypii* Glover (Homoptera, Aphididae) obtained from cotton fields near Adana in the east Mediterranean region of Turkey were colonized on *Gossypium hirsutum* L. 'Çukurova 1518' in a climatic room. The effect of host transfer from cotton to common mallow, *Malva sylvestris* L., and okra, *Abelmoschus esculentus* (L.) Moench 'Bamya 501', on performance of *A. gossypii* was studied at constant 25 ± 1°C, 60 ± 5 % relative humidity and 16 h of artificial light (5000 lux) in temperature cabinets. Three subsequent generations of *A. gossypii* from cotton were additionally tested on okra. Fecundity tables were constructed to compare the performance of the cotton aphid on the three different Malvaceae hosts.

Developmental time (6.0 days) was longer and fecundity reduced (4.5 nymphs/aphid) on okra compared to common mallow (5.6 days and 62.8 nymphs/aphid) and cotton (5.5 days and 37.9 nymphs/aphid). The highest age-specific number of nymphs (m_x) occurred on common mallow at an age of nine days with 6.8 nymphs/aphid, and the lowest on okra with only 1.2 nymphs/aphid at the ninth day. *A. gossypii* on cotton produced a maximum age-specific number of nymphs at day ten with 3.4 nymphs/aphid. Generation times (T_o) were similar for all three host plants, however, the mean number of aphids laid during an individual's lifetime (Ro) varied largely between 4.2 aphids/aphid on okra to 65.7 nymphs/aphid on common mallow. The significantly lowest intrinsic rate of increase (r_m) (0.129 aphids/aphid/day) was calculated for *A. gossypii* on okra. Even after three subsequent generations on okra, the performance did not improve, indicating that genetically distinct host races exist in *A. gossypii*. On common mallow an r_m-value of 0.397 aphids/aphid/day occurred, whilst on cotton the intrinsic rate of increase was significantly lower with 0.338 aphids/aphid/day.

Aphis gossypii Glover (Homoptera: Aphididae)'nin üç Malvaceae bitkisinde gelişme süreleri ve üreme güçleri

Özet: Doğu Akdeniz Bölgesi'nde Adana yakınlarındaki bir pamuk tarlasından elde edilen *Aphis hossypii* Glover (Homoptera: Aphididae) bireyleri iklimlendirme odasında *Gossypium hirsutum* L. (Çukurova-1518) üzerinde kültüre alınmıştır. Pamuktan ebegümecine (*Malva sylvestris* L.) ve bamya (*Abelmoschus esculentus* (L.) Moench)'nın "Bamya 501" çeşidine yapılan konukçu değiştirmelerinin *A. gosypii* performansına etkisi 25±1°C sıcaklık, %60±5 nem ve 16 saat aydınlatmalı (5000 lüx) iklimlendirme dolaplarında çalışılmıştır. Ek olarak pamuktan alınan *A. gosypii* bireylerinin birbirini takip eden üç döl boyunca bamya üzerindeki performansları incelenmiştir. Elde edilen verilerden *A. gossypii*'nin üç değişik Malvaceae bitkisi üzerindeki performanslarını karşılaştırmak için üreme güçleri ile ilgili tablolar oluşturulmuştur.

A. gossypii'nin bamya üzerindeki gelişme süresi 6.0 gün ile en uzun, bırakılan yavru sayısı ise 4.5 nimf/afid ile en az olurken bu değerler ebegümecinde 5.6 gün ve 62.8 nimf/afid ve pamukta da 5.5 gün ve 37.9 nimf/afid olarak bulunmuştur. En fazla birey başına yavru sayısı (mx) dokuzuncu günde 6.8 nimf/afid olarak ebegümecinde, en az ise yine dokuzuncu günde 1.2 nimf/afid değerleriyle bamyada gerçekleşmiştir. Pamukta ise *A. gossypii* birey başına en fazla yavru sayısını 10. günde 3.4 nimf/afid olarak bırakmıştır. Döl süresi (T_o) her üç konukçuda da birbirine yakın olurken, tüm yaşam boyunca birey başına bırakılan ortalama yavru sayısı (R_o); bamyada 4.2 afid/afid bulunurken ebegümecinde 65.7 afid/afid olarak zok büyük bir değişim göstermiştir. En düşük kalıtsal üreme yeteneği (r_m) 0.129 afid/afid/gün ile bamya üzerindeki *A. gossypii* bireylerinde hesaplanmıştır. *A. gossypii*'nin bamya üzerinde birbirini takip eden üç dölden sonra bile performansı gelişmemiştir, bu da genetiksel farklı ve belirgin konukçu ırkları bulunduğunun bir göstergesidir. Ebegümecinde r_m değeri 0.397 afid/afid/gün olarak bulunurken pamukta ise 0.338 afid/afid/gün değeri ile ebegümecine göre daha düşük olmuştur.

Introduction

The cotton or melon aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), is a cosmopolitan, polyphagous species widely distributed in tropical, subtropical, and temperate regions. This aphid is a pest of cotton, cucurbits and citrus, and in temperate zones principally attacks vegetables in fields and greenhouses (1, 2). *A. gossypii* causes direct damage, resulting from searches for food that may induce plant deformation and indirect damage caused either by honeydew or by transmission of viruses. The cotton aphid is the vector of 76 virus diseases in a very large range of plants (3).

The cotton aphid was long considered as a minor pest in the eastern Mediterranean region of Turkey (4-6). In recent years, however, *A. gossypii* has emerged as one of the main aphid species attacking citrus, cotton, cucurbits, and greenhouse-grown vegetables (7-9). Besides the appearance of insecticide resistance (10-13) and the elimination of beneficial insects, changes in nutritional and bioclimatic factors may result in conditions more favorable to *A. gossypii*, which in consequence may account for increasing pressure on crop plants.

In spite of its large host plant range (1, 2, 14, 15), it is well known that the performance of *A. gossypii* originating from different plant hosts and/or geographical regions varies largely among different host plant species and regions (1, 16-20). Furthermore, more recent studies provided strong evidence that genetically distinct host races exist in *A. gossypii*. Cotton aphid clones from cucumber performed badly on chrysanthemum and similarly those from chrysanthemum developed poorly on cucumber (21). Genetically distinct forms of *A. gossypii* were also reported from cotton and cucumber (22).

From the present knowledge, it may be concluded that the existence of host incompatibility and host races is a common phenomena in *A. gossypii*. To determine the importance of the host plant for the performance of the cotton aphid, its host plant relationship should be therefore studied in more detail. Thus, the aim of the present study was to determine the suitability of three different Malvaceae hosts for the development and reproduction of a cotton population of *A. gossypii* under constant conditions in the laboratory.

Material and Methods

A. gossypii were obtained from cotton fields near Adana in the eastern Mediterranean region of Turkey and colonized on *Gossypium hirsutum* L. 'Çukurova 1518' at 26±2°C, 65 ± 10 % relative humidity and 16 h of artificial light of about 10,000 lux in a climatic room. Aphids had been reared in laboratory for more than one year before being used in the experiments. Host plants were greenhouse-grown cotton 'Çukurova 1518' and okra, *Abelmoschus esculentus* (L.) Moench 'Bamya 501', as well as field-grown common mallow, *Malva sylvestris* L. Leaves of the greenhouse-grown plants used in the experiments were between 4 - 6 wk of age; fully expanded, but tender leaves of common mallow were collected in the field in April/May.

Randomly selected apterous females from the stock culture were transferred onto excised leaf disks of each of the three host plants placed upside down on wet cotton wool in the Petri dishes (5 cm diameter). Offspring born within 24 h were individually confined on leaf disks in the Petri dishes. All replications in which nymphs died within 24 h after transfer or in which individuals were lost during the experiment were omitted. The cotton wool in the Petri dishes was saturated daily with water and every 3 - 5 days aphids were transferred to new leaf disks. The experiments were terminated after 20 days.

In addition, the developmental time and fecundity of *A. gossypii* were determined for three subsequent generations on okra. The experimental design was essentially the same as described above. When the first generation aphids became adults, they were used to produce the experimental larvae for the second generation. Similarly, a third generation was produced.

The experiments were conducted at constant 25 ± 1°C , 60±5 % relative humidity and 16 h of artificial light (5000 lux) in temperature cabinets. Immature and adult specimens were observed daily and their survivorship recorded. The exuviae were used to determine molting time; new born larvae were removed after counting.

Differences in developmental time and fecundity were tested by analysis of variance (Anova). If significant differences were detected, multiple comparisons were made using the Scheffé test (p=0.01). For each host plant survival curves were calculated employing a product limit technique. Individuals that were still alive at the end of the 20-day experiment period were censored. Survival curves were analyzed using the log rank test and the Chi-square test was used to separate differences among curves.

Population growth rates were computed from the equation of Lotka (23):

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

in which: x = age in days, r = intrinsic rate of increase, 1_x = age-specific survival, m_x = age-specific number of female offspring.

After "r" was computed for the original data (r_{all}), differences among r_m-values were tested for significance by estimating variances through the jackknife method (24). The jackknife pseudo-value "r_j" was calculated for the "n" samples using the following equation:

$$r_j = n * r_{all} - (n-1) * r_i \qquad (2)$$

The mean of "n" jackknife pseudo-values for each treatment was subjected to analysis of variance. The scheffé test was used to compare mean growth rates for different host plants ($p = 0.01$). Because low probability levels were used, there was no concern about inflation of experiment-wise error rates (25). Each of the above-mentioned analyses were conducted using the Statgraphics software package.

Results

Mortality of *A. gossypii* nymphs as considerably low for all three host plants tested, with a maximum rate of 4.4% on okra (table 1). Developmental time lasted 5.5 days on cotton and 5.6 days on common mallow. This was shorter than that of A. gossypii confined to okra with 6.0 days. The host plant strongly affected the fecundity of *A. gossypii*. As many as 62.8 nymphs/aphid were produced on common mallow within 20 days, whilst the reproduction was significantly lower on cotton (37.9 nymphs/aphid). On average, only 4.5 nymphs/aphid were deposited on okra (table 1).

The course of the age-specific survival rate (1_x) and the age-specific number of progeny per day (m_x) of A. *gossypii* for each host plant are presented in figure 1. Adult mortality on common mallow and cotton depended strongly on age, whilst for *A. gossypii* on okra mortality increased considerably shortly after the peak in nymph production. Survival curve analyses revealed that significant differences exist among the three host plant tested (Chi-squared = 55.7; df = 2; $p < 0.0001$). The median and the form of the survival curve of the *A. gossypii* population enclosed with okra was significantly different from that on common mallow (Chi-squared = 27.82; df = 1; $p < 0.0001$) and cotton (Chi-squared = 45.2; df = 1; $p < 0.0001$). No significant differences were observed between the survival curves of *A. gossypii* on common mallow and cotton at the 1% level (Chi-squared = 3.9; df = 1; $p = 0.0481$).

The highest age-specific number of nymphs per aphid and day (m_x) occurred on common mallow at an age of nine days with 6.8 nymphs/aphid, and the lowest on okra with only 1.2 nymphs/aphid on the ninth day. *A. gossypii* on cotton produced a maximum number of nymphs on day ten with 3.4 nymphs/aphid (figure 1). The generation time (T_o) of *A. gossypii* on the three Malvaceae hosts ranged between 11.1 days (okra) and 12.8 days (cotton) (table 2). Because *A. gossypii* has overlapping generations, the definition of R_o, generally referred to as net reproductive rate, is more limited here and only depicts the mean number of aphids laid during an individual's lifetime. R_o-values for the cotton aphid were calculated to be 65.7 nymphs/aphid on common mallow, 36.3 nymphs/aphid on cotton and 4.2 nymphs/aphid on okra. The highest intrinsic rate of increase (r_m) occurred on common mallow with 0.397 aphids/aphid/day and the lowest on okra with only 0.129 aphids/aphid/day. The mean intrinsic rate of increase for *A. gossypii* on cotton was calculated to be 0.338 aphids/aphid/day.

Table 1. Mortality, developmental time, and fecundity of a cotton population of Aphis gossypii on three different Malvaceae hosts at 25°C in the laboratory

Host plant	n	Nymphal mortality rate (%)	Developmental time (days) Mean ± SEM	1st nymph-1st nymph(days) Mean ± SEM	Total number of offspring per female Mean ± SEM
Common mallow	43	0.0	5.6 ± 0.10 a	5.9 ± 0.13 a	62.8 ± 3.33 c
Cotton	46	2.2	5.5 ± 0.12 ab	5.7 ± 0.15 a	37.9 ± 2.14 b
Okra	45	4.4	6.0 ± 0.10 b	6.4 ± 0.18 ab	4.5 ± 0.43 a

Table 2. Generation time (To), net reproductive rate (Ro), and rate of population growth (r_m) of a cotton population of Aphis gossypii on three different Malvaceae hosts at 25 °C in the laboratory

Host plant	Generation time (To) (days)	reproduction rate (Ro) (aphids/aphid)	Intrinsic rate of increase (aphids/aphid/day) Mean±SEM
Common mallow	12.2	65.7	0.397±0.0062 c
Cotton	12.8	36.3	0.338±0.0076 b
Okra	11.1	4.2	0.129±0.0092 a

Generation	n	Nymphal mortality rate (%)	Developmental time (days) Mean±SEM	Total number of offspring per female Mean±SEM
F-1	45	4.4	6.3±0.14 a	5.6±0.50 a
F-2	46	2.3	7.2±0.18 b	2.9±0.31 b
F-3	46	2.3	7.8±0.19 b	2.8±0.31 b

Table 3. Mortality, developmental time, and fecundity of a cotton population of Aphis gossypii during three subsequent generations on okra hosts at 25°C in the laboratory

A. gossypii from cotton reared for three subsequent generations on okra did not improve their performance. Developmental time increased significantly from 5.6 days in the first generation to 7.8 days in the third generation. At the same time the fecundity was significantly higher in the first generation than in the third generation (6.3 and 2.8 nymphs/aphid, respectively) (table 3). In consequence, the intrinsic rate of increase of a cotton population of *A. gossypii* significantly decreased from 0.186 to 0.095 aphids/aphid/day over three subsequent generations on okra (figure 2).

Discussion

Although *A. gossypii* is known as a polyphagous species, it is seems widely accepted in the literature that its performance varies widely among different host plants (see Introduction). There are three possible reasons, which may account, alone or in combination, for the observed differences: i) host plants vary widely in their nutritional value for *A. gossypii*; ii) the utilization of a new host plant dependson the experience of the aphid in that *A. gossypii* needs time to adapt to a new host; and iii)

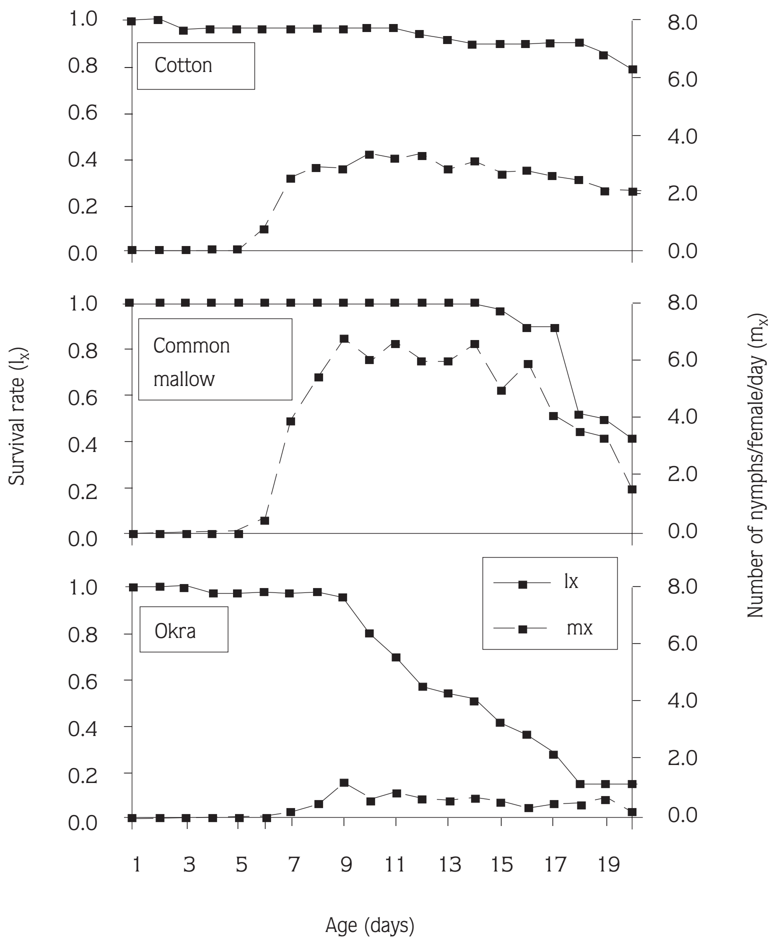

Figure 1. Age-specific survival rate (lx) and age-specific fecundity (mx) of a cotton population of Aphis gossypii on three different Malvaceae hosts at 25°C in the laboratory

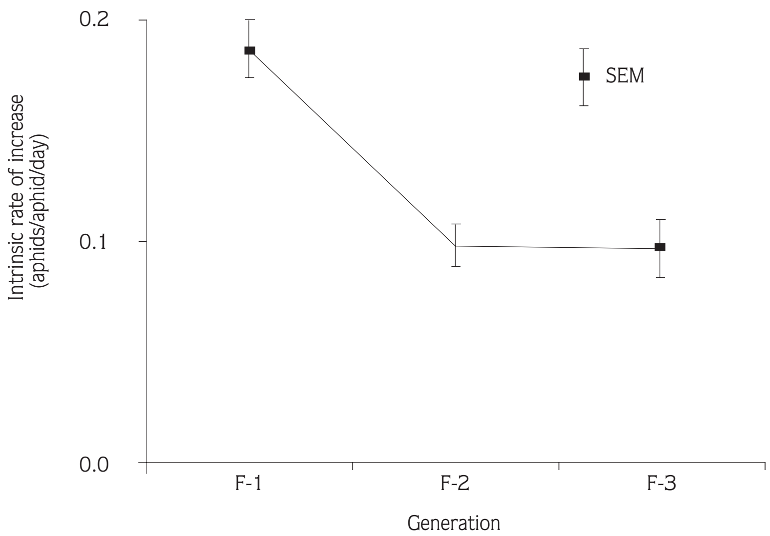

Figure 2. Intrinsic rate of increase of a cotton population of Aphis gossypii during three subsequent generations on okra at 25°C in the laboratory (SEM = Standard Error of Mean)

genetically distinct forms or host races exist in *A. gossypii*, which differ in their ability to colonize various host plants.

In the present experiments only one line of *A. gossypii* was tested, originally obtained from cotton and maintained on the same host plant in the laboratory for more than one year (>50 generations). Thus, it seems convenient to presume that this population was well adapted to *G. hirsutum* 'Çukurova 1518'. Transfer to a new host plant should therefore affect the performance of the cotton aphid; while some may succeed, others may be totally unable to adapt to the new host (26). In aphids, in which the offspring are born live and generations are "telescoped" in that embryos of granddaughters are already developing within the embryonic daughters of a given female, maternal effects on offspring quality seems particularly likely. Embryos are bathed in any ingested compound that passes into the hemolymph. This very early experience could potentially bias subsequent feeding preferences for alternative host plants, and even a brief delay on an unusual host plant in an early-instar aphid could prejudice its subsequent performance (27). The negative correlation of aphids to utilize new host plants has been already reported for several species, including A. gossypii (16, 28-33).

The present experiments demonstrated significant differences in the performance of the cotton aphid among the three Malvaceae hosts tested. *A. gossypii*, at least for the cotton aphid population used in our experiments, performed significantly better on common mallow than on cotton and only developed poorly on okra. *A. esculentus* is suggested as a superior host plant of *A. gossypii*. Ekukolé (17) reported that a higher fecundity of the cotton aphid occurred on okra compared with on five other Malvaceae hosts, including cotton. The reduction in fecundity observed for *A. gossypii* after host transfer to okra cannot be explained by lack of adaptation time - since the reproduction capacity did not depend on experience - but can be attributed to the existence of different host races. Even after three generation on okra, the performance did not improve, but population growth rates fell significantly from 0.186 to 0.095 aphids/aphid/day. It is therefore suggested that the cotton population of *A. gossypii* used in our experiments differs genetically from the African population used by Ekukolé (17).

The cotton aphid displayed a significant higher fecundity on common mallow than on cotton and only small differences were observed between developmental times on both plants. Thus for *A. gossypii*, common mallow appears to be of higher nutritional value than cotton. However, besides a lower nutrition value, the existence of defense mechanisms in cotton such as hairs, trichomes or allelochemical defenses might be responsible for the low reproduction of *A. gossypii* on cotton. Nevertheless, Tezcan and Özmen (34) reported a higher fecundity of the cotton aphid on common mallow compared with on cotton, however, they observed, in contrast to our own results, a significantly longer developmental time of *A. gossypii* on M. sylvestris. Atakan (35) determined Malva spp. as the most important winter host of *A. gossypii* in the eastern

Mediterranean region of Turkey, where numerous adults (apterae and alatae) and nymphs were encountered. Both studies support our own results that common mallow is an excellent host plant of *A. gossypii* supporting high reproduction rates similar to those reported for cucumber, eggplant, pepper, and squash (36-38).

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