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Impact of *Aphis gossypii* GLOVER (Homoptera: Aphididae) on growth rate of okra plant, *Abelmoschus esculentus* (L.)

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Abstract

To evaluate the effect of melon aphid, *Aphis gossypii* GLOVER, on the growth rate of its host plant, okra plants were infested with constant 0, 5, 25, or 50 aphids per plant over three periods, 7, 14, and 21 days, under greenhouse conditions. Each aphid density was released onto plants at two stages of plant development, 14 and 28 days after seedling emergence. Results showed that the relative growth rate of 14 day-old plants were significantly reduced to 44 and 27% in response to 25 and 50 infestation levels over 7 days, respectively, in comparison with control. 50 aphids per plant induced only a significant decrease (14%) at day 14 after infestation. Response of mean unit leaf rate of okra plants to the aphid attack followed a similar pattern as observed by the relative growth rate. Twenty-five and 50 aphids decreased the unit leaf rate to 49 and 26% over 7 days, respectively, compared to the aphid-free plants. A significant reduction in the unit leaf rate (22%) was recorded between plants infested with 50 aphids and control over 14 days. When plants were infested at 28 days after seedling emergence, a significant decrease in the relative growth rate and unit leaf rate was evident at all infestation levels over 21 days compared to control. On both dates of infestation, the leaf area ratio increased in general with increasing aphid density. Net relative growth rate, net weight gain per unit leaf area, and average leaf area ratio were decreased in response to aphid infestation. Degree of the reduction was proportional to the infestation levels. However, older plants were less affected than young plants. Mechanisms underlying the effects on these physiological processes are still poorly understood.

Keywords: *Aphis gossypii*, growth rate, okra

Introduction

Melon aphid, *Aphis gossypii* GLOVER (Homoptera: Aphididae), is a cosmopolitan and extremely polyphagous species with a range of 220 host plants belonging to over 46 families. Like finding in different aphid-host combinations (LESER *et al.*, 1992; BAGWELL *et al.*, 1991; KING *et al.*, 1987), feeding of *A. gossypii* causes crinkling and cupping of leaves, failure of leaves to expand, defoliation, and severe stunting of seedling growth. Several changes in the plant growth were also ascribed to the attack by this aphid. Usually, aphid infestation reduces the achieved total plant biomass and crop yield, and even leads to prematurely death of plants (HARRIS *et al.*, 1992; ANDREWS & KITTEN, 1989; SLOSSER *et al.*, 1989).

Injury derived from melon aphid infestation could be referred to different mechanisms. Aphids damage directly a plant by sucking the plant juice and presumably by the injection of aphid saliva into plant tissues, which leads sometimes to a decline in photosynthetic capacity of the infested plant. Indirect harm of melon aphid can arise from "sticky" cotton at harvest due to the contamination of open boll lint with honeydew, which adversely affects the performance of cotton in spinning and waving (KAN-RICE, 1991; SCHEPERS, 1989). Honeydew and sooty molds coating fruits may, moreover, render various crops un-saleable. Growers respond sometimes by washing contaminated fruits prior to the marketing. Unfortunately, such fruits often become of a lower grade due to the difficulty of the fungus to be washed off. Also, aphid excretion and saprophytic fungi alter some physiological processes in the host plant such as photosynthesis, respiration, and transpiration, in addition to the negative influence on leaf duration (HAWKINS *et al.*, 1987; BARLOW & MESSMER, 1982). Furthermore, *A. gossypii* is an efficient vector of about 60 viral diseases (KERSTING *et al.*, 1999; EASTOP, 1983).

There are evidences that feeding of different aphid species has contrary effects on such physiological plant processes, which indicate that aphid injury goes beyond the removal of plant sap (DEGUINE *et al.*, 2000; KERSTING *et al.*, 1999; CAMMELL, 1981) and these responses are specific to plant-aphid combinations investigated (HAWKINS *et al.*, 1987).

Despite the significance of *A. gossypii* as agricultural pest on several crops in many countries, little attempts have been made to understand how this aphid influences the growth rates of different host plants. Therefore, the present work was performed to assess the effect of melon aphid on the relative growth rate, unit leaf rate, and leaf area ratio of okra plant under greenhouse conditions.

Materials and Methods

Stock of melon aphid, *A. gossypii*, was collected from infested fields of okra in Irbid, Northern Jordan. Aphids were reared on potted okra plants, local variety, placed in organdy screened cages (80 x 60 x 60 cm) under insectary room conditions at temperature of 24 ± 3°C, 40-70% relative humidity, and 16:8 (L:D) photoperiod regime. Plants senesced as a result of sever aphid feeding were replaced by new ones grown under greenhouse conditions.

Seeds of okra plant, local variety, were potted in peat moss and perlite with

2/1 (v/v) at a rate of three seeds per pot (12 cm diameter). Seeded pots were arranged on the benches in a clear greenhouse under natural light conditions. Seven days after seedling emergence, plants were thinned to one seedling per pot and watered every two days with a similar amount of water during the whole experimental period.

Effect of melon aphid was assessed at constant infestation levels of 0, 5, 25, and 50 aphids per plant over three periods, 7, 14, and 21 days. At least eight plants were used at each infestation level and time period. Late-nymphal instars (8-day old) obtained from a synchronized aphid colony were used for all treatments. Aphids were transferred to the experimental plants using a fine, moist, camel's hair brush. Subsequent to the aphid release, an organdy screen cylinder (50 cm height x 12.5 cm diameter) was placed over each pot to avoid aphids to escape. During the entire experimental period, progeny of aphids was removed and the naturally dead aphids were replaced with aphids of the same age, both at 24 hours intervals.

Two series of experiments were conducted. In the first series, aphids were introduced into experimental plants at 14 days after seedling emergence, while plants in the second series were infested with similar aphid densities after a further two weeks. Immediately prior to the aphid release, five 14 day-old plants from the first series and other five 28 day-old plants from the second series of experiment were harvested to determine their initial growth rates. The remaining plants were harvested after a further 7, 14, and 21 days in each experimental set. Harvested plants were washed, and separated into roots, leaves, and stems. Then, the total fresh and dry weight along with the leaf area, were measured.

Relative growth rate, net assimilation rate, and leaf area ratio were determined to describe the effect of aphids on the plant growth. An increase in the plant weight per unit of weight per unit of time (net relative growth rate) was calculated according to the procedures of EVANS (1972). Differences in the total plant dry weights at the beginning and the end of the period were divided over a period from first and second times. Unit leaf rate (the net gain in weight per unit leaf area), which is considered as a physiological index of productive efficiency closely associated with the plant assimilation rate was estimated according to the methods described by WILLIAMS (1946). Calculation based on the equation described by HUNT (1982) was used to determine the mean leaf area ratio (morphological index of plant leafiness), which is the ratio of total leaf area to whole plant dry weight.

Collected data from all experiments were subject to analysis of variance (ANOVA) and means were compared using Fisher's least significant differences test at a 0.05 probability level.

Results

Effect of *A. gossypii* on net relative growth rate

Impact of different infestation levels of aphid on the average net relative growth rate of 14 day-old okra plants is presented in Ttable 1. The results

Table 1. Average net relative growth rate (R), mean unit leaf rate (E), and average leaf area ratio (F) of 14-day old okra plants infested by different number of melon aphids for different time periods.

Infestation period (day)	No. of aphids/plant	R ($g.g^{-1}.day^{-1}$)	E ($mg.cm^{-2}.day^{-1}$)	F ($cm^2.mg^{-1}$)
7	0	0.1835 a	0.7340 a	0.2518 a
	5	0.1643 a	0.6600 ab	0.2508 a
	25	0.1033 b	0.3722 c	0.2760 b
	50	0.1338 b	0.5434 b	0.2482 a
14	0	0.1134 a	0.5691 a	0.2141 a
	5	0.1071 ab	0.5186 ab	0.2189 a
	25	0.1072 ab	0.4904 ab	0.2279 a
	50	0.0974 b	0.4437 b	0.2281 a
21	0	0.0889 a	0.5404 a	0.1922 a
	5	0.0884 a	0.5482 a	0.1900 a
	25	0.0856 a	0.5031 a	0.1953 a
	50	0.0641 b	0.3417 b	0.2046 b

Means within column for each infestation period followed by the same letter(s) are not significantly different at P=0.05.

indicated that there was an evidence for a significant reduction in relative growth rate of some aphid-infested treatments. The extent of this reductions was erratic among the infestation densities and intervals. Plants infested with 50 aphids on day 14 decreased significantly the relative growth rate to 27, 14, and 28% over 7, 14, and 21 days, respectively, in comparison with aphid-free plants.

Furthermore, the net relative growth rate of plants infested with 50 aphid was significantly less at 7 and 21 days than those attacked by 5 aphids. Over 7 days, plants with lowest infestation level showed considerably greater growth rate than that of 50 aphids per plant, whereas 25 infestation level caused an apparent reduction in the relative growth rate by 7 days after aphid release (Table 1).

When similar levels of aphid densities occurred on the okra plant at a later stage of plant development, 28 day-old plants, the consequence of aphid feeding on the relative growth rat was much more moderated compared to those of young plants (Table 2). By 7 and 14 days, plants with aphids did not showed a significant decrease in the relative growth rate, compared to control. A significant reduction was merely observed over 21 days in all infested treatments when compared to the aphid-free plants. Five, 25, and 50 infestation levels induced a reduction in the relative growth rate to about 85, 73, and 78% of that of control plants, respectively.

Effect of *A. gossypii* on unit leaf area

Feeding by melon aphid altered also the plant unit leaf rate for all treatment combinations. These changes pursued a similar pattern as for the relative growth rate. The magnitude of the reduction was not proportional neither to

Table 2. Average net relative growth rate (R), mean unit leaf rate (E), and average leaf area ratio (F) of 28-day old okra plants infested by different number of melon aphids for different time periods.

Infestation period (day)	No. of aphids/plant	R ($g.g^{-1}.day^{-1}$)	E ($mg.cm^{-2}.day^{-1}$)	F ($cm^2.mg^{-1}$)
7	0	0.1223 a	0.7633 a	0.1744 a
	5	0.1193 a	0.7202 a	0.1782 a
	25	0.1050 a	0.6404 a	0.1763 ab
	50	0.1007 a	0.5606 a	0.1879 b
14	0	0.0835 a	0.5312 a	0.1742 a
	5	0.0853 a	0.6279 a	0.1603 b
	25	0.0894 a	0.5833 a	0.1720 a
	50	0.0967 a	0.6984 a	0.1629 ab
21	0	0.0772 a	0.5816 a	0.1609 a
	5	0.0657 b	0.5642 ab	0.1497 b
	25	0.0565 b	0.3552 c	0.1755 c
	50	0.0601 b	0.4264 bc	0.1639 ac

Means within column for each infestation period followed by the same letter(s) are not significantly different at P=0.05.

the number of aphids released nor to the length of infestation period (Tables 1 and 2). However, infestation with 25 and 50 aphids per plant started on day 14 decreased considerably the unit leaf area by 49 and 26% compared to the aphid-free plants, respectively. Over 14 and 21 days, the unit leaf area declined at the highest aphid density to 22 and 37%, in that order, and was significantly different from control plants.

When aphid infestation was postponed two weeks, old okra plants performed better withstand to the aphid attack resulting in an obvious less decrease in the unit leaf area (Table 2). At 28 days after plant emergence, all treatments did not differ significantly among each other, apart from plants infested by 25 and 50 aphids over 21 days where their average unit leaf areas were significantly reduced to 39 and 27%, respectively, compared to the control.

Effect of *A. gossypii* on leaf area ratio

Tables 1 and 2 summarize the influence of aphid invasion on the average ratio of leaf area to total dry weight of plant. Performances of the plants were widely inconsistent among different infestation levels of aphid within each infestation period and time. Aphids attacked the plants at an early stage of plant development gave rise to a significant increase in the leaf are ratio occasionally. At 7 days after aphid infestation, plants with 25 aphids showed a greater ratio of leaf area when compared with other treatments. But simultaneously no significant differences were evident between aphid-infested plants over the further two weeks of infestation, except for the plants with 50 aphid density that their leaf area ratio surpassed remarkably other treatments over 21 days (Table 1).

At the second infestation time, aphids caused no change, a decline, or an increase in the leaf area ratio depending on infestation level and intervals (Table 2). After 7 days, the mean leaf area ratio of the treatment infested with 50 aphids went significantly beyond those of 0 and 5 infestation levels. In addition, a significant decline in the leaf area ratio was detected in plants occupied with 25 aphids in both successive infestation periods with respect to the control plants. Over 21 days, 28 day-old plants infested with 50 aphid density showed only a significant increase in the leaf area ratio in comparison with lowest infestation level (Table 2).

Discussion

Outcome of our experiments indicated that control plants possessed better ability for the net relative growth rate than those infested with aphids. A reduction in the relative growth rates of 14 day-old plants as a result of aphid feeding was quantitatively not related to infestation level of aphid and length of feeding period. The outsized alteration in the mean relative growth rate was identified at 25 and 50 aphid densities over 7 days following the infestation. Since the mean unit leaf area mathematically counts on the relative growth rate and total leaf area ratio, a decline in the mean unit leaf area of aphid-infested plants followed a similar pattern as recognized by relative growth rate in this trial. Infestation density of 25 aphids per plant diminished the net assimilation rate up to 49% over 7 days. This indicates that a small number of aphids was capable to cause sever damage to okra plant. However, infestation of 28 day-old plants with different aphid densities induced just a decrease in the relative growth rate and mean leaf area at 21 days after aphid infestation.

Confirming our data, different aphid-host combinations in the literature showed that the maximum stress to the younger plants on which aphids were nourished occurred over 7 day, whereas plant resistance to aphid attack enhanced with increasing plant age and size (HAWKINS *et al.*, 1985; BARLOW & MESSMER, 1982; WU & THROWER, 1981). A significant reduction in the mean relative growth rates and unit leaf areas as a result of aphid feeding is reported for numerous aphid-plant systems (HAWKINS *et al.*, 1985; BARLOW & MESSMER, 1982; MALLOTT & DAVEY, 1978). In these investigations, however, percent decline in both growth parameters for the same infestation level varied from each other and differed also from our results, most likely due to dissimilarity in the size and age of plants used at the time of infestation.

In most cases, *A. gossypii* caused either no significant change in leafiness of plant, relative to their weight, or an increase with increased numbers of aphid. So that aphid feeding must not have reduced the proportion of assimilates that were involved in leaf area expansion. A similar trend for slight and constant increase in the average leaf area ratio with increasing infestation level of aphids has been obtained in studies conducted by BARLOW & MESSMER (1982) and MALLOTT & DAVEY (1978). However, significant differences in the leaf area ratio between control and infested plant were absent in other aphid-plant combinations (HAWKINS *et al.*, 1985). These contradictory outcomes could indicate that the responses are specific to the plant-aphid system tested.

Changes in plant physiological processes have been ascribed to many factors, which include translocate removal by aphids, lessening in the efficiency at converting light to chemical energy, and the respiratory loss from new assimilate in the infested plants (HAWKINS *et al.*, 1985; BARLOW & MESSMER, 1982), thus resulting in a significant reduction of the average unit leaf area, in most cases, in direct proportion to decreases in relative growth rate. However, the mechanism in which aphids induce physiological changes in the infested plants is mysterious. Metabolically active substances secreted by aphids into the phloem stream, which might interact with photosynthetic system could account for the decreased photosynthesis of aphid-infested plants (EDWARDS & WRATTEN, 1980). Aphid feeding has been also reported to reduce the quantity of chlorophyll content (RIEDELL, 1989) and to diminish appreciably the function of residual chloroplasts, as indicated by maximum chlorophyll fluorescence, thereby the internal injury to photosynthetic system decreases the capacity of leaf to fix atmospheric carbon dioxide (BURD & TODD, 1992).

Finally, sever aphid attack should be avoided while plants are at the seedling stage of growth, to permit okra plants for further growth and productivity. Even though intense aphid plagues will have the aptitude to reduce plant growth at any stage, older plants are better competent to endure withdrawal of photosynthate and water caused by aphids. How the decrease in relative plant growth was initiated is unclear, but it may be via decreased rates of photosynthesis and increased transpiration, as responses to toxins injected by the aphids. Further studies investigating in more details some of those proposals are worthwhile.

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