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Effect of temperature on population parameters of *Aphis gossypii* Glover and *Myzus persicae* (Sulzer) (Homoptera: Aphididae) on pepper

Der Einfluß der Temperatur auf Populationsparameter von *Aphis gossypii* Glover und *Myzus persicae* (Sulzer) (Homoptera: Aphididae) auf Paprikapflanzen

S. Satar[1,*], U. Kersting[2] & N. Uygun[1]
[1] Department of Plant Protection, University of Çukurova, Turkey
[2] Faculty of Agricultural Sciences and Technologies, European University of Lefke, TRNC
* Corresponding author, e-mail hserhat@cu.edu.tr

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Summary

The developmental times, survival rates and reproduction of the cotton aphid, *Aphis gossypii* Glover and the green peach aphid, *Myzus persicae* (Sulzer) were separately evaluated on detached pepper leaves at eight constant temperatures (15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0, and 32.5°C) in temperature cabinets. Immature stages of *A. gossypii* developed significantly faster than those of *M. persicae* at temperatures of 20.0 and 22.5°C, and 27.5 and 30.0°C. The green peach aphid had a significantly shorter developmental period than the cotton aphid at 15.0°C. Constant 32.5°C was lethal to immature stages of *M. persicae*. The intrinsic rates of increase of *A. gossypii* were statistically higher than those of *M. persicae* at temperatures of 17.5°C and above. It was evident that *M. persicae* performed better at cooler temperatures, having the capability to colonize pepper plants in greenhouses during winter and spring. As soon as average daily temperatures exceed 20.0°C, the cotton aphid will outperform the green peach aphid and has a higher likelihood to colonize pepper plants quickly.

Key words: *Aphis gossypii*, development, *Myzus persicae*, pepper, population parameters

Zusammenfassung

Die Entwicklungsdauer, die Überlebensrate und die Vermehrung der Baumwollblattlaus, *Aphis gossypii* Glover und der Grünen Pfirsichblattlaus, *Myzus persicae* (Sulzer) wurde getrennt bei acht Dauertemperaturen (15,0; 17,5; 20,0; 22,5; 25,0; 27,5; 30,0 und 32,5°C) auf Blattscheiben von Paprikapflanzen in Klimaschränken untersucht. Die Nymphstadien von *A. gossypii* entwickelten sich bei Temperaturen von 20,0; 22,5 sowie 27,5 und 30,0°C signifikant schneller als die von *M. persicae*. Demgegenüber hatte die Grüne Pfirsichblattlaus bei einer Temperatur vom 15,0°C eine deutliche kürzere Entwicklungsdauer. Die Dauertemperatur von 32,5°C erwies sich gegenüber den Nymphstadien von *M. persicae* als lethal. Das Populationswachstum von *A. gossypii* war bei Dauertemperaturen von 17,5°C und höher statistisch signifikant größer als das von *M. persicae*. Bei 15,0°C hingegen war das Populationswachstum der Grünen Pfirsichblattlaus signifikant schneller. Durch die Untersuchungen wurde deutlich, das sich *M. persicae*-Populationen besser bei kühlen Temperaturen entwickeln. Sie sind somit in der Lage, Paprikapflanzen im Gewächshaus im Winter und zeitigen Frühjahr zu befallen. Sobald die täglichen Durchschnittstemperaturen 20,0°C erreichen, ist die Baumwollblattlaus der Grünen Pfirsichblattlaus überlegen und besitzt daher eine größere Wahrscheinlichkeit, die Paprikapflanzen schnell zu besiedeln.

Stichwörter: *Aphis gossypii*, Entwicklung, *Myzus persicae*, Paprika, Populationsparameter

1 Introduction

A total of 401.325 da of greenhouse cultivation areas has been reported in Turkey and approximately 70% takes places in East Mediterranean Region of Turkey (Anonymous 1998). Warm and humid climate of the region gives the farmers established high or low plastic (76%) or glass (24%) greenhouses (Kuden 1998). The pepper production of Turkey was 1.7 million ton and third biggest producer of the World after China and Mexico and 18% of it were cultivated under greenhouses.

The cotton aphid, *Aphis gossypii* Glover and the green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae) are important pest of greenhouse and field crops in East Mediterranean region of Turkey (Bulut and Göçmen 2000). *A. gossypii* and *M. persicae* cause direct damage resulting from searches for food that may induce plant deformation and indirect damage caused either by honeydew or by transmission of viruses. Large scale ecomic losses sourced both aphid species by transmitting many virus were recorded in an important and widely grown vegetables and trees (van Emden et al. 1969; Bar-Joseph et al. 1983; Blackman and Eastop 1984; Leclant and Deguine 1994).

Heavy infestations of vegetables crops, cotton, tobacco, and citrus, etc., with aphids pushed growers to regularly apply different insecticides in an attempt to control the cotton aphid and the green peach aphid. As a consequence of the frequent use of pesticides, a strong selection pressure has led *A. gossypii* and *M. persicae* to evolve different forms of resistance to insecticides such as organophosphorous, carbamates, and pyrethroids (Attia and Hamilton 1978; Attia et al. 1979; Furk et al. 1980; Sawicki et al. 1980; Furk 1986; Foster et al. 2000). Similar result were obtained in the East Mediterranean region of Turkey by Velioğlu et al. (2007a, b). They reported that high carboxylesterase activity of *M. persicae* were detected in the population collected from Antalya and high esterase activity associated with insecticide resistance of a *A. gossypii* population collected from Adana province were determined. Heavy aphid infestations of crops combined with insecticide resistance necessitate the need to embark on integrated pest management strategies to control the cotton aphid and the green peach aphid. No system exists to predict aphid population development, and management of the pest is usually based on crop inspection. The development of IPM strategy for *A. gossypii* and *M. persicae* relies on thorough understanding of the biology of the pest and in particular of the effect of prevailing temperature on life history parameters and the timing and the rate of population development. Combined the data of field population dynamic will help to program and improve IPM strategies like forecasting system of pest and the releasing time and the number of beneficial insect especially parasitoids species.

A. gossypii and *M. persicae* have adapted to specific host plants and some populations show a distinctive host plant

specialization (KLINGAUF 1987). The cotton aphid and the green peach aphid appear to be species comprising of distinct genotypes; they differ in life cycle, morphological characters, and host plant performance (BLACKMAN 1987; GULDEMOND et al. 1994; KERSTING et al. 1998; VANLERBERGHE-MASUTTI and CHAVIGNY 1998; ZITOUDI et al. 2001; MARAGARITOPOLOUS et al. 2000; 2002). In particular, the performance of *A. gossypii* differed significantly on various host plants and these differences were independent of embryonic or maternal experiences (GULDEMOND et al. 1994; KERSTING et al. 1998). Several reports have been published on the effects of temperature and host plant on cotton aphid and green peach aphid life histories but none has provided information on how they interact to affect aphid development reproduction and survival, and the relevance of the result to Eastern Mediterranean region of Turkey condition is unknown.

The present study was designed to provide data on developmental rate, survival, and fecundity of *A. gossypii* and *M. persicae*, important aphid pests of pepper in Turkey. The obtained population parameters might be used for developing IPM strategies, in particular monitoring and sampling plans of the cotton aphid and the green peach aphid in the Eastern Mediterranean region of Turkey.

2 Materials and methods

2.1 Experimental design

Aphis gossypii and *M. persicae* were obtained from greenhouse-grown pepper near Adana in the Eastern Mediterranean region of Turkey and separately colonized on *Capsicum annum* cv. 'Kandil Dolma' at 26 ± 2°C, 65 ± 10% r. h. and 16 h of artificial light of about 10,000 Lux in growth rooms. Aphids had been reared in laboratory for several generations before individuals were used in the experiments (KINDLMANN and DIXON 1989).

Randomly selected apterous females of *A. gossypii* and *M. persicae* from the stock cultures were separately transferred onto excised pepper leaf disks placed upside down on wet cotton wool in Petri dishes (Ø 5 cm). Offspring born within 24 h was confined individually on pepper leaf disks in Petri dishes. All replications in which nymphs died within 24 h after transfer were omitted. The cotton wool in Petri dishes was wetted daily and every 3–5 days aphids were transferred to new leaf disks. Leaves used in the experiments were obtained from greenhouse-grown pepper plants (cv. Kandil Dolma) that were between 4–6 wk of age.

Experiments were conducted at eight constant temperatures ranging from 15 – 32.5 ± 1°C in 2.5°C increments, 60 ± 5% r. h. and 16 h of artificial light (5000 Lux) in temperature cabinets. Immature stages and adults were observed daily and their survival rate recorded. The exuviae were used to determine molting time; newly born larvae were removed after counting. All experiments were terminated after 40 days.

2.2 Data analysis

Differences in developmental time, longevity, and reproduction were tested by analysis of variance (Anova). If significant differences were detected, multiple comparisons were made using Tukey's HSD Multiple Range Test (P = 5%).

Population growth rates were calculated from the equation of Lotka (BIRCH 1948). After the intrinsic rate of increase was computed for the original data (r_{all}), differences in r_m-values were tested for significance by estimating variances through the jackknife method (MEYER et al. 1986). The jackknife pseudo-value r_j was calculated for the n samples using the following equation:

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

The means of jackknife pseudo-values for each treatment were subjected to analysis of variance. Tukey's HSD Multiple Range Test was used to compare mean growth rates at different temperatures, applying low probability levels (P = 1%) (JONES 1984). Each of the above-mentioned analyses was conducted using Statgraphics software package (STATISTICAL GRAPHIC CORPORATION 1988).

3 Results

A two-factorial variance analysis indicated that both the temperature (F = 454.6; df = 6, 615; $P < 0.01\%$) and the aphid species (F = 613.8; df = 1,615; $P < 0.01\%$) significantly affected the intrinsic rates of increase (r_m) of *A. gossypii* and *M. persicae*. Due to significant interactions between temperature and aphid species (F = 212.0; df = 6,615; $P < 0.01\%$), the performance of each aphid species on pepper was analyzed separately.

3.1 Development

The developmental time of the cotton aphid significantly decreased with increasing constant temperatures ranging from 13.0 days at 15.0°C to 4.0 days at 30.0°C. Similarly, the green peach aphid developed significantly faster at warmer temperatures than at cooler temperatures with the longest developmental time at 15.0°C (11.6 days) and the shortest at 25.0°C with 5.1 days (Table 1). *A. gossypii* developed significantly faster than *M. persicae* at temperatures of 20.0 and 22.5°C, and at 27.5 and 30.0°C, while the green peach aphid developed faster at 15.0°C. No statistical significant differences between the developmental times of both aphid species were observed at 17.5 and 25.0°C.

A. gossypii have had a considerable higher mortality during development at cooler temperatures of 15.0 and 17.5°C and again at warm temperatures of 32.5°C. Total nymphal mortality rates of *M. persicae* were highest at 30.0°C, but low at cool temperatures. For the green peach aphid, the constant temperature of 32.5°C was lethal to early nymphal stages (Table 1).

3.2 Longevity and reproduction

Survival rates of adults of *A. gossypii* and *M. persicae* sharply decreased right after the peak of nymph production at higher temperatures, while a relatively long post-reproductive period was observed between 15.0°C and 27.5°C (Fig. 2). The net reproductive rate (R_o) of the cotton aphid was highest at 22.5°C (68.38 aphids aphid^{-1}) and lowest at 32.5°C with as less as 0.22 aphids aphid^{-1}. Reproduction rates of the green peach aphid were in general higher at temperatures between 20.0 and 27.5°C (79.29 – 85.33 aphids aphid^{-1}) and decreased with an increase in temperature to 5.00 aphids aphid^{-1} at 30.0°C (Table 2).

3.3 Fecundity

Aphis gossypii populations kept at warmer temperatures showed higher per capita growth rates, being highest at 30.0°C with 0.504 aphids aphid^{-1} day^{-1}. The optimum temperature for population growth of *M. persicae* occurred at 25.0°C (0.412 aphids aphid^{-1} day^{-1}). The lowest intrinsic rate of increase occurred at 15.0°C for the cotton aphid (0.162 aphids aphid^{-1} day^{-1}) and at 30.0°C for the green peach aphid (0.143 aphids aphid^{-1} day^{-1}). For temperature above 15.0°C, the intrinsic rates of increase of *A. gossypii* on pepper were statistically significant higher than those of *M. persicae*. In contrast, the green peach aphid had significantly higher

Table 1: Developmental time and mortality rate of *Aphis gossypii* and *Myzus persicae* on excised pepper leaf discs at eight constant temperatures

Temperature (± 1°C)	*Aphis gossypii*			*Myzus persicae*		
	n	Developmental time (days) (mean ± SEM)	Total nymphal mortality rate (%)	n	Developmental time (days) (mean ± SEM)	Total nymphal mortality rate (%)
15.0	41	13.0 ± 0.30 e ***	41.5	47	11.6 ± 0.11 f	2.2
17.5	49	8.9 ± 0.19 d	32.7	45	9.2 ± 0.12 e	2.0
20.0	46	6.6 ± 0.09 c ***	0.0	46	7.1 ± 0.07 d	5.0
22.5	47	5.5 ± 0.09 b ***	2.1	46	5.9 ± 0.07 bc	5.1
25.0	42	5.1 ± 0.12 b	0.0	43	5.1 ± 0.05 a	11.9
27.5	41	4.9 ± 0.08 b ***	2.4	42	6.1 ± 0.07 b	7.6
30.0	48	4.0 ± 0.02 a ***	2.1	48	6.4 ± 0.15 c	20.6
32.5	40	7.2 ± 0.29 c	17.5	50	–	100.0

Means in columns followed by the same letter are not significantly different by Tukey 's Multiple Range Test (P = 5%).
*** Denotes a statistical significant difference between developmental times of *A. gossypii* and *M. persicae* at the same temperature (Student's t-test, P < 1%).

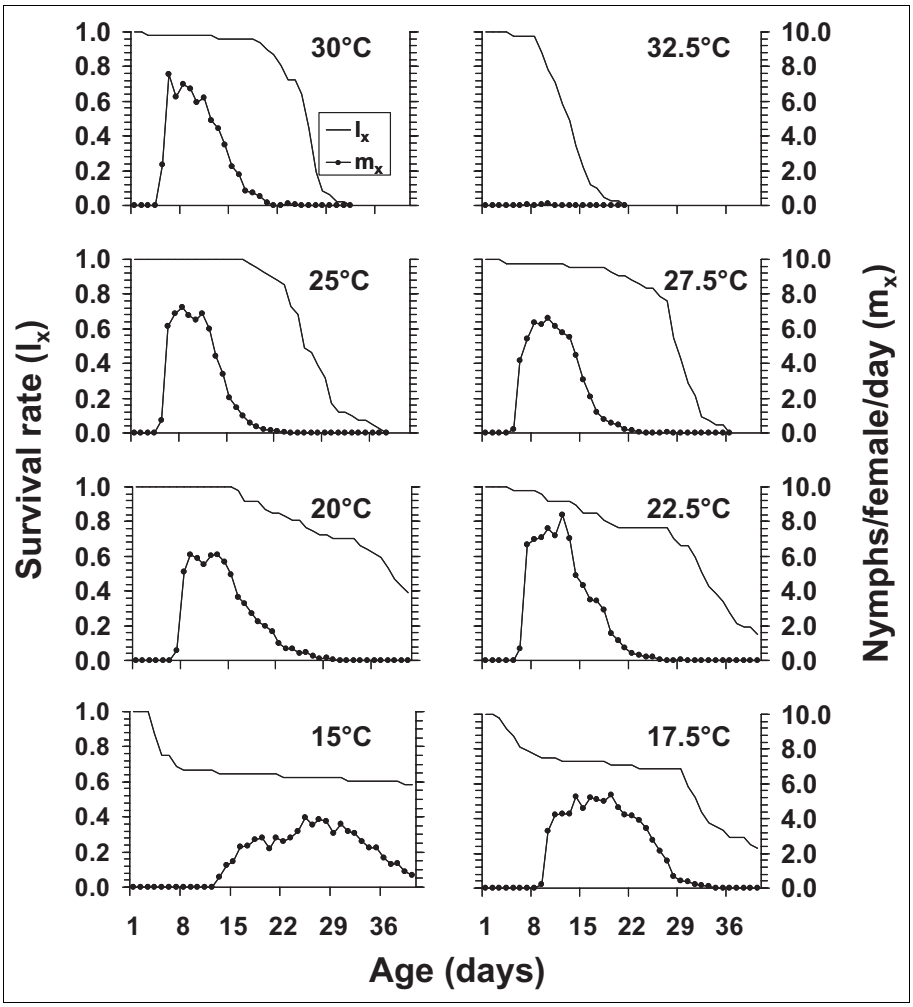

Fig. 1: Age-specific survival rate (l_x) and age-specific fecundity (m_x) of *Aphis gossypii* on excised pepper leaf discs at eight constant temperatures

intrinsic rates of increase at 15.0°C (0.189 aphids aphid^{-1} day^{-1}) than the cotton aphid (Table 2).

4 Discussion

The results on important population growth parameters presented here provide a direct comparison of the intrinsic rates of increase of *A. gossypii* and *M. persicae* attacking pepper in greenhouse and field in the East Mediterranean region of Turkey.

The capita growth rate of the cotton aphid was significantly greater than that of the green peach aphid at temperatures above 15.0°C. At cooler temperatures of 15.0°C, the green peach aphid performed significantly better than the cotton aphid. If both species coexist at warm temperatures and if

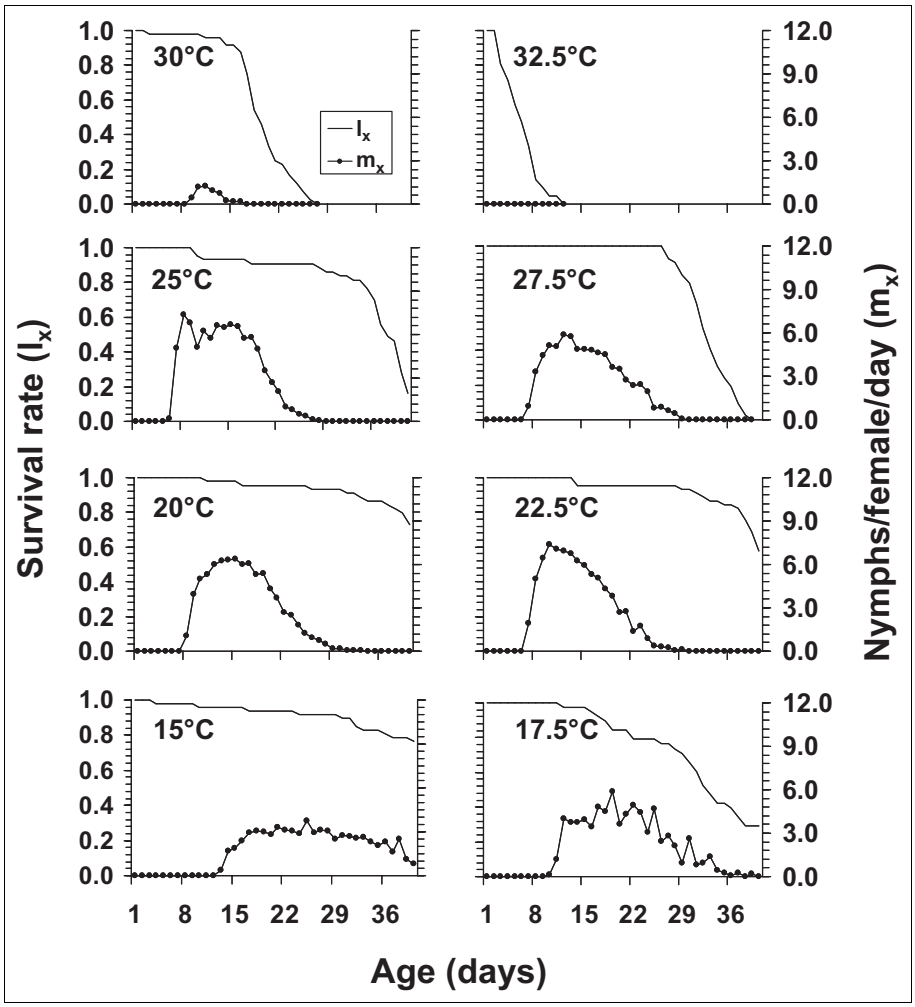

Fig. 2: Age-specific survival rate (l_x) and age-specific fecundity (m_x) of *Myzus persicae* on excised pepper leaf discs at eight constant temperatures

Table 2: Generation time (T_o), net reproductive rate (R_o), and rate of population growth (r_m) of *Aphis gossypii* and *Myzus persicae* on excised pepper leaf discs at seven constant temperatures

	Generation time (T_o) (days)	Reproduction rate (R_o) (aphids aphid^{-1})	Intrinsic rate of increase (r_m) (aphids aphid^{-1} day^{-1})		Generation time (T_o) (days)	Reproduction rate (R_o) (aphids aphid^{-1})	Intrinsic rate of increase (r_m) (aphids aphid^{-1} day^{-1})
15.0	25.89	42.12	0.162 ± 0.0067 a	***	25.66	62.15	0.189 ± 0.0027 b
17.5	17.84	53.97	0.264 ± 0.0095 b	**	19.82	63.24	0.244 ± 0.0038 c
20.0	13.51	63.19	0.366 ± 0.0053 c	**	15.98	79.29	0.350 ± 0.0058 d
22.5	11.91	68.38	0.427 ± 0.0067 d	***	13.98	80.91	0.386 ± 0.0039 e
25.0	10.23	60.76	0.482 ± 0.0066 e	***	13.86	85.33	0.412 ± 0.0034 f
27.5	10.91	57.59	0.445 ± 0.0066 d	***	15.32	73.69	0.350 ± 0.0033 d
30.0	10.01	59.43	0.504 ± 0.0071 e	***	11.50	5.00	0.143 ± 0.0095 a
32.5	8.44	0.22	−0.176 ± 0.0089 f		–	–	–

Means in column followed by the same letter are not significantly different by Tukey's HSD Multiple Range Test (α = 0.01).
** Denotes a statistical significant difference between developmental times of *A. gossypii* and *M. persicae* at the same temperature (Student's t-test, P < 5%).
*** Denotes a statistical significant difference between developmental times of *A. gossypii* and *M. persicae* at the same temperature (Student's t-test, P < 1%).

other factors are equal, we could expect the cotton aphid to quickly become the dominant species on pepper because of its much greater reproduction potential. At cooler temperatures (below 17.5°C), *M. persicae* would eventually become the dominant species, but would require a much longer time. At temperatures above 30.0°C, the cotton aphid and the green peach aphid could probably not survive or at least the population sizes should decrease dramatically.

These laboratory results confirm our own observations in greenhouses (Satar and Kersting, unpublished data) that during the cooler spring months (January until March) *M. persicae* is the dominant aphid species of greenhouse-grown pepper plants in the East Mediterranean Region of Turkey. Although *A. gossypii* is present during these months, only few individuals can be encountered. When the temperature in greenhouses increases in April and May, the population

density of the cotton aphid increases and become the dominant species with only few *M. persicae* left on the plant. A further increase of temperature until mid of June results in a complete disappearance of the green peach and the cotton aphid from pepper in greenhouses.

Data on the intrinsic rate of increase of the green peach given in literature differ considerably from the results presented here. DeLoach (1974) reported lower capita growth values of *M. persicae* on cabbage with a maximum of 0.277 aphids aphid^{-1} day^{-1} at 25.0°C. These findings are similar to that of Harrison (1969) who obtained an intrinsic rate of increase of 0.26 aphids aphid^{-1} day^{-1}on Maryland tobacco at an average temperature of 22.4°C. Higher r_m-values for the green peach at all temperatures tested are reported by Barlow (1962), being more similar to the results obtained from the study presented here. On winter weeds, Fernandez-Quintanilla et al. (2002) reported for *M. persicae* intrinsic rates of increase of 0.20–0.24 aphids aphid^{-1} day^{-1} at a temperature regime of 20/10°C, the population growth rates being highest on *Brassica kaver*. The same authors determined the highest capita growth values on the summer weed *Solanum nigrum* with up to 0.40 aphids aphid^{-1} day^{-1} at a temperature regime of 25/20°C. The green peach aphid showed also variable performance on different tobacco varieties ranging from 0.235 to 0.318 at constant 20.0°C, with a lower population growth rate Virginia types compared to Oriental types (Goundoudaki et al. 2003). The performance of the *M. persicae* population on pepper used in our experiments was considerably higher for most of the temperature tested than those reported in the literature for various host plants, indicated the excellent suitability of pepper as host plant for green peach aphid.

Population growth rates of the cotton aphid are also strongly depending on host plant. Compared to the results obtained on pepper, the highest intrinsic rates of increase reported for *A. gossypii* on citrus, cotton, and okra are significantly lower, ranging from 0.129 to 0.413, depending on temperature and host plant (Komazaki 1982; Satar et al. 1998; 1999; Kersting et al. 1999). The capita growth rate of the *A. gossypii* reported for cucumber and squash in the literature are much closer to that obtained on pepper in our study, reaching up to 0.5 aphids aphid^{-1} day^{-1} on squash at 25.0°C (Aldyhim and Khalil 1992; Kocourek et al. 1994; van Steenis and El-Khawass 1995; Satar et al. 2005). According to our results, pepper appears to be an excellent host plant for *A. gossypii* allowing the aphid to reach high populations even at temperatures as low as 20°C. In general, the cotton aphid reaches higher intrinsic rates of increase on pepper than on any other host plant.

Both, the green peach aphid and the cotton aphid are well adapted to pepper plants capable of quickly colonizing the host plant over a wide range of temperatures. Despite the fact that *M. persicae* significantly performed better at cool temperatures than *A. gossypii*, both species may concurrently settle on pepper. Further studies are necessary to enlighten the effect of co-colonization on the capita growth rates of both aphid species at different temperatures.

Literature

Anonymous, 1998: The action plan of Metil Bromür (Mebr) using in Agricultural application in Turkey. TKB, TÜGEM Data, Ankara, Turkey.

Attia, F.I., D.J. Hamilton, 1978: Insecticide resistance in *Myzus persicae* in Australia. J. Econ. Entomol. **71**, 851-853.

Attia, F.I., J.T. Hamilton, B.A. Franzmann, 1979: Carbamate resistance in a field strain of *Myzus persicae* (Sulzer) (Hemiptera: Aphididae). Gen. Appl. Entomol. **11**, 24-26.

Aldyhim, Y.N., A.F. Khalil, 1992: Influence of temperature and daylength on population development of *Aphis gossypii* on *Cucurbita pepo*. Entomol. Exp. Appl. **67**, 167-172.

Barlow, C.A., 1962: The influence of temperature on the growth of experimental populations of *Myzus persicae* (Sulzer) and *Macrosiphum euphorbiae* (Thomas) (Aphididae). Can. J. Zool. **40**, 145-156.

Bar-Joseph, M., N. Roistacher, S.M. Garnsey, 1983: The epidemiology and control of citrus tristeza virus. In: R.T. Plumb, J.M. Tresh (eds.): Plant Virus Epidemiology, pp. 61-72. Blackwell, Oxford, United Kingdom.

Birch, L.C., 1948: The intrinsic rate of natural increase of an insect population. J. Anim. Ecol. **17**, 15-26.

Blackman, R.L., 1987: Morphological discrimination of a tobacco-feeding form from *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), and a key to New World *Myzus* (Nectarosiphon) species. B. Entomol. Res. **77**, 713-730.

Blackman, R.L., V.F. Eastop, 1984: Aphids of the World's Crop: An Identification and Information Guide. John Wiley & Sons, London.

Bulut, E., H. Göçmen, 2000: Pests and their natural enemies on greenhouse vegetables in Antalya. IOBC WPRS Bull. **23**, 33-37.

DeLoach, C.J., 1974: Rate of increase of populations of cabbage, green peach, and turnip aphids at constant temperatures. Ann. Entomol. Soc. Am. **67**, 332-340.

Fernandez-Quintanilla, C., L. Fereres, L. Godfrey, R.F. Norris, 2002: Development and reproduction of *Myzus persicae* and *Aphis fabae* (Hom., Aphididae) on selected weed species surrounding sugar beet fields. J. Appl. Entomol. **126**, 198-202.

Foster, S.P., I. Denholm, A.L. Devonshire, 2000: The ups and downs of insecticide resistance in green peach aphids (*Myzus persicae*) in the UK. Crop Prot. **19**, 873-879.

Furk, C., 1986: Incidence and distribution of resistant strains of *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) in England and Wales 1980–1984. B. Entomol. Res. **76**, 53-58.

Furk, C., D.F. Powel, S. Heyd, 1980: Pirimicarb resistance in the melon and cotton aphid, *Aphis gossypii* Glover. Plant Pathol. **29**, 191-196.

Goundoudaki, S., J.A. Tsitsipis, J.T. Magraitopoulos, K.D. Zarpas, S. Divanidis, 2003: Performance of the tobacco aphid *Myzus persicae* (Hemiptera: Aphididae) on Oriental and Virginia tobacco varieties. Agr. Forest Entomol. **5**, 285-291.

Guldemond, J.A., W.T. Tiggers, P.W.F. de Vrijer, 1994: Host races of *Aphis gossypii* (Homoptera: Aphididae) on cucumber and chrysanthemum. Environ. Entomol. **11**, 1235-1240.

Harrison, F.P., 1969: Reproductive capacity of the green peach aphid on Maryland tobacco. J. Econ. Entomol. **62**, 593-596.

Jones, D., 1984: Use, misuse, and role of multiple-comparison procedures in ecological and agricultural entomology. Environ. Entomol. **13**, 635-649.

Kersting, U., S. Satar, N. Uygun, 1998: Genetically distinct forms of *Aphis gossypii* Glover (Homoptera, Aphididae) on cotton and cucumber. In: Proc. VIth European Congress of Entomology, 23–29 August. Ceske Budejoivice, Czech Republic.

Kersting, U., S. Satar, N. Uygun, 1999: Effect of temperature on developmnt rate and fecundity of apterous *Aphis gossypii* (Hom., Aphididae) reared on *Gossypium hirsutum* L. J. Appl. Entomol. **123**, 23-27.

Kindlmann, P., A.F.G. Dixon, 1989: Development constraints in the evolution of reproductive strategies: telescoping of generations in parthenogenetic aphids. Funct. Ecol. **3,** 531-537.

Klingauf, A.F., 1987: Feeding, adaptation and excretion. In: A.K. Minks, P. Harrewijn (eds.): World Crop Pests, Aphids – Their Biology, Natural Enemies and Control, Vol. 2A, pp. 225-253. Elsevier, Amsterdam.

Kocourek, F., J. Havelka, J. Beránková, V. Jarosik, 1994: Effect of temperature on development rate and intrinsic rate of increase of *Aphis gossypii* reared on greenhouse cucumbers. Entomol. Exp. Appl. **71**, 59-64.

Komazaki, S., 1982: Effects of constant temperature on population growth of three aphid species, *Toxoptera citricidus* (Kirkaldy), *Aphis citricola* van der Goot and *Aphis gossypii* Glover (Homoptera: Ahididae) on citrus. Appl. Entomol. Zool. **17**, 75-81.

KUDEN, A., 1998: Horticultural research in Turkey. ISHS World Conference on Horticultural Research, June 17-20, 1998: Rome, Italy.

LECLANT, F., J.P. DEGUINE, 1994: Aphids (Hemiptera: Aphididae). In: G.A. Matthew, J.P. Tunstall (eds.): Insect Pests of Cotton, pp. 285-323. CAB International, Wallingford, United Kingdom.

MARAGARITOPOLOUS, J.T., J.A. TSITSIPIS, E. ZINTZARAS, R.L. BLACKMAN, 2000: Host-correlated morphological variation of *Myzus persicae* (Hemiptera: Aphididae) populations in Greece. B. Entomol. Res. **90**, 233-244.

MARGARITOPOULOUS, J.T., J.A. TSITSIPIS, S. DOUDOUDAKI, R.L. BLACKMAN, 2002: Life cycle variation of *Myzus persicae* (Hemiptera: Aphididae) in Greece. B. Entomol. Res. **92**, 309-319.

MEYER, J.S., C.G. INGERSOLL, L.L. MCDONALD, M.S. BOYCE, 1986: Estimating uncertainty in population growth rates: jackknife vs. bootstrap techniques. Ecology **67**, 1156-1166.

SATAR, S., U. KERSTING, N. UYGUN, 1998: Effect of different citrus host plants and temperatures on development rate and fecundity of apterous *Aphis gossypii* Glover (Homoptera: Aphididae). Türk. Entomol. Derg. **22**, 187-197.

SATAR, S., U. KERSTING, N. UYGUN, 1999: Development and fecundity of *Aphis gossypii* Glover (Homoptera: Aphididae) on three Malvaceae hosts. Turk. J. Agric. For. **23**, 637-643.

SATAR, S., U. KERSTING, N. UYGUN, 2005: Effect of temperature on development and fecundity of *Aphis gossypii* Glover (Homoptera: Aphididae) on cucumber. J. Pest Sci. **78**, 133-137.

SAWICKI, R.M., A.L. DEVONSHIRE, R.W. PAYNE, S.M. PETZING, 1980: Stability of insecticide resistance in the green peach aphid, *Myzus persicae* (Sulzer). Pestic. Sci. **11**, 33-42.

STATISTICAL GRAPHIC CORPORATION, 1988: Statgraphics Users' s Guide System. STSC, Inc., Rockville, MD, USA.

VAN EMDEN, H.F., V.F. EASTOP, R.D. HUGHES, M.J. WAY, 1969: The ecology of *Myzus persicae*. Annu. Rev. Entomol. **14**, 197-270.

VANLERBERGHE-MASUTTI, F., P. CHAVIGNY, 1998: Host-based genetic differentiation in the aphid *Aphis gossypii* Glover, evidenced from RAPD fingerprints. Mol. Ecol. **7**, 905-914.

VAN STEENIS, M.J., K.A.M.H. EL-KHAWASS, 1995: Life history of *Aphis gossypii* on cucumber: influence of temperature, host plant and parasitism. Entomol. Exp. Appl. **76**, 121-131.

VELIOĞLU, A.S., C. ERDOĞAN, M.O. GÜRKAN, 2007a: Determination of the correlation between insecticide resistance and carboxylesterase activity of *M. persicae* (Sulzer) (Homoptera: Aphididae) population damaging on the vegetables in Turkey. Proceedings of the Second Plant Protection Congress of Turkey, 27-29 August, Isparta, Turkey.

VELIOĞLU, A.S., C. ERDOĞAN, M.O. GÜRKAN, 2007b: Determination of the Insecticide resistance mechanism using biochemical methods in the Aphis gossypii Glover (Homoptera: Aphididae) population damaging on cotton in Turkey. Proceedings of the Second Plant Protection Congress of Turkey, 27-29 August, Isparta, Turkey.

ZITOUDI, K., J.T. MARGARITOPOULOS, Z. MAMURIA, J.A. TSITSIPIS, 2001: Genetic variation in *Myzus persicae* populations associated with host-plant and life cycle strategies. Entomol. Exp. Appl. **99**, 303-311.