Developmental biology of citrus mealybug, *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae), on ornamental plants

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Abstract: Development, longevity, fecundity and life-table parameters of *Planococcus citri* (Hemiptera: Pseudococcidae) feeding on *Nerium oleander, Schefflera arbicola, Kalanchoe blossfeldiana* and *Sygonium podophyllum* at 28±1°C, 65±10% RH and 16L:8D under laboratory conditions were investigated. The development time of female *P. citri* ranged from 20.33±0.52 on *N. oleander* to 22.85±0.64 days on *S. arbicola.* For males, it ranged from 17.60±0.26 days on *S. podophyllum* to 20.60±0.051 on *S. arbicola*. Immature *P. citri* displayed the lowest mortality rate on *S. podophyllum* and the highest mortality rate on *S. arbicola*. Life expectancy of *P. citri* was shortest on *S. arbicola* (18.05±0.47 days) and the number of eggs laid on this host was the lowest (96.20±0.51). Longevity (28.82±1.88 days) and number of eggs laid (363.10±19.63) were highest on *S. podophyllum*. The lowest (75%) and highest (95.66%) rate of egg hatching occurred on *S. arbicola* and *S. podophyllum* respectively. The sex ratio of *P. citri* favoured females, which comprised 54-66% of the population. The highest reproductive rate (R_0) occurred on *S. podophyllum,* with 205.46 female offpring/ female, and the lowest occurred on *S. arbicola,* with 32.27 female offpring/female. The intrinsic rate of increase (r_m) was significantly different among hosts, with the highest rate (0.138 female offpring/female/day) on *S. podophyllum*.

Key words: *Planococcus citri*, development, fecundity, longevity, life table.

Introduction

Citrus mealybug (*Planococcus citri* (Risso), Hemiptera: Pseudococcidae) is the most economically important mealybug species on citrus and other crops in Turkey (Bodenheimer, 1953; Duzgunş, 1982; Uygun *et al*., 2001). Recent research on the mealybug has shown that *P. citri* is the commonest mealybug on indoor plants in Ankara (Kaydan *et al*., 2005). It can overwinter at all stages outdoors in subtropical regions and indoors (Duzguneş, 1982; Uygun *et al*., 2001). *Planococcus citri* severely affects plant quality by sap extraction and fouling with honeydew excretions. Feeding by citrus mealybug can cause premature leaf drop, dieback, and may even kill plants if the pest is not controlled. *P. citri* also transmits Schefflera ringspot and Kalanchoe top-spotting virus diseases (Brunt, 1992; Lockhart & Olszewski, 1988), so it can be an economic pest even at low densities.

Information on citrus mealybug development on ornamental plants in the literature is limited. However, it has been studied on citrus, coffee, pumpkin and a few ornamentals (such as coleus and rose) (Ben-Dov, 1994; Malleshaiah *et al*., 2000; Sadof *et al*., 2003; Laflin & Parella, 2004). Development, longevity and fecundity of the mealybugs vary according to the suitability of the host.

The control of citrus mealybug is not successful in Ankara; its biological and morphological characteristics under glass and indoors are ill-defined in this region. Hence, information on its development could be very important for the optimal timing of natural enemy releases and other control methods for growers of ornamental plants.

In the current study, the suitability of four ornamental plant species as hosts for citrus mealybug was examined. Specifically, development, fecundity and longevity of the citrus mealybug on these hosts were determined.

Materials and methods

Test plants

The acceptability and host suitability of four potted ornamental plant species for *P. citri* were tested. *Kalanchoe blossfeldiana* (Crassulaceae), *Nerium oleander* (Apocynaceae), *Syngonium podophyllum* (Araceae) and *Schefflera arbicola (*Araliaceae) were chosen for the study because they are common hosts of *P. citri* and are common indoor plants in Ankara, Turkey (Kaydan *et al*., 2005).

Rearing Planococcus citri

Citrus mealybugs were collected from greenhouse and indoor plants in Ankara and reared for one generation on *K. blossfeldiana, N. oleander, S. podophyllum, S. arbicola*. The cultures were maintained in a climate chamber at 28±1°C, 60±5% RH and a photoperiod of 16L : 8D. Five or six weeks after the initial infestation, ovisacs of *P. citri* were collected from each host plant and used for the experiments. The remaining mealybugs were used as a stock culture of *P. citri.*

Experimental procedure

Leaves of uninfested *K. blossfeldiana, N. oleander, S. podophyllum,* and *S. arbicola* were used. For each host plant, one leaf was placed in a plastic petri dish (6.9 cm) on several layers damp filter paper. Each petri dish lid had 4 ventilation openings (1 cm diameter), each of which was covered by muslin. One ovisac reared on *K. blossfeldiana, N. oleander, S. podophyllum,* or *S. arbicola* was put into each petri dish and observed daily under a stereomicroscope for hatching. When crawlers were observed, they were transferred to fresh leaves in other petri dishes using a camel-hair brush. Dead and stuck nymphs were recorded and removed from the petri dishes. Records of larval growth and moults were made daily, and exuviae were removed promptly. When 'pupae' and adult males were observed, the number of days to this stage was recorded. The number of days from hatching to the last moult for female nymphs (pre-ovisac females) was also recorded to calculate female development time. The eggs laid on different hosts were counted and removed daily. The number of crawlers emerging from each ovisac was recorded daily. The total number of crawlers and unhatched eggs was noted for each ovisac, to estimate percentage hatching success. All experiments were repeated 20 to 50 times.

Data for development time for juvenile instars, males and females, sex ratio, number of eggs per ovisac, days to hatching, and percentage hatching on the different host plants were analysed by ANOVA and Duncan's Multiple Range Test (P≤0.05).

Population growth rates on different ornamental host plants were calculated by constructing life tables according to Andrewartha & Birch (1970): $1 = \Sigma\, e^{-r}\, m^{x}\, l_x\, m_x$.

To construct life tables, age-specific survival rates (l_x) and number of female offspring (m_x) for each age interval (x) per day were used. From those data, net reproductive rate (R_0=female/female/generation), intrinsic rate of increase (r_m=female/female/day) and mean generation time ($T_0 = \ln(R_0/r)$, in days) were calculated. For the original data (r_{a11}), the differences in r_m- values were tested for significance by estimating the variance using the jack-knife method (Sokal & Rohlf, 1995; Meyer *et al*., 1986). The jack-knife pseudo-value rj was calculated for the n samples using the following equation: $r_j = n \times r_{a11} - (n-1) \times r_{i.}$

Following calculation of the reproduction capacity (r_m), standard deviations of the r_m values were calculated by the jack-knife method to determine the differences between citrus mealybugs produced on different host plants. The calculated average jack-knife values were estimated at the p = 0.05 level (T test, using Statistica 6.0 for Windows 95, Anova), and statistical differences between them were determined.

Results and discussion

Host plant quality is a key determinant of the fecundity of herbivorous insects. Components of host plant quality (such as carbon, nitrogen, and defensive metabolites) directly affect potential and achieved herbivore fecundity (Awmack & Leather, 2002).

The present study showed that development time, longevity and fecundity of *P. citri* were affected when fed on different host plant species. The mean development time of first instar *P. citri* on *S. arbicola* was significantly longer than on other hosts, and was significantly shorter on *S. podophyllum* ($F_{(3.135)}$=20.015), but there was no significant difference between the values on *K. blossfeldiana* and *N. oleander*. The development time of males was similar to that of females; significantly fastest on *S. podophyllum* and slowest on *S. arbicola* (Table 1).

Table 1. Duration of immature stages of *Planococcus citri* on different host plants (mean ±SE).

Host	n	The duration of developmental stages (days)								
		♀				♂				
		I.	II.	adult	Total	I.	II.	pupae	total	adult
K. blosfeldiana	50	6.74± 0.14b	6.56± 0.13b	7.20± 0.14bc	20.50± 0.30b	6.78± 0.12b	5.44± 0.16ab	7.24± 0.11a	19.46± 0.17b	2.18± 0.12a
S. podophyllum	40	5.61± 0.14c	7.53± 0.15a	8.74± 0.18a	21.89± 0.32a	5.55± 0.07c	5.02± 0.01b	7.02± 0.16a	17.60± 0.26c	2.30± 0.13a
S. arbicola	20	7.90± 0.33a	7.25± 0.20a	7.70± 0.21b	22.85± 0.64a	7.55± 0.26a	5.9± 0.02a	7.15± 0.37a	20.60± 0.51a	1.75± 0.16b
N. oleander	30	6.66± 0.21b	6.60± 0.23b	7.06± 0.21c	20.33± 0.52b	6.6± 0.17b	4.96± 0.02b	7.23± 0.17a	18.80± 0.38b	2.53± 0.14a

Within each column, figures ending in the same letter showed no significant difference (P<0.05)

Development times for 2nd–instar female *P. citri* nymphs on *K. blossfeldiana* and *N. oleander* were significantly shorter than on *S. podophyllum* and *S. arbicola* ($F_{(3.135)}$=8.2503, p=0.0000). For 2nd-instar male nymphs, development times on *S. podophyllum* and *N. oleander* were significantly shorter than on other host plants ($F_{(3.136)}$=4.1095, p=0.07) (Table 1). Female 3rd instar nymphs developed significantly faster on *N. oleander* and *K. blossfeldiana* than on *S. arbicola* and *S. podophyllum* ($F_{(3.135)}$=19.12, p=0.0000). However, development of the male prepupa+pupa instars was not significantly different on the four host plants ($F_{(3.136)}$=.35153, p=0.78810). Total development times of females were significantly slower on *S. arbicola* and *S. podophyllum* than on *K. blossfeldiana* and *N. oleander* (p<0.05). Total development time for males was significantly slower on *S. arbicola* than on *K. blossfeldiana* and *N. oleander,* and it was significantly faster on *S. podophyllum* than on other host plants (Fig 1). Adult female longevity was lower on *S. arbicola* and higher *S. podophyllum* than on other hosts ($F_{(3.135)}$=8.6531, p=0.0000). Adult males reared on *S. arbicola* lived for significantly less time than those from other host plants (Table 2).

The preoviposition period of *P. citri* on *S. podophyllum* was significantly longer than on other host plants ($F_{(3.135)}$=35.052, p=0.000). The oviposition period lasted 15.96±0.80 days on *N. oleander* and was significantly longer than that on other host plants. The postoviposition period ranged from 2.60±0.16 days on *S. arbicola* to 3.76±0.34 days on *N. oleander* ($F_{(3.135)}$ =4.8454, p=0.003) (Table 2).

Both daily and total counts showed that female *P. citri* laid significantly more eggs on *S. podopyllum* than on the other host plants. The incubation period on *S. arbicola* (4.43±0.06 days) was significantly longer than the other 3 host plants. The percentage of eggs hatching was significantly higher on *K. blossfeldiana*, on *S. podophyllum* and on *N. oleander* than on *S. arbicola* ($F_{(3.9)}$=29.37, p=0.0000).

The longevity of adult female *P. citri* was shortest, and egg yield was lowest, on *S. arbicola*. On the other hand, these values were longest and highest, respectively, on *S. podophyllum*. *N. oleander* and *K. blossfeldiana* are variegated plant species; the total development time of females was not affected, but their reproduction and longevity were influenced by both these host plants.

Laflin & Parrella (2004) studied the development of *P. citri* at constant and varying temperatures on roses, *Rosa hybrida* L. For females reared at 26.6°C during the day and 15.5°C during the night, the thermal constant was 326 day-degrees, and the median number of days to egg hatch, second instar, third instar and adulthood were 6, 17, 26 and 32 respectively. In this study, on the four host plants the mean incubation period was between 3.11-4.43 days. Mean duration of the developmental stages (from hatching to adult) for female and males of *P. citri* were 20.33-22.85 and 17.60-20.60 respectively. The median number of days from eggs to adult for females was therefore found to be 23-27 days. The development stages took less time than Laflin & Parrella (2004) found on the roses.

The sex ratios favored females on all four host plants, 34.32%: 65.68% (male:female) on *K. blossfeldiana,* 42.16%:57.84% on *S. podophyllum*, 46.07%: 53.93% *S. arbolicola* and 43.96%: 56.04% on *N. oleander.* Figure 1 shows the relationship between the age specific survival (l_x) and the various stages of development of *P. citri* on *K. blossfeldiana*. Mortality was relatively high till the adult stage (Day 20), but then did not change until Day 38 when adults began to die. The last adult died on the 63rd day. Female *P. citri* began to lay eggs on Day 28 and the majority of eggs were laid in the first half of the oviposition period. The most eggs were laid on the 38th day, followed by a decrease by the end of 57th day.

On *S. podophyllum,* no mortality was seen during juvenile development, and only commenced once they had become adult at 43 days of age (Fig. 1). Oviposition began on the 31st day and ceased on the 53rd day. All adults were dead by the 57th day. On *S. arbicola,* the age-specific survival (l_x) of *P. citri* decreased on the 6th day. The adult stage began on the 23rd day and mortality did not begin until the 39th day; the last individual died on the 53rd day. Oviposition began on the 29th day, and ended on the 50th day (Fig. 1). The age-specific survival (l_x) of *P. citri* on *N. oleander* showed no significant differences from that on the other hosts. The mortality of adults began on the 39th day and lasted until the 61st day. The first egg was laid on the 37th day, and oviposition finished on the 58th day.

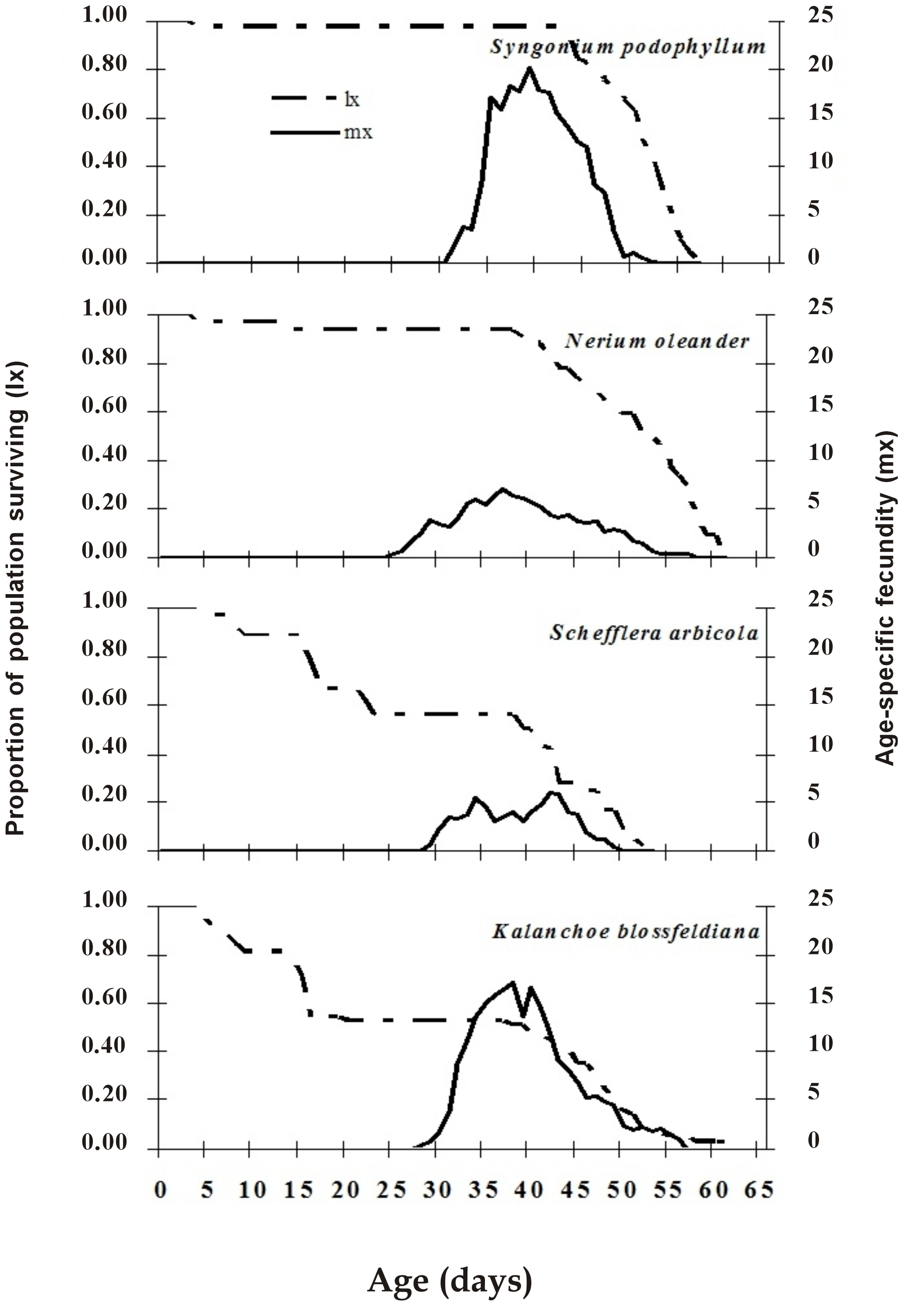

Figure 1. Survivorship curve (lx) and age-specific fecundity rate (mx) of *Planococcus citri* on four ornamental plants.

Table 2. Longevity and fecundity of *Planococcus citri* on different host plants (all data are mean ±SE).

Host plant species	Durations (days)			Longevity (days)	No of offspring per female		Hatching of eggs (%)	Duration of hatching
	Pre ovi.	Ovi.	Post ovi.		Per day	Total		
K. blossefeldiana	7.58± 0.14b	12.60± 0.55b	2.94± 0.20b	23.12± 0.67b	22.50± 1.00b	281.96± 16.09b	92.25± 1.37a	3.65± 0.06b
S. podopyllum	10.02± 0.20a	11.33± 0.38b	3.66± 0.17a	28.82± 1.88a	32.16± 1.28a	363.10± 19.63a	95.66± 0.33a	3.19± 0.04c
S. arbicola	7.95± 0.25b	7.50± 0.02c	2.60± 0.16b	18.05± 0.47c	12.81± 0.84c	96.20± 5.09d	75.00± 3.05b	4.43± 0.06a
N. oleander	7.86± 0.23b	15.96± 0.80a	3.76± 0.34a	27.60± 1.022a	11.14± 0.71c	177.23± 14.80c	92.66± 0.66a	3.11± 0.05c

Within each column, figures ending in the same letter showed no significant difference (P<0.05)

Net reproductivity (R_o) of *P. citri* was greatest on *S. podophyllum*, because fecundity was highest on this plant. The intrinsic rates of population increase (r_m) were significantly different on each host plant, ranging from 0.09 to 0.13 (P< 0.059) (Table 3). Longevity of generation (T_o) ranged from 35.75 to 36.40; generation times were shorter on *N. oleander* and longer on *S. podophyllum* (Table 3).

Table 3. Net reproductive rate (*R*0), intrinsic rate of increase (*r*m) and generation time (*T*0) of *Planococcus citri* on four ornamental plants.

Host plants	(R_o) ♀/♀/generation	(T_m) ♀/♀/ generation	(T_o) day
Kalanchoe blossefeldiana	116.5681	0.1282±0.000023b	37.1140
Syngonium podopyllum	205.4615	0.1380±0.000051a	38.5981
Schefflera arbicola	32.2770	0.0954±0.000111d	36.4077
Nerium oleander	95.5278	0.1275±0.000153c	35.7537

Within each column, figures ending in the same letter showed no significant difference (P<0.05)

The net reproductivity number (R_o) and intrinsic rate of population increase (r_m) of *P. citri* changed according to the host species. The highest R_o and r_m were calculated at the females fed by *S. podophyllum*. The lowest reproductivity number (R_o) and the intrinsic rate of population increase (r_m) were recorded on *S. arbicola* as seen for the other aspects. Based on the results obtained, it is clearly seen that *S. podophyllum* is the best of the 4 hosts studied host for the development and fecundity of *P. citri*. *S. arbicola* was not suitable compared to the other hosts. The factors affecting this might be the physical and chemical differences of leaves of this plant (Sadof *et al*., 2003; Hogendrop *et al*., 2006).

Plant chemistry can interfere with chemical processes associated with short- and long-range host finding as well as host utilization by pests and their natural enemies. Studies on both the citrus mealybug, *P. citri*, and its parasitoid, *Leptomastix dactylopii* (Howard) (Hymenoptera: Encyrtidae), indicate that coleus leaf variegation can affect the rate of fecundity, survivorship, and population growth of both organisms (Yang & Sadof, 1997). Çalisir *et al*. (2005) showed that, total numbers of female *Anagyrus pseudococci* (Girault)

(Hymenoptera: Encyrtidae) were importantly highest on 18 days old than 12 days old citrus mealybugs. Therefore the best time of release of *A. pseudococci* is 18 days old citrus mealybug for the successful biological control. Here, the development time of *P. citri* was shorter on *K. blossfeldiana* and *N. oleander*. These results show that *A. pseudococci* can be released earlier than other host plants.

In summary, our findings indicate that *P. citri* has fewer generations and the greatest populations on *S. podophyllum,* and of the most generations on *S. arbicola* the populations are smaller. Based on these biological data, growers can decide on the best control methods and how often and when to apply them. These data may also help the grower to determine the numbers of beneficial insects that need to be released andwhen to repeat of the application.

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References

Andrewartha, H.G. & Birch, L.C. 1970. The distribution and abundance of animals, University of Chicago Press, Chicago.

Awmack, C.S. & Leather, S.R. 2002. Host plant quality and fecundity in herbivorous insects. Annual Review of Entomology 47:817-844.

Ben-Dov, Y. 1994. A systematic catalogue of the mealybugs of the world (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with data on geographical distribution, host plants, biology and economic importance. Intercept Limited, Andover, UK.

Bodenheimer, F.S. 1953. The Coccoidea of Turkey II. Revue de la Faculté des Sciences de l'Université d'Istanbul 18:1-61.

Brunt, A.A. 1992. Plant viruses online – Kalanchoe top-spotting badnavirus. http://biology.anu.edu.au/Groups/MES/vide [need to give the date when this information was accessed online for this study].

Çalisir, S., Kilinçer, A.N., Kaydan, M.B. & Ülgentürk, S. 2005. Some biological aspects of *Anagyrus pseudococci* (Girault) (Hymenoptera: Encyrtidae) on different ages of *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae). Journal of Agricultural Sciences 11:242-247 (Turkish with English abstract).

Duzguneş, Z. 1982. Studies on Turkish Pseudococcidae (Homoptera: Coccoidea) species. Ankara University, Publications of Faculty of Agriculture. No: 836 (in Turkish).

Hogendorp, B.K., Cloyd, R.A. & Swiader, J.M. 2006. Effect of nitrogen fertility on reproduction and development of citrus mealybug, *Planococcus citri* Risso (Homoptera: Pseudococcidae), feeding on two colors of coleus, *Solenostemon scutellarioides* L. Codd. Environmental Entomology 35:201-211.

Kaydan, M.B., Kilincer, N. & Kozár, F. 2005. Studies on Pseudococcidae (Hemiptera: Coccoidea) fauna of urban ecosystem of Ankara Province. Bollettino di Zoologia Agraria e di Bachicoltura (Milano) Ser.II 37:85-95.

Laflin, H. & Parella, P. 2004. Developmental biology of citrus mealybug under conditions typical of California rose production. Annals of the Entomological Society of America 97:982-988.

Lockhart, B.E.L. & Olszewski, N.E. 1988. Schefflera ringspot virus, a widely distributed mealybug -transmitted bandavirus occurring in Schefflera and Aralia. ISHS Acta Horticulturae 234:73, IX. International Symposium on Virus Diseases of Ornamental Plants.

Malleshaiah, B.K. Rajagopal, K. & Gowda, K.N.M. 2000. Biology of the citrus mealybug *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae). Crop Research 20:130-133.

Meyer, J.S., Ingersoll, C.G., Mcdonald, L.L. & Boyce, M.S. 1986. Estimating uncertainty in population growth rates: jackknife vs. bootstrap techniques. Ecology 67:1156-1166.

Sadof, C.S., Jonathan, J.N. & Cloyd, R.A. 2003. Effects of variegation on stem exudates of coleus and life history characteristics of citrus mealybug (Hemiptera: Pseudococcidae). Environmental Entomology 32:463-469.

Sokal, R.R. & Rohlf, F.J. 1995. Biometry. The principles and practice of statistics in biological research. 3rd ed. W.H. Freeman and Co., New York.

Uygun, N., Karaca, I., Ulusoy, R. & Senal, D. 2001. Pests of citrus. In Uygun N. (ed.): Integrated management on citrus orchards in Turkey. Publications of Agricultural Researches, TARP, Adana, pp. 9-57 (in Turkish).

Yang, J. & Sadof, C.S. 1997. Variation in the life history of the citrus mealybug parasitoid, *Leptomastix dactylopii* (Hymenoptera: Encyrtidae) on three varieties of *Coleus blumei.* Environmental Entomology 26:978-982.