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# Thermal Effect on the Biology and Life Tables of *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae)

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**Abstract:** The life history and life table of *Bemisia tabaci* Gennadius on cucumber was studied under laboratory conditions at 20, 25 and 30°C. The overall developmental time varied from 34.8 days at 20°C to 14.1 days at 30°C. Immature mortality decreased from 45.8 to 17.3% with increasing temperature. The threshold temperatures of egg, 1st, 2nd, 3rd and 4th nymphal stage and a generation were 14.72, 14.36, 10.18, 11.40, 14.36 and 13.07°C whereas the degree-day requirement at each stage was 64.44, 42.39, 49.19, 33.19, 35.46 and 229.52 DD, respectively. Female longevity ranged from 16.8-34.1 days. Mean total fecundity ranged from 150-263 eggs/female. Mean daily fecundity ranged from 4.2-12.7 eggs/female, increasing with increasing temperature. Values for $r_m$ varied from 0.066 to 0.191 being least at 20°C and greatest at 30°C. Generation times decreased from 43 to 19 days with increasing temperature. The results indicate that *B. tabaci* is well adapted to high temperatures and may extend its distribution if mean world temperatures increase as a result of global warming.

**Key words:** *Bemisia tabaci*, cotton whitefly, biology, life table, thermal, cucumber

## INTRODUCTION

The cotton whitefly, *Bemisia tabaci* Gennadius (Homoptera : Aleyrodidae) is an important pest on various crops. Its first record as a pest was reported in cotton fields of Greece in 1889 (Cock, 1993). It is a polyphagous species with a world wide distribution (Mound and Halsey, 1978; Cock, 1993; Mckenzie *et al*., 2004). Damage caused includes reduction in yield and fruit quality as well as virus transmission (Byrne *et al*., 1990; Oetting and Buntin, 1996; Schuster *et al*., 1996). In addition, *B. tabaci* is a polymorphic species. It is variable not only in its morphology (size and form of nymphs) (Mound and Halsey, 1978; Bethke *et al*., 1991) but also in its ecological characteristics (environmental requirements, development, fecundity, insecticide resistance, virus transmission, natural enemy complexes and endosymbiont complement (Xu *et al*., 2003; Al-Zeyoud and Sengonca, 2004; Horowitz and Ishaya, 1996; Markham *et al*., 1996; Rowland *et al*., 1991; Costa *et al*., 1993a, b; Bedford *et al*., 1994; Costa *et al*., 1995; Kirk *et al*., 2000). Therefore, for each pest management program, an exact determination of the crucial population parameters is required.

In Khouzestan province (Southwestern of Iran) *B. tabaci* utilizes several key plant species, particularly cucumber and other cucurbitaceous plants for feeding and reproduction. Very little information is available regarding life history traits of *B. tabaci* population infesting cucurbitaceous host plants in this area (Kocheili *et al*., 2005). In the present study, the effect of temperature on development, mortality, longevity, fecundity, sex ratio and life table characteristics of *B. tabaci* on cucumber was investigated.

## MATERIALS AND METHODS

**Stock culture maintenance:** Adult cotton whitefly, *Bemisia tabaci* used in these studies were collected by an aspirator in September 2006 from a cucumber (*Cucumis sativus* L.) field near Ahwaz, Iran and reared on the foliage of cucumber plants (cultivar Superdominus) grown from seeds in plastic pots (10 cm diameter). Infested plants were kept in wooden-framed rearing cages (120×60×60 cm) covered with white nylon mesh of 210 μm apertures. They were maintained in a laboratory with seasonal temperature ranging from 16-25°C and relative humidity 40-50%. The photoperiod was 16:8 (L:D) h, with illumination (4000 lux) provided from fluorscent lamps. Plant were kept in the cages until they were severely damaged by the whiteflies, new plants being added when needed.

**Development and mortality:** Forty to fifty adult whiteflies of both sexes (roughly 50% male: 50% female) were placed

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in each clip cages attached to the underside of expanding cucumber leaves. The clip cage were similar to those described by Lewis (1973) with some modifications. The clip cage was made of a plastic vial (1.5 cm diameter, 1 cm length). The bottom of the cage was covered with nylon organdy for ventilation. A 0.6 cm hole in the body of the cage served as an entrance for the whiteflies. The hole was accommodated by a small cork stopper. The test plants were maintained at 25°C for 24 h to allow deposition of eggs, after which the clip cages and adult whiteflies were removed. The plants were then placed in temperature-controlled cabinets at three constant temperatures: 20, 25 and 30±1°C. Relative humidity was kept at a minimum of 50% and a photoperiod of 16:8 (L:D) was maintained with light intensity set at 1800 lux. The plants were watered as needed. The development of each life stage, determined by measuring the size of the insect (Nechols and Tauber, 1977), was monitored with a dissection microscope until adult eclosion. The duration of immature stages and mortality were recorded daily.

**Longevity, fecundity, sex ratio and population parameters:** The effect of different temperatures on longevity, fecundity and other population parameters was studied by confining one adult female and one adult male immediately on emergence on the undersurface of a cucumber leaf by means of a plastic clip cage. Every other day, whiteflies were transferred to a new leaf and the eggs laid were counted. Any male insect that was accidentally lost, or that died before the female, was replaced. Each experiment was terminated with the natural death of the female. All eggs laid in fecundity experiment were observed daily until adult eclosion and the numbers of male and female whiteflies were recorded to determine the sex ratio.

**Statistical analysis:** Analysis of variance (ANOVA) and Duncan multiple range tests was used to examine differences in developmental times, longevity and fecundity across temperatures (SAS Institute, 1997). A series of Chi-square tests were conducted to determine if there were any significant differences in stage mortality for insects reared at different temperatures.

The reciprocals of the observed developmental times, in days, provided developmental rates for each stage at each temperature. Lower developmental threshold temperatures were estimated by the X-intercept method of Arnold (1959). The mean number of degree-days (DD) required for development of each life stage was calculated using the equation:

$$DD = D\,(T - t)$$

where:

- D = The developmental time (days)
- T = The temperature (°C) during development
- t = The lower developmental threshold (°C) (Price, 1984).

A life table using time-specific survival rates ($l_x$) and fecundity ($m_x$) for each 24 h period was constructed for calculating the following life table parameters (Southwood, 1978).

Net reproduction rate of increase: $R_0 = \Sigma\, l_x m_x$; Mean generation time (in days) : $T = \Sigma l_x m_x / R_0$; Intrinsic rate of increase: $r_m = \ln R_0/T$; Finite rate of increase: $\lambda = e^{rm}$; Population doubling time: $DT = \ln 2/r_m$. Data on the different treatments were compared with the Jacknife program developed by Maia *et al.* (2000).

## RESULTS AND DISCUSSION

**Development and mortality:** The developmental times for all immature stages were inversely proportional to temperature. The duration of the egg stage varied from 11.86 days at 20°C to 4.18 days at 30°C. Mean development times for first-to third-instar *B. tabaci* were usually slightly shorter than for its egg and fourth instar (pupal) development times. Some authors have reported that the egg and fourth-instar are the longest stages for other aleyrodids (Powell and Bellows, 1992a; Roermond and van Lenteren, 1992; Shishehbor and Brennan, 1995). It is of interest to know which life stages are longest when making pest management decisions, such as which biological control agents to use (e.g., egg parasitoid versus nymphal parasitoid) or which pesticide is most appropriate (e.g., one with ovicidal versus insecticidal properties) (Leddy *et al.*, 1995).

The mean total developmental period for *B. tabaci* varied from 34.84 days at 20°C to 14.10 days at 30°C (Table 1). Analysis of variance indicated significant differences in development time between the temperature examined ($F = 1500$; $df = 2, 57$; $p = 0.001$). In a comparable study Powell and Bellows (1992a) obtained a total development time of 38.20, 20.22 and 17.36 days on cucumber at 20, 25.5 and 29°C, respectively, which is longer than the results in our study. The discrepancy between the two studies may be due to differences in whitefly populations and experimental conditions (host plant cultivar). Bethke *at al.* (1991) examined biology, morphometrics and development of two populations of *B. tabaci* on cotton and poinsettia. Their study indicated

Table 1: Developmental times of the immature stages of *Bemisia tabaci* in days (Mean±SE) on cucumber

| | Temperature (°C) | | |
|---|---|---|---|
| Stages | 20 | 25 | 30 |
| Egg | 11.86±0.19a | 6.50±0.06b | 4.18±0.09c |
| First instar | 6.18±0.13a | 5.00±0.13b | 2.50±0.09c |
| Second instar | 5.75±0.13a | 2.75±0.11b | 2.63±0.09b |
| Third instar | 3.03±0.10a | 2.30±0.08b | 2.27±0.07b |
| Fourth instar | 7.16±0.23a | 2.77±0.08b | 2.32±0.09c |
| Total | 34.84±0.25a | 19.23±0.13b | 14.10±0.11c |
| N[a] | (59) | (62) | (52) |

Means in each row followed by the same letter(s) were not statistically significantly different (p>0.01); [a]: Sample size (N) in parenthesis

Table 2: Developmental rates (Y; 1/day) for immature instars regressed on constant temperatures (X), stimated lower developmental thresholds (t) and mean numbers of Degree-Days (DD) required for development of the immature stages of *B. tabaci*

| | Rate (Y) regressed on temperature (X) (°C) Y = - a+bX | | | | |
|---|---|---|---|---|---|
| Stages | a | b | $R^2$ | t (°C) | DD±SE |
| Egg | 0.228 | 0.015 | 0.99 | 14.72 | 64.44±1.24 |
| First instar | 0.342 | 0.024 | 0.87 | 14.36 | 42.39±5.54 |
| Second instar | 0.210 | 0.021 | 0.80 | 10.18 | 49.19±4.28 |
| Third instar | 0.130 | 0.011 | 0.77 | 11.40 | 33.19±4.80 |
| Fourth instar | 0.418 | 0.029 | 0.92 | 14.36 | 35.46±3.10 |
| Total | 0.055 | 0.004 | 0.99 | 13.07 | 229.52±13.8 |

Table 3: Percentage mortality within immature stages of *Bemisia tabaci* reared on cucumber at different temperatures

| | Temperature (°C) | | |
|---|---|---|---|
| Stages | 20 | 25 | 30 |
| Egg | 25.4 (15) | 6.5 (4) | 3.8 (2) |
| First instar | 13.6 (6) | 3.4 (2) | 0.0 (0) |
| Second instar | 5.3 (2) | 7.1 (4) | 4.0 (2) |
| Third instar | 5.6 (2) | 1.9 (1) | 6.3 (3) |
| Fourth instar | 5.9 (2) | 3.9 (2) | 4.4 (2) |
| Total | 45.8 (59) | 20.9 (62) | 17.3 (52) |

Sample size (n) in parenthesis is number dying in each stage except for the total which is the initial number entering the egg stage

Table 4: Longevity in days (Mean±SE, range, (N)) of adult female and male *Bemisia tabaci* on cucumber at three different temperature

| | Temperature (°C) | | |
|---|---|---|---|
| Sex | 20 | 25 | 30 |
| Female | 34.14±3.13a | 26.75±1.95b | 16.88±1.20c |
| Range | 15-51 | 9-39 | 2-23 |
| (N)[a] | (14) | (16) | (17) |
| Male | 29.50±2.99a | 17.50±2.24b | 11.23±0.79c |
| Range | 7-42 | 7-37 | 5-15 |
| (N)[a] | (14) | (16) | (17) |

Means in each row followed by the same letter(s) were not statistically significantly different (p>0.01); [a]: Sample size (N) in parenthesis

that, based on both morphometric and fecundity differences, there are distinct populations exploiting both cotton and poinsttia.

The lower threshold temperatures differed among the developmental stages (Table 2). Overall, the lower threshold for complete development of *B. tabaci* was apparently higher than 13.07°C. The predicted minimum thresholds of *B. tabaci* is lower than other reports for this aleyrodid. Powell and Bellows (1992 a) observed the lower thresholds for development of *B. tabaci* to be 14.65°C on cotton and 16.71°C on cucumber. However, Gerling *et al.* (1986) reported that the lower developmental threshold for *B. tabaci* is 11°C.

The mean number of degree-days required by *B. tabaci* to complete its development was 229 DD (Table 2). This is higher than that of Powell and Bellows (1992 a) for *B. tabaci* (195 DD) on the same host plant. The differences could be partly due to the lower minimum threshold temperature of *B. tabaci* in this study.

There were significant differences in mortality for different temperature regimes for eggs ($\chi^2$ = 52; df = 3; p = 0.04) and the first instar ($\chi^2$ = 7.8 ; df = 2 ; p = 0.04) but not for the second ($\chi^2$ = 0.193; df = 2; p = 0.97), third ($\chi^2$ = 1.29 ; df = 2; p = 0.73) and fourth ($\chi^2$ = 0.29 ; df = 2; p = 0.96) instars (Table 3). Total mortality was highest at 20°C (45.8 %), declined as temperature increased from 20 to 30°C (17.3 %). Present result agree with those of Powell and Bellows (1992a) who stated that total pre-adult mortality of *B. tabaci* decreased as temperature increased (from 20 to 32°C).

**Longevity:** An inverse relationship exists between temperature and mean adult longevity of *B. tabaci* across the full temperature range investigated (Table 4). ANOVA indicated that temperature was a highly significant factor affecting the longevity of both females (F = 81.16; df = 2, 74; p = 0.0001) and males (F = 383.35; df = 2, 36; p = 0.0001). The maximum longevity observed for an individual whitefly was 51 days for a female at 20°C.

The longevities of adult *B. tabaci* determined in the present study were greater than those reported in other studies conducted at similar constant temperatures. Three studies (Butler *et al.*, 1983; Powell and Bellows, 1992b; Fekrat and Shishehbor, 2004) conducted on cotton, cucumber and aubergine, respectively, at constant temperature reported adult longevity shorter than those obtained in the present study. Butler *et al.* (1983) reported that at 26.7 and 32.2°C females lived 8.0 and 10.4 days and males 7.6 and 11.7 days, respectively. Powell and Bellows (1992b) reported that females lived 24.6, 15.5 and 9.64 days and males 18.6, 12.23 and 7.03 days at 20, 25.5 and 29°C, respectively. Fekrat and Shishehbor (2004) found that at 20, 25 and 30°C females lived 18.14, 13.14 and 8.0 days and males 12.71, 9.78 and 5.92 days, respectively. As in the present study, most researchers reported that female insects lived longer than males (Butler *et al.*, 1983; Hendi *et al.* 1984; Powell and Bellows, 1992b; Fekrat and Shishehbor, 2004). Differences in population of whiteflies and host plants may account for greater longevity of *B. tabaci* in the present study.

Table 5: Total fecundity, daily fecundity (Mean±SE, range) and sex ratio of *B. tabaci* females on cucumber at three different temperatures

| | Temperature (°C) | | |
|---|---|---|---|
| Parameters | 20 | 25 | 30 |
| Total egg | 150.29±22.8b | 263.75±24.4a | 204.71±16.9ab |
| range (N)[a] | 49-324 (14) | 204-466 (16) | 44-291 (17) |
| Average eggs/day | 4.24±0.44c | 9.92±0.69b | 12.75±0.44a |
| Range | 3-7 | 7-13 | 8-16 |
| Sex ratio (female) | 0.502±0.012c | 0.560±0.008b | 0.599±0.120a |
| Female:Male | 1.04:1 | 1.27:1 | 1.49:1 |

Means in each row followed by the same letter(s) were not statistically significantly different (p>0.01); [a]Sample size (N) in parenthesis

**Fecundity and sex ratio:** ANOVA indicated significant overall temperature effects on mean total fecundity ($F = 22.19$; $df = 2, 74$; $p = 0.0001$) and mean daily fecundity ($F = 373.19$; $df = 2, 74$; $p = 0.0001$). Peak egg production occurred at 30°C (204.7 eggs) (Table 5). At this temperature, the maximum number of eggs produced in a single day by an individual female was 16.

At 30°C Hendi *et al.* (1984) reported means of 203.1 eggs laid by *B. tabaci* on tomato which compares favourably with the results obtained in the present study. However, other laboratory studies have reported a variety of fecundity values for this species. Horowitz (1983) reported that *B. tabaci* deposited a mean total number of 95.5 eggs on cotton at 30°C. At 20, 25.5 and 29°C Powell and Bellows (1992b) found that *B. tabaci* laid 196.5, 175.3 and 208.6 eggs, respectively, on cucumber. At 26.7 and 32.2°C Butler *et al.* (1983) found that *B. tabaci* laid a mean of 81 and 72 eggs, respectively, on cotton. Fekrat and Shishehbor (2004) found that *B. tabaci* laid a mean of 78.6, 71.3 and 51.8 eggs at 20, 25 and 30°C, respectively, on aubergine. By comparison in the present study on cucumber at 20, 25 and 30°C, the mean total eggs were 150.29, 263.75 and 204.71, respectively, generally higher than most other reports. The differences may be explained by disparities in host plant suitability to *B. tabaci* and population differences of whiteflies used in these studies.

Daily oviposition rates of *B. tabaci* obtained in the present study were higher than the values cited by Hendi *et al.* (1984), Powell and Bellows (1992b) and Fekrat and Shishehbor (2004). Hendi *et al.* (1984) reported that *B. tabaci* female laid 8 eggs daily at 30°C on tomato. In a laboratory experiment, Powell and Bellows (1992b) reported daily egg production rates of 4.95, 5.97 and 9.71 for *B. tabaci* female on cucumber at 20, 25.5 and 29°C, respectively. Fekrat and Shishehbor (2004) reported that *B. tabaci* laid 3.9, 5.0 and 5.8 eggs daily at 20, 25 and 30°C, respectively, on aubergine.

The sex ratio varied from 1:1 (male:female) at 20°C to 1:1.49 at 30°C (Table 5). Gameel (1978) reported that the sex ratio of *B. tabaci* is usually 1:1 on cotton. Coudriet *et al.* (1986) stated that he found approximately a 1:1 sex ratio during the summer.

Table 6: Life table parameters (Mean±SD) of *B. tabaci* on cucumber at three different temperatures

| | Temperature (°C) | | |
|---|---|---|---|
| Parameters | 20 | 25 | 30 |
| $r_m$ | 0.066±0.003a | 0.136±0.002b | 0.191±0.003c |
| $R_0$ | 18.000±2.660a | 38.430±3.550b | 40.480±3.330c |
| λ | 1.068±0.003a | 1.145±0.003b | 1.210±0.004c |
| T | 43.860±0.940a | 26.890±0.660b | 19.340±0.410c |
| DT | 10.460±0.440a | 5.100±0.110b | 3.620±0.050c |

Means in each row followed by the same letter(s) were not statistically significantly different (p>0.01)

**Life table parameters:** Calculated daily intrinsic rates of natural increase ($r_m$) ranged from 0.066 for whiteflies held at 20°C to a maximum peak rate of 0.191 at 30°C (Table 6). The finite rate of increase (λ) ranged from 1.068 times per individual per day at 20°C to 1.210 times per individual per day at 30°C (Table 6). Mean generation time (T) decreased consistently with rising temperature across the entire temperature range observed. The time required to double population number reached a minimum of only 3.62 days at 30°C.

The values of $r_m$ of *B. tabaci* on cucumber at 20 and 25.5°C were found by Powell and Bellows (1992b) to be 0.062 and 0.142 $day^{-1}$, respectively, which corresponds well with the results at the same temperatures in the present study. However, Fekrat and Shishehbor (2004) reported that at 20, 25 and 30°C the intrinsic rate of increase and net reproductive rate of *B. tabaci* on aubergine were 0.081, 0.092, 0.141 and 23.80, 21.67 and 18.12 $day^{-1}$, respectively. The values for both rates are lower than found in the present study (Table 6), reflecting higher juvenile mortality, lower fecundity and shorter adult life span in the study of Fekrat and Shishehbor (2004). Differences in the ecological factors, *viz.*, population of whiteflies, host plants as well as measurement methods may provide and explanation for higher $r_m$ and $R_0$ values for *B. tabaci* on cucumber than on aubergine.

The optimum temperature for development and reproduction of *B. tabaci* was 30°C, within the temperature range examined. Present data indicate that *B. tabaci* is adapted to warm areas. In the context of global warming, it would appear that *B. tabaci* has a greater chance of survival, consequently it may widen its geographical distribution and pose a new threat to agroecosystems, as a result of a greater access to new host plants.

## REFERENCES

Al-Zeyoud, F. and C. Sengonca, 2004. Development, longevity and fecundity of *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) on different host plants at two temperatures. Mittelungen der Deutschen Gesellschaft fur Algemeine und Angewandte Entomologie, 14: 373-376.

Arnold, C.Y., 1959. The determination and significance of the base temperature in a linear heat unit system. Proc. Am. Soc. Hortic. Sci., 74: 430-445.

Bedford, I.D., P.J. Markham, J.K. Brown and R.C. Rosell, 1994. Geminivirus transmission and biological characterization of whitefly (*Bemisia tabaci*) types from different world regions. Ann. Applied Biol., 125: 311-325.

Bethke, J.A., T.D. Paine and G.S. Nussly, 1991. Comparative biology, morphometrics and development of two populations of *Bemisia tabaci* (Homoptera: Aleyrodidae) on cotton and poinsettia. Ann. Entomol. Soc. Am., 84: 407-411.

Butler, G.D. Jr., T.J. Hennerberry and T.E. Clayton, 1983. *Bemisia tabaci* (Homoptera: Aleyrodidae): Development, oviposition and longevity in relation to temperature. Ann. Entomol. Soc. Am., 76: 310-313.

Byrne, D.N., T.S. Jr. Bellows and M.P. Parrella, 1990. Whiteflies in Agricultural Systems. In: Whiteflies: Their Bionomics, Pest Status and Management. Dan Gerling (Ed.), Intercept and Over, pp: 552.

Cock, M.J.W., 1993. *Bemisia tabaci*- An update 1986-1992 on cotton whitefly with an annotated bibliography. CABI, Ascot, pp: 78.

Costa, H.S., J.K. Brown, S. Sivasupramanian and J. Bird, 1993a. Regiona distribution, insecticide resistance and reciprocal crosses between the A and B biotypes of *Bemisia tabaci*. Insect. Sci. Applied, 14: 127-138.

Costa, H.S., D.M. Westcot, D.E. Ulman and M.W. Johnson, 1993b. Ultrastructure of the endosymbionts of the whitefly, *Bemisia tabaci* and *Trialeurodes vaporariorum*. Protoplasma, 176: 106-115.

Costa, H.S., D.M. Westcot, D.E. Ullman, R. Rosell, J.K. Brown and M.W. Johnson, 1995. Morphological variation in *Bemisia* endosymbionts. Protoplasma, 189: 194-202.

Fekrat, L. and P. Shishehbor, 2004. Biological characteristics and life table of cotton whitefly, *Bemisia tabaci* Gennadius on aubergine at different constant temperatures. Sci. J. Agric., 27: 21-32.

Gameel, O.I., 1978. The cotton whitefly, *Bemisia tabaci* (Genn.) in the Sudan Gezira. Third Ciba-Geigy seminar on the strategy for cotton pest control in the Sudan (Basel, 8-10 May 1978), pp: 111-131.

Gerling, D., A.R. Horowitz and J. Baumgartner, 1986. Autecology of *Bemisia tabaci*. Agric. Ecosyst. Environ., 17: 5-19.

Hendi, A., M.I. Abdel-Fattah and A. El-Sayed, 1984. Biological study on the whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae). Bull. Entomol. Soc. Egy., 65: 101-108.

Horowitz, A.R., 1983. Population dynamics of the tobacco whitefly (*Bemisia tabaci* Gennadius) on cotton. Ph.D Thesis, Tel Aviv University.

Horowitz, A.R. and I. Ishaya, 1996. Chemical Control of *Bemisia*. Management and Application. In: *Bemisia* 1995, Taxonomy, Bioloy, Damage, Control and Management. Dan Gerling and Richard T. Mayer (Eds.), Intercept and Over, pp: 702.

Kirk, A.A., L.A. Lacey, J.K. Brown, M.A. Ciomperlik, J.A. Goolsby, D.C. Vacek, L.E. Wendel and B. Napompeth, 2000. Variation within the *Bemisia tabaci* species complex (Hemiptera: Aleyrodidae) and its natural enemies leading to successful biological control of *Bemisia* biotype B in the USA. Bull. Entomol. Res., 90: 317-327.

Kocheili, F., M.S. Mossadegh, K. Kamali and A. Soleiman-Nejadian, 2005. A comparative study on the preimaginal developmental time of sweetpotato whitefly, *Bemisia tabaci* Gennadius (Hom: Aleyrodidae) on melon, cucumber and okra under laboratory conditions. Sci. J. Agric., 27: 37-44.

Leddy, P.M., T.D. Paine and T.S. Jr. Bellows, 1995. Biology of *Siphoninus phyllyreae* (Haliday) (Homoptera: Aleyrodidae) and its relationship to temperature. Environ. Entomol., 24: 380-386.

Lewis, T., 1973. Thrips: Their Biology, Ecology and Economic Importance. Academic Press. London, pp: 349.

Maia Aline, D.H., J.B. Alfredo and C. Campanhola, 2000. Statistical influence on associated fertility life table parameters using Jacknife technique: Computational aspects. J. Econ. Entomol., 93: 511-518.

Markham, P.G., I.D. Bedford, S. Liu, D.R. Frolich, R. Rosell and J.K. Brown, 1996. The Transmission of Geminiviruses by Biotypes of *Bemisia tabaci*. In: *Bemisia*: 1995, Taxonomy, Biology, Damage, Control and Management. Dan Gerling and Richard T. Mayer (Eds.), Intercept and Over, pp: 702.

McKenzie, C.L., P.K. Anderson and N. Villareal, 2004. An extensive survey of *Bemisia tabaci* (Homoptra: Aleyrodidae) in agricultural ecosystems in Florida. Florida Entomol., 87: 403-407.

Mound, L.A. and S.H. Halsey, 1978. Whitefly of the World. Wiley and Sons, New York, pp: 340.

Nechols, J.R. and M.J. Tauber, 1977. Age-specific interaction between the greenhouse whitefly and *Encarsia Formosa*: Influence of host on the parasites oviposition and development. Environ. Entomol., 6: 207-210.

Oetting, R.D. and D. Buntin, 1996. *Bemisia* Damage Expression in Commercial Greenhouse Production. In: *Bemisia* 1995, Taxonomy, Biology, Damage, Control and Management. Dan Gerling and Richard T. Mayer (Eds.), Intercept and Over, pp: 702.

Powell, D.A. and T.S. Jr. Bellows, 1992a. Preimaginal development and survival of *Bemisia tabaci* on cotton and cucubmber. Environ. Entomol., 21: 359-363.

Powell, D.A. and T.S. Jr. Bellows, 1992b. Adult longevity, fertility and population growth rates for *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) on two host plant species. J. Applied Entomol., 113: 68-78.

Price, P.W., 1984. Insect Ecology. 2nd Edn., Wiley and Sons, New York, pp: 607.

Roermound, H.J.W. and J.C. van Lenteren, 1992. The parasite-host relationship between *Encarsia Formosa* (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) XXXIV. Life history of the greenhouse whitefly, *Trialeurodes vaporariorum* as a function of host plant and temperature. Wageningen Agric. Univ. Papers, 92: 1-102.

Rowland, M.B., B. Ackett and M. Stribley, 1991. Evaluation of insecticide in field-control simulators and standard laboratory bioassays against resistant and susceptible *Bemisia tabaci* (Homoptera: Aleyrodidae) from Sudan. Bull. Entomol. Res., 81: 189-199.

SAS Institute, 1997. SAS/STAT User Guide. Version 6.9. Cary. NC.

Schuster, D.J., P.A. Stansley and J.A. Polston, 1996. Expressions of Plant Damage by *Bemisia*. In: *Bemisia* 1995, Taxonomy, Biology, Damage, Control and Management. Dan Gerling and Richard T. Mayer (Eds.), Intercept and Over, pp: 702.

Shishehbor, P. and P.A. Brennan, 1995. Environmental effects on preimaginal development and survival of castor whitefly, *Trialeurodes ricini* Misra. Insect. Sci. Applic., 16: 325-331.

Southwood, T.R.E., 1978. Ecological Methods, with Particular Reference to the Study of Insect Populations. Chapman and Hall, London, pp: 524.

Xu, W.H., R.Z. Guo, J.Z. You, J.W. Quing, Y.X. Bao and L.L. Gui, 2003. Analysis of the life table parameters of *Bemisia tabaci* feeding on seven species of host plants. Entomol. Knowledge, 40: 453-455.