Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2015; 3 (3): 117-121

Received: 19-04-2015
Accepted: 17-05-2015

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Life history of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) biotype B on tomato and cotton host plants

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Abstract
Bemisia tabaci (Gennadius) (Homoptera: Aleyrodidae) is a serious pest of tomato and cotton, worldwide. In the present research work, life history of *B. tabaci* was studied on tomato and cotton host plants under laboratory conditions at a temperature of 25±2°C, relative humidity of 60±5%, photoperiod of 16:8h (L:D) and an artificial light intensity of about 4000 lux. The results showed that *B. tabaci* total duration from egg to adult stage was longer on cotton (38.8 days) than on tomato (33.6 days). Total mortality from egg to adult stage was higher on tomato (34.4%) than on cotton (28.2%). The females lived longer than males on both the host plant species. Mean adult longevity of female and male was 19.1, 18.5 days on tomato and 21.0, 20.7 days on cotton, respectively. Fecundity of females was higher on cotton (92.0 eggs/female) than on tomato (78.3 eggs/female). Overall, the *B. tabaci* had longer embryonic as well as immature developmental duration and longevity on cotton than on tomato. Also, fecundity was higher on cotton than tomato. Mortality in each insect developmental stage was lower on cotton than on tomato. The female: male adults sex ratio was higher on cotton (55:45) than on tomato (52:48). The present results will help in better understanding of *B. tabaci* population dynamics, which will lead to its efficient control under glasshouse and field conditions.

Keywords: *Bemisia tabaci* biotype B, Cotton, Life history, Tomato

1. Introduction
Bemisia tabaci (Gennadius) (Homoptera: Aleyrodidae) has a wide host range of more than 500 host plant species [1] belonging to more than 60 plant families [2]. *B. tabaci* is an economical pest of many field and horticultural crops world-wide [3]. Both the nymphs and adults of *B. tabaci* cause direct as well as indirect damages to its host plants including tomato and cotton. In direct damages, it pierces and sucks cell contents and excretes huge amounts of honeydew that induce and increase sooty mould fungal development and reduces the photosynthetic efficiency of the plant and thus yield. The honeydew sticks cotton lint together, making it more difficult to gin and therefore reducing its value as well as fruit quality grade [4, 5]. The host plants are indirectly damaged by the transmission of more than 50 Gemini viruses e.g., tomato yellow leaf curl virus [4], tomato mottle virus and bean golden mosaic virus [5].
B. tabaci is one of the most noxious pests of field and greenhouse crops around the world [2]. The pest is difficult to control with conventional insecticides because of its high reproductive rate and preferred habitat on the undersurface of leaves [6].
B. tabaci pose high threat to the production of food and fiber provides throughout the world. Biological control offers good solution to combat this pest. Biological control is an ecological phenomenon providing environmentally harmonious and economical pest management [7]. Estimation of life-history parameters under different biotic or abiotic conditions provide understanding many basic tools including changes in the status of pest species [8, 9, 10, 11].
In the present research work, development, mortality, longevity and fecundity as biological parameters of *B. tabaci* were studied in the laboratory on its two major host plants tomato and cotton.

2. Materials and Methods
2.1. Insect and Plant Culture
The experiments were conducted at the Chinese Academy of Agricultural Sciences (CAAS) Beijing, China during 2006-07. A stock culture of *B. tabaci* was maintained on tomato plants, variety Zhong Za No. 9, with few individuals obtained from cotton plants, variety Shi Yuan

No. 321, in a glasshouse at CAAS. The plants were kept in aluminum cages (80x50x60 cm), which were sealed with muslin cloth from all sides for providing ventilation. The cages were deposited in a climatically controlled chamber at the Institute of Plant Protection (IPP), CAAS Beijing, at a temperature of 25±2°C, relative humidity of 60±5%, photoperiod of 16:8 h (L:D) and artificial light intensity of about 4000 lux. The tomato and cotton plants were regularly grown in small pots (10-cm diameter and 8-cm height) in a glasshouse and transferred to the growth chamber in the institute when 2-3 weeks old.

The tomato and cotton plants were exposed to *B. tabaci* adult's infestation in the stock culture. Thereafter, the adults were removed and the plants were incubated under the climatic conditions as mentioned above. The plants were observed daily for obtaining the different insect stages (eggs, nymphs, pupae or adults) for the experiments. The old plants were used to infest the new ones and to feed the predator.

2.2. Embryonic development

For the embryonic development experiments, newly emerged *B. tabaci* adult pairs were caged for 48 h and then transferred to 2-3 week old plants of both hosts to lay eggs for 24 hours. The adults were removed the next day and 25 of the laid eggs were daily observed for development. The plants were stored in the growth chamber. The embryonic developmental duration was determined after all the eggs hatched.

2.3. Immature development

For the immature development experiments, 25 fresh individuals of each nymphal stage (N_1, N_2, N_3, N_4) as well as pupal stage, collected carefully by daily observation, were marked and confined separately on uniform sized fresh leaves of each host plant using plastic clip-cages, with a mesh-covered hole in the bottom for ventilation. The plants were stored in the growth chamber. The leaves were daily inspected to observe the different insect developmental stages on it. The date of entering each nymphal and pupal stage into the next stage was recorded.

2.4. Mortality

Mortality during embryonic and immature stages was recorded in another experiment. For this, 300 freshly laid eggs as well as newly hatched 1st instar nymphs as well as 2-4 instar nymphs and pupae were located and confined on the leaves of both host plants using clip cages. The plants were stored in the growth chamber. Embryonic mortality was determined by counting the number of hatching nymphs. Mortality during the nymphal instars and pupal stage was calculated by counting the number of individuals developing to the subsequent stage.

2.5. Longevity

For longevity experiment, newly emerged *B. tabaci* adult pairs were released in the clipped cage on each host plant. The observations were made daily until all the adults died. Twenty five replicates were set up for each plant species.

2.6. Fecundity

Fecundity of *B. tabaci* was determined in another experiment. For this, newly emerged adults pairs were aspirated into clipped cages attached to the two host plant leaves. The number of eggs laid per female during its lifetime was counted until the last female died. There were 13 replications of the experiment for each plant species.

2.7. Sex ratio

The sex ratio of *B. tabaci* was established from one hundred randomly collected adults from the stock culture, which were sexed under a binocular microscope. The number of females and males were counted and female: male ratio was determined.

In all the experiments, 2-3 weeks old plants of the two host species and uniform sized fresh leaves were used as arenas of observations in the different experiments. All the experiments were conducted at 25±2°C temperature, 60±5% RH, 16:8h photoperiod and a light intensity of 4000 lux.

2.8. Statistical Analysis

The life history data of *B. tabaci* on tomato and cotton host plants were obtained subject to t-test and significance levels determined at $p \leq 5\%$.

3. Results and Discussion

3.1. Embryonic and immature development

The present results revealed that duration of embryonic development, N_1, N_2, N_3, N_4 and pupal stage of females as well as males was significantly lower on tomato with a mean of 7.4, 3.6, 3.9, 4.2, 5.0, 9.6 days and 6.9, 3.6, 3.7, 4.1, 4.9, 9.4 days than on cotton with 8.2, 4.3, 4.8, 5.2, 5.6, 10.7 days and 7.8, 4.2, 4.7, 5.1, 5.6, 10.5 days, respectively (Fig. 1, 2). Mean total duration from egg to adult stage of females as well as males was significantly lower on tomato (33.6, 32.6 days) than on cotton (38.8, 37.9 days).

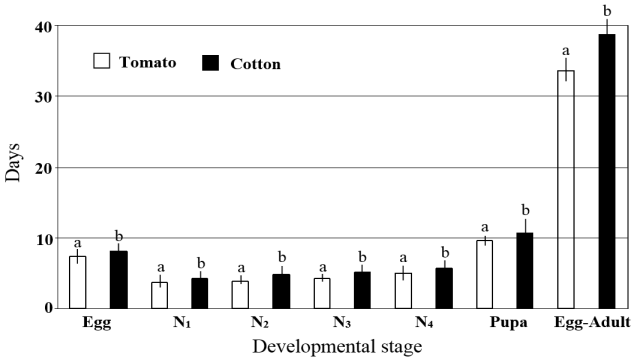

Fig 1: Mean duration of different development stages (days) of *Bemisia tabaci* females on two host plants at 25±2°C, 70±5% RH, 16:8h photoperiod. Bar heads within the same developmental stage followed by different letters are significantly different at $p \leq 5\%$ (t-test). Lines at bar heads indicate Standard Error.

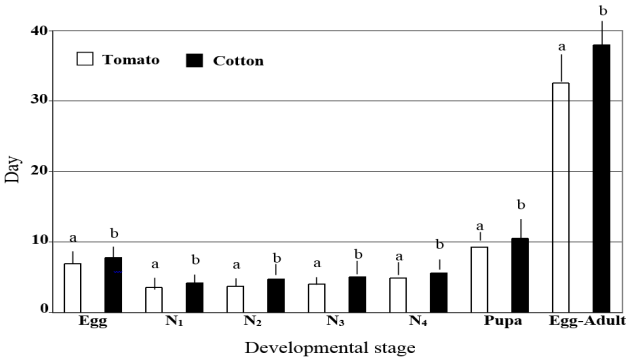

Fig 2: Mean duration of different development stages (days) of *Bemisia tabaci* males on two host plants at 25±2°C, 70±5% RH, 16:8h photoperiod. Bar heads within the same developmental stage followed by different letters are significantly different at $p \leq 5\%$ (t-test). Lines at bar heads indicate Standard Error.

The present results of *B. tabaci* embryonic development on tomato host were almost similar to that reported by earlier researchers, e.g., 6-7 days [12], 6-7 days [5]; 5-7 days [13]; but one day shorter than on cotton host. Some authors had reported longer embryonic duration of 7-10 days [14]. Mean developmental duration of the N_1 and N_2 was longer than 2-3 days [5] and much longer than combined 7 days of N_1-N_4 [14]. Similarly, mean developmental duration of N_4 and pupal stage was longer than 5-6 days [5] and duration of pupal stage was much longer than 6 days [14]. Developmental time from egg to adult of *B. tabaci* was different on the six cotton cultivars, i.e., 22.3, 21.9, 24.2, 21.6, 22.5 and 20.8 d on various biotypes, i.e. GK-12 (Bt), AST-104, CCRI19, Liao-Yang (hirsute), ZGK-9708 (Bt+CpTI) and Liao 7238, respectively [15]. Many researchers have found immature developmental time of *B. tabaci* (from egg to adult) dependent on the host plant [16, 17, 18, 19, 20; 21, 22] as well as on its populations or biotypes [23, 24].

3.2. Immature mortality

Mortality during embryonic, N_1, N_2, N_3, N_4 and pupal stage was comparatively higher on tomato with 11.0, 7.7, 4.0, 4.0, 2.7 and 5.0% than on cotton with 10.0, 5.3, 3.3, 3.3, 2.3 and 4.0%, respectively (Table 1). Total mortality during embryonic, nymphal stages and pupal stage was 34.4% on tomato and 28.2% on cotton. The total survivorship from egg to adult *B. tabaci* was different on the six cotton cultivars, i.e., 39.3, 37.0, 29.3, 58.3, 38.8, and 25.0% on GK-12 (Bt), AST-104, CCRI19, Liao-Yang (hirsute), ZGK-9708 (Bt+CpTI) and Liao 7238, respectively [15].

Table 1: Mortality (%) of embryonic and immature stages of *Bemisia tabaci* biotype B on tomato and cotton host plants at 25±2ºC, 70±5% RH and 16:8h (L:D).

Host plant	n	Mortality (%) during Egg stage*	Mortality (%) during immature stages					Total Mortality (%)
			N_1	N_2	N_3	N_4	Pupa	
Tomato	100	11.0	7.7	4.0	4.0	2.7	5.0	34.4
Cotton	100	10.0	5.3	3.3	3.3	2.3	4.0	28.2

*Mortality during egg stage includes undeveloped and hatched uncompleted individuals.

3.3. Longevity

Duration of pre-oviposition period was non-significantly different (3.4 days on tomato and 3.5 days on cotton) on the two host plants, but oviposition period was significantly longer on cotton (17.5 days) than on tomato (15.7 days). Mean adult longevity of females and males was significantly lower on tomato with 19.1, 18.5 days than on cotton with 21.0, 20.7 days, respectively (Fig. 3). The pre-oviposition period recorded in the present study was similar to that reported by [5, 12, 14]. The females lived longer than males on both the host plants. *B. tabaci* may complete its entire life cycle in 1-2 months [14].

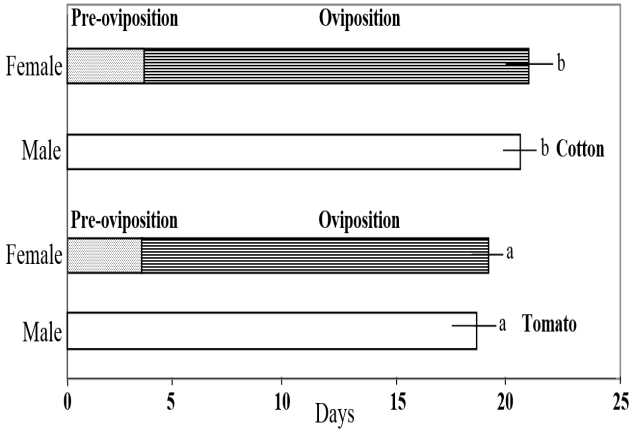

Fig 3: Mean duration of longevity (days) of *Bemisia tabaci* adults on two host plants at 25±2ºC, 70±5% RH, 16:8h photoperiod. Bar heads within the same sex followed by different letters are significantly different at p ≤ 5% (t-test). Lines at bar heads indicate Standard Error.

3.4. Fecundity

Fecundity of female was significantly higher on cotton (92.0 eggs/female) than on tomato (78.3 eggs/female), where the mean daily no. of laid eggs fluctuated mostly between 4-5 on tomato and 5-6 on cotton (Fig. 4). Earlier researchers have reported highly variable fecundities of *B. tabaci* females, e.g., 66 to 300 eggs (5), 30-500 eggs [14], varied on the six cotton cultivars from 138.1 eggs/female on CCRI 19 to 80.8 eggs/female on GK-12 [15]. Generally, *B. tabaci* fecundity is highly variable and depends on temperature [26; 5], host-plant species [5, 27] and cultivar [28].

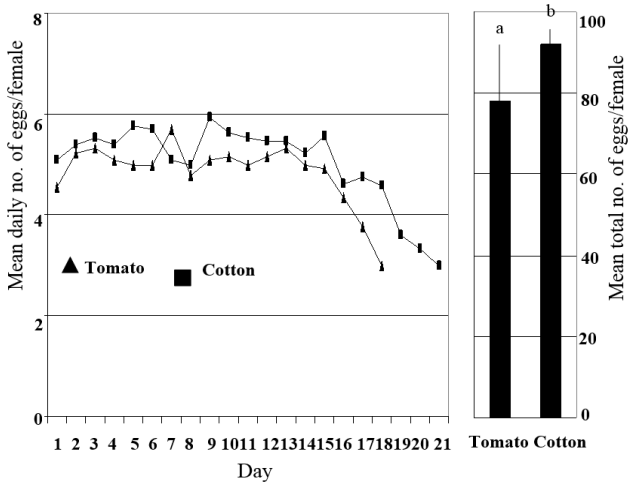

Fig 4: Mean daily and total fecundity of *Bemisia tabaci* females (no. of eggs/female) on two host plants at 25±2ºC, 70±5% RH, 16:8h photoperiod. Bar heads followed by different letters are significantly different at p ≤ 5% (t-test). Lines at bar heads indicate Standard Error.

3.5. Sex ratio

B. tabaci sex ratio investigation revealed 52:48 and 55:45 female to male ratio on tomato and cotton hosts, respectively (Table 2). *B. tabaci* biotype B male: female sex ratio was 0.56 and 0.53 on *Datura stramonium* and *Solanum nigrum*, respectively [24]. Due to arrhenotokous ability [29], *B. tabaci* can lay unfertilized eggs, which develop into males only. The highly variable *B. tabaci* sex ratio throughout the season makes it difficult to draw any conclusions [12].

Table 2: Sex ratio (female: male) of *Bemisia tabaci* biotype B adults on tomato and cotton host plants at 25±2ºC, 70±5% RH and 16:8h (L:D).

Host plant	n	Female (%)	Male (%)	Sex ratio (Female: Male)
Tomato	100	52	48	52:48
Cotton	100	55	45	55:45

3.6. Longevity

B. tabaci had longer embryonic as well as immature duration and longevity on cotton than on tomato. Also, fecundity and female:male sex ratio was higher on cotton than on tomato. But, mortality was lower on cotton than on tomato.

The present results on life history of *B. tabaci* might help better understand and predict its population dynamics and development under glasshouse and field conditions. This information will be used in devising new or improving the already existing integrated pest management programs for suppression of the pest using mainly its natural enemies in the different agricultural cropping systems. The differences observed between the present and previous studies might be due to the fact that life-history parameters are highly influenced by temperature, insect biotype, host plant species and varieties as reported by [20, 21, 23, 24].

4. Acknowledgment

The research work was a part of the National Basic Research and Development Program (Grant No. 2002CB111400, funded by Ministry of Science and Technology, China) and the research project titled "Group function of different predators and parasitoids combinations on *Bemisia tabaci*" funded by the Academic Committee of the State Key Laboratory for Biology of Plant Diseases and Insect Pests, the Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing 100094, P.R. China. Project no. 2007IP13.

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