Effect of Temperature on Life History of
*Bemisia Tabaci* (Gennadius) (Homoptera: Aleyrodidae) on Cassava *Manihot Esculenta* Crantz

Nguyen Duc Khanh, Le Ngoc Anh & Ho Thi Thu Giang
Faculty of Agronomy, Vietnam National University of Agriculture, Hanoi 131000, Vietnam

Abstract

The aim of the present study was to evaluate the relationships between environmental temperatures and life-history traits of whitefly *Bemisia tabaci* on cassava in the Northern part of Vietnam. The influence of temperature on the biological characteristics of whitefly *B. tabaci* fed on cassava was evaluated at 20°C, 25°C, 27.5°C, and 30°C using individual insect rearing methodology. Results of the study showed that the development time from egg to adult of *B. tabaci* was influenced by temperatures. The data indicated that under different temperatures (20°C, 25°C, 27.5°C, and 30°C), the life cycle of *B. tabaci* were 41.46, 28.64, 24.29, and 20.25 days, respectively. The determination of lower developmental threshold and degree days for whitefly development were 11.2°C and 344.8 degree-days. There were 14.31 whitefly generations within 1 year on cassava suggesting this plant is a suitable host plant for the development and reproduction of *B. tabaci*. Female longevity ranged from 4.92 to 10.23 days. The fecundity ranged from 49.3 to 74.0 eggs/female. The mortality rate reached its highest rate of 36.27% at 30°C. Our results suggested that *B. tabaci* had high reproduction rates and demonstrated their positive fitness traits on cassava in a wide range of temperatures, being a potential important pest of cassava cultivars.

Keywords
*Bemisia tabaci*, cassava, temperature, life table, mortality rate

Introduction

Whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) is one of the most serious pests on many crops such as pulses, cotton, cucumber, tomatoes, eggplant, tobacco, and cassava in tropical and subtropical areas. The damage of crops caused by *B. tabaci* leads to reductions in yield and product quality. In addition, this pest can cause damages directly through plant sap-feeding and indirectly through the transmission of plant pathogenic viruses, primarily *begomoviruses* (Geminiviridae), *Crinivirus* (Closteroviridae), and
Carlavirus (Potyviridae), such as yellow leaf curl virus, bean yellow mosaic Virus, Sri Lankan Cassava Mosaic Virus (SLCMV) (Oliveira et al., 2001; Jones, 2003; Legg et al., 2014; Swati et al., 2017; Khan & Wan, 2015; Wang et al., 2018; Plant Protection Department of Vietnam, 2018). More than 900 host plants have been recorded for B. tabaci belonging to over 63 plant families (Perring, 2001; Buxton, 2005). Biological characteristics of B. tabaci have been studied for various host plants, different temperatures reported as cotton, tomato, tobacco, and soybean, etc. (Le Thi Lieu & Tran Dinh Chien, 2004; Touhidul & Ren, 2007; Tran Dinh Pha et al., 2008; Dam Ngoc Han et al., 2012; Le Thi Tuyet Nhung, 2014; Khan & Wan, 2015). B. tabaci normally completes life development in 2 to 3 weeks in warm weather, but it takes approximately 2 months under cool conditions. The development time from egg to adult whitfly ranges from 15-70 days, depending on the temperature and host plant (Swati et al., 2017). The longevity of B. tabaci adults ranges from 3.1 to 15 days at a temperature above 20°C, but the low temperature (10°C) significantly increases the longevity to 30-60 days (Gerling et al., 1986). The average number of eggs produced per female ranges from 50 to 400 (Swati et al., 2017; Carabali et al., 2010).

In Vietnam, cassava is the third key food crop after rice and maize, with the cultivating area reaching 519,300ha with a yield of 10.1 million tons in 2019 (General Statistics Office of Vietnam, 2019). In 2018, it was reported that Sri Lankan Cassava Mosaic Virus (SLCMV) appeared on cassava in Vietnam due to whitfly B. tabaci ASIA1 transmission and raised concerns of widespread diseases (Uke et al., 2018). The Plant Protection Department of Vietnam (2020) reported that a total of 42,000 hectares had been affected by SLCMV, which covered 17 provinces in the Southern and Central parts of Vietnam. Therefore, studies on cassava feeding whitfly and their life-history traits (i.e., development time, survival, and reproduction rate) in relation to environmental temperature are important to provide baseline information for the development of pest and disease control strategies on cassava production in Vietnam.

Materials and Methods

The culture of host plants

Cassava variety KM419 young plants were grown in small pots (10cm diameter and 8cm height) containing a mix of 1/3 prepared garden soil + 1/3 rice husk ash + 1/3 coconut coir and kept in a net cage (1m x 1m x 1m). Three-week-old plants were introduced to B. tabaci adults for their infestation in the stock culture.

The culture of B. Tabaci

Whitefly stock colony was collected from cassava fields at Hoa Binh province. Newly emerged adults of B. tabaci were kept on leaves of potted cassava plants, and the whole plants were placed in separated cages sized 40 x 40 x 80cm in the laboratory of the Department of Entomology, Faculty of Agronomy, Vietnam National University of Agriculture. The whitefly culture colony was then maintained under laboratory conditions with a temperature of 26-28°C, relative humidity of 70-75%, and a 16:8h (L:D) photoperiod. The next generations of adults’ B. tabaci colony were used as the test materials in this study.

The influence of temperature on the development, mortality, and fecundity of B. tabaci

Twenty pairs of early emerged adults of B. tabaci (20 pairs: male and female) were placed in each isolation plastic cages (45cm x Ø 20cm) containing a two-leaf cassava plant, and the top of the cage was covered with mesh for ventilation. Adult whiteflies were placed and left for 3 hours in the cages for laying eggs, then being removed. Deposited eggs were transferred into the climate chamber at 20, 25, 27.5, and 30 ± 0.5°C, 70-75% RH, and a 16:8h (L:D) photoperiod. Eggs located on the cassava leaves were marked and kept in clip cages to prevent whiteflies from escaping. Daily observation was made under a binocular microscope to determine egg hatching, nymphal development, and adult eclosion. Individual nymphs were checked every 12h to determine the development time of each immature stage until adult whiteflies emerged.
and the sex ratio was determined (Carabali et al., 2010).

**Mortality rate**

One-hundred freshly laid eggs were located and kept on the leaves of the cassava host. The plants were then transferred to the climate chamber. The number of hatching nymphs was counted to determine whitefly embryonic mortality. Mortality during the nymphal instars was calculated by counting the number of individuals developing to the next stage.

**Adult longevity**

Pairs of newly emerged *B. tabaci* adults were introduced in plastic cages, each of which contains a pot of two-leaf cassava plants. All cages were kept in climate chambers under 4 temperature conditions that were mentioned above for daily observations until all the adults died.

**Fecundity**

One newly emerged female and male were placed into the plastic cages attached to the cassava plant. The number of eggs deposited by a single female was counted daily until they all died. There were 11-14 replications for each temperature were observed.

**Statistical analysis**

One-way ANOVA was performed to examine the differences in the development times and if significant (*P* ≤ 0.0001) differences were found, the Turkey post-hoc test was used to rank the group. To estimate the low developmental threshold temperature for each immature stage, they were regressed against temperatures using a least-square linear regression. Low developmental threshold temperatures were calculated as:

\[
y = a + bx
\]

where *y* = developmental rate, *a* = constant term, and *b* = regression coefficient.

The lower developmental threshold (*T₀* ) is determined as:

\[
T₀ = -a/b
\]

The sum of effective temperatures (*K*):

\[
K = 1/b
\]

The thermal units required for completion of development of each stage are determined according to the equation of thermal summation:

\[
K = y (T - T₀)
\]

where *y* = developmental rate, *T* = temperature in Celsius degree, *T₀* = lower threshold of development, and *K* = thermal constant (degree-days- DD) (Virachack et al., 2018).

**Results and Discussion**

**The influence of temperature on the development time of *B. tabaci***

The whitefly development time from eggs to adults decreased when the temperature increased (Table 1), whereby there was a significant difference between the egg and nymph development periods by the change of temperature from 20°C to 30°C (*F* = 791.68; *df* = 3; *P* < 0.0001). The longest developmental duration of *B. tabaci* recorded was 41.46 days at 20°C, while the shortest one lasted only 20.25 days at 30°C. At the temperature of 20°C, 25°C, 27.5°C, and 30°C, eggs lasted for 9.61, 6.16, 5.30, and 4.32 days, respectively. The results indicated that the development time of egg and fourth nymph (pupal) instar were longer than other stages, which is in accordance with the finding of other studies. Some authors have reported that mean development times of first to third nymphal *B. tabaci* were usually slightly shorter than for its remaining stages (Powell & Bellows, 1992; Sohani et al., 2007). The pre-oviposition time of female *B. tabaci* was significantly different when rearing at different temperatures (2.85 days at 20°C, 2.09 days at 25°C, and 1.42 days at 30°C). The effects of temperature on development time of *B. tabaci* were demonstrated on other host plants. In a comparable study Sohani et al. (2007) obtained total developmental time on cucumber at 20°C, 25°C, and 30°C were 34.84, 19.23, and 14.0 days, respectively. Powell & Bellows (1992) recorded development times of 38.20, 20.22, and 17.43 days on cucumber at 20°C, 25.5°C, 29°C, and 32°C, respectively. Other studies showed that on soybean at 17°C, 21°C, 25°C, 29°C, and 33°C the life cycle of whitefly were 62.3, 44.9, 27.7, 19.1,
and 18.4 days, respectively (Dam Ngoc Han, 2013); at 24.4°C and 17°C on tomato, development times were 23.7 and 61.7 days, respectively (Le Thi Tuyet Nhng, 2014). Our study results confirm the consistent positive effect of temperatures on the development rate of whitefly.

Furthermore, Carabali et al. (2010) looked at rearing whitefly biotype B on different cassava varieties in Colombia, in which B. tabaci needed at least 33.3 days to complete its life cycle at 25°C, 70% RH. The present result reported that the total life cycle of B. tabaci was only 28.64 days, thus further experiments are needed to explain the effects of cassava host plants on local whitefly populations.

Determining threshold temperatures and degree-days of B. tabaci on cassava will allow people to predict the number of generations in a year. The whitefly lower threshold temperature (T₀) varied from 10 to 12.0°C among developmental stages and degree-day (K) ranged from 59.2 to 80.6°C (Table 2). The influence of temperature on egg development was indicated by a linear regression equation (y = 0.0124x – 0.15) with a high correlation coefficient (r² = 0.99). This indicated that an increase in temperatures could lead to higher egg developmental rates, thus supporting the positive correlation between the variables. The lower developmental threshold (T₀) of B. tabaci eggs, therefore, was estimated to be 11.8°C, and the thermal constant for the development of eggs (K) was 80.6 day-degrees. Our results were higher than that of Sohani et al. (2007) who conducted research on whitefly on cucumber, whereby the lower developmental threshold (T₀) of B. tabaci eggs was 14.72°C, and the thermal constant was 64.44 day-degrees.

At the nymphal stage, the lower developmental threshold (T₀) of B. tabaci nymph instars was measured in the first, second, third, and fourth instar as 11.3, 11.4, 12.0, and 10.0°C, respectively, and the thermal constant (K) was 67.6, 59.5, 59.2, and 79.4 day-degrees, respectively. These results support the findings of Sohani et al. (2007) with whitefly on cucumber. The lower developmental threshold (T₀) of the first, second, third, and fourth nymphal instar were 11.3, 11.4, 12, and 10°C, respectively. The thermal constant (K) was 67.6, 59.5, 59.2, and 79.4 day-degrees.

Our result also demonstrated that the egg to adult threshold temperature of B. tabaci was 11.2°C, which is consistent with the findings of Gerling et al. (1986) and Bosco & Caciagli (1998). However, the values for temperature threshold calculated here is slightly lower than those of Powell & Bellows (1992) (14.65°C on cotton and 16.71°C on cucumber), Sohani et al. (2007) (13.07°C on cucumber), and Le Thi Tuyet Nhng (2014) (12.37°C on tomato and 12.25°C on kohlrabi).

Table 1. Development times of B. tabaci on cassava at difference temperatures

| Stages                 | Mean development time (days) (± SE) |
|------------------------|-------------------------------------|
|                        | 20°C (n = 45)                      | 25°C (n = 46) | 27.5°C (n = 39) | 30°C (n = 34) |
| Egg                    | 9.61±0.11                          | 6.16±0.13    | 5.30±0.09       | 4.32±0.10     |
| 1st nymphal instar     | 7.55±0.11                          | 5.32±0.08    | 4.00±0.11       | 3.64±0.12     |
| 2nd nymphal instar     | 6.85±0.13                          | 4.00±0.10    | 3.63±0.10       | 3.21±0.08     |
| 3rd nymphal instar     | 6.94±0.07                          | 4.65±0.08    | 4.23±0.08       | 3.07±0.05     |
| 4th nymphal instar     | 7.76±0.10                          | 5.89±0.11    | 4.33±0.10       | 4.00±0.09     |
| Pre-Oviposition        | 2.85±0.19                          | 2.09±0.09    | 1.86±0.10       | 1.42±0.15     |
| Life cycle             | 41.46±0.33                         | 28.64±0.28   | 24.29±0.37      | 20.25±0.31    |

Note: Humidity: 70- 75% RH. Means within a row followed by the difference letter are significantly different at P< 0.0001. n: Number observed.
Effects of temperature on life history of Bemisia Tabici on cassava manihot esculenta crantz

Table 2. Developmental rates, threshold temperatures, and the thermal constants of B. tabaci on cassava

| Stages             | Rate regressed on temperature (°C) (X) | Y = -a+bx         | R²   | Tₜ   | K (DD) |
|--------------------|----------------------------------------|-------------------|------|------|--------|
|                    | 20°C          | 25°C          | 27.5 | 30°C          |        |        |        |
| Egg                | 0.104         | 0.162         | 0.189 | 0.231         | y = 0.0124x - 0.15 | 0.99   | 11.8  | 80.6   |
| 1st nymphal instar | 0.132         | 0.188         | 0.250 | 0.275         | y = 0.0148x - 0.17 | 0.97   | 11.3  | 67.6   |
| 2nd nymphal instar | 0.146         | 0.227         | 0.275 | 0.313         | y = 0.0168x - 0.19 | 0.99   | 11.4  | 59.5   |
| 3rd nymphal instar | 0.144         | 0.215         | 0.236 | 0.326         | y = 0.0169x - 0.20 | 0.93   | 12.0  | 59.2   |
| 4th nymphal instar | 0.129         | 0.179         | 0.231 | 0.249         | y = 0.0126x - 0.13 | 0.97   | 10.0  | 79.4   |
| Life cycle         | 0.026         | 0.038         | 0.047 | 0.055         | y = 0.0029x - 0.03 | 0.99   | 11.2  | 344.8  |

The average number of degree-days needed to complete the egg to adult development was 344.8 degree-days, in agreement with the finding in other studies conducted at the same temperatures on bean (324 degree-days) and on cotton (316 degree-days) using simple regressions (Bosco & Caciagli, 1998; Zalom et al., 1985). On the other hand, our calculated number of degree-days is higher than the 229.52 degree-days and 195.0 degree-days on cucumber (Sohani et al., 2007; Powell & Bellows, 1992) and 285.11 degree-days on tomato (Le Thi Tuyet Nhung, 2014). According to this result, the possible number of generations of B. tabaci in Hanoi, Vietnam is 14.31 generations per year on cassava plant, with the total thermal units required per year for B. tabaci is 4.935 degree-days. Similar studies also reported that 14.51 generations of B. tabaci can occur within 1 year on tomato (Le Thi Tuyet Nhung, 2014) or 11-15 generations can occur within 1 year depending on the climate conditions (Raveesh & Charu, 2018).

Mortality rates of B. tabaci adults

Mortality rates of B. tabaci on cassava under four different temperature conditions are shown in Table 3. The mortality rates of B. tabaci egg, nymph stages were affected greatly by temperature. Mortality during the embryonic stage, first, second, third, and fourth nymphal instars at 30°C were 18.0%, 6.10%, 3.90%, 4.05%, and 4.23%, respectively. Pre-adult mortality was the lowest at 19.26% at 25°C, whereas it was 22.72% at 27.5°C and 36.27% at 30°C. At 20°C, the mortality rate of B. tabaci was also high, at 25.99%.

We found a higher mortality of eggs than nymphs. In general, the most sensitive nymphal stage was the first nymphal instar. Sohani et al. (2007) found that on cucumber, the total mortality of B. tabaci was the highest, at 20°C (45.8%); at 25°C and 30°C, the mortality rates were 20.9% and 17.3%, respectively. Our result is in accordance with the previous study of Le Thi Tuyet Nhung (2014), whereby the total pre-adult mortality of B. tabaci on kohlrabi at 17°C (24.18%) was higher than that at 24.4°C (16.41%). In addition, Khan & Wan (2015) recorded the total mortality from whitefly eggs to adults, showing that the mortality was 34.4% on tomato and 28.2% on cotton. The mortality rate of the immature stages on cassava M. carthaginensis and M. esculenta in Colombia was 40.0% and 72.5%, respectively (Carabali et al., 2010). Results from our study indicate that similar to most ectothermic organisms, the B. tabaci was sensitive to changes in temperatures. In other words, changes in temperatures had an influence on its development times and survival.

Longevity of B. tabaci adults

At all studied levels of temperature, the mean adult longevity of B. tabaci showed its negative correlation to environmental temperature (Figure 1). The longevity of females and males decreased as the temperature increased. The data indicated that temperature was a highly significant factor affecting the longevity of both females (F = 35.48; df = 3; P< 0.0001) and males (F = 80.22; df = 3; P< 0.0001). The maximum longevities observed for an individual whitefly were 10.23 and 9.29 days for females and males at 20°C. Mean adult longevity

916 Vietnam Journal of Agricultural Sciences
**Table 3. Pre-adult mortality of B. tabaci reared on cassava at different temperatures**

| Stages                  | 20°C  | 25°C  | 27.5°C | 30°C  |
|-------------------------|-------|-------|--------|-------|
| Egg                     | 14.00 (14) | 9.00 (9) | 11.00 (9) | 18.00 (18) |
| 1st nymphal instar      | 4.65 (4)   | 3.30 (3)   | 3.37 (3)   | 6.10 (5)   |
| 2nd nymphal instar      | 2.44 (2)   | 2.27 (2)   | 3.49 (3)   | 3.90 (3)   |
| 3rd nymphal instar      | 1.00 (3)   | 1.16 (1)   | 1.20 (1)   | 4.05 (3)   |
| 4th nymphal instar      | 3.90 (3)   | 3.53 (3)   | 3.66 (3)   | 4.23 (3)   |
| Total                   | 25.99 (26) | 19.26 (18) | 22.72 (19) | 36.27 (32) |

*Note: Sample size (n) in parenthesis is the number dying in each stage.*

**Figure 1. Longevity of B. tabaci adults at different temperatures**

of females and males were significantly lower at 27.5°C with 7.07, 6.47 days in comparison with those at 25°C with 8.09, 7.11 days, respectively. The shortest longevity of B. tabaci was observed at 30°C and 4.92 days (female) and 4.0 days (male). Our present study collected data were slightly lower than those reported by previous publications at the same temperatures. The research of Sohani et al. (2007) showed that whitefly on cucumber had longer longevity than those indicated in this study, whereby the females lived 34.14, 26.75, and 16.88 days and male lived 29.50; 17.50 and 11.23 days at the temperature of 20°C, 25°C, and 30°C, respectively. Fekrat & Shishehbo (2004) found that on aubergine, at 20°C, 25°C, and 30°C, females lived for 18.14, 13.14, and 8 days, respectively; while males survived for 12.71, 9.78, and 5.92 days, respectively. However, Carabali et al. (2010) found at 25°C on wild and commercial cassava (M. carthaginensis and M. esculenta), the longevity of B. tabaci were only 5.1 and 3.1 days, which were shorter than our present result. The females lived significantly longer than males (F = 9.58; df = 1; P = 0.007). Similar results also obtained in the present study were seen in Fekrat & Shishehbor (2004), Sohani et al. (2007), and Khan & Wan (2015).

**Fecundity of B. tabaci**

Generally, B. tabaci fecundity is highly variable and dependent on temperature, host-plant species, and cultivar (Khan & Wan, 2015). B. tabaci fecundity varied among temperature when they were reared in cassava (Table 4). There were statistically significant effects of temperature on mean total fecundity (F = 27.07; df = 3; P< 0.0001) and mean daily fecundity (F
Effects of temperature on life history of Bemisia Tabici on cassava manihot esculenta crantz

Table 4. Total fecundity, daily oviposition, and sex ratio of B. tabaci on cassava at different temperatures

| Traits                            | Temperature | 20°C          | 25°C          | 27.5°C         | 30°C          |
|-----------------------------------|-------------|---------------|---------------|---------------|---------------|
| Mean total fecundity (eggs/female)|             | 59.77 ± 2.06  | 65.82 ± 2.28  | 74.00 ± 2.22  | 49.30 ± 1.28  |
| Mean daily fecundity (eggs/day/female) |       | 6.01 ± 0.32   | 8.30 ± 0.42   | 10.59 ± 0.42  | 10.27 ± 0.54  |
| Sex ratio (female/male)            |             | 1.01/1        | 0.97/1        | 1.13/1        | 1.26/1        |

Note: Means within a row followed by the difference letter are significantly different at P< 0.0001.

Effects of temperature on life history of Bemisia Tabici on cassava manihot esculenta crantz

= 22.44; df = 3; P< 0.0001). The highest average number of eggs per female was 74.0 at 27.5°C and the lowest one of 49.3 eggs/female was at 30°C. Meanwhile, the mean daily number of eggs per female at 27.5°C and 30°C were 10.59 and 10.27, respectively.

In our study, whitefly reared on cassava showed their lower capacity of egg deposition in comparison with previous studies. The mean total eggs deposited per female recorded in four temperature experiments treatments (20°C, 25°C, 27.5°C, and 30°C) were 59.77, 65.82, 74.0, and 49.3, respectively. Fekrat & Shishehbor (2004) reported that on aubergine B. tabaci laid, a total of 78.6, 71.3, and 51.8 eggs at 20°C, 25°C, and 30°C, respectively. Carabali et al. (2010) explained how the unlocal type B strain of B. tabaci survived and laid 8.2 eggs/female when reared on M. esculenta in Columbia, thus, our present result supports the ability of adaptation and/or differentiation of whitefly population on cassava.

Daily fecundity of whitefly B. tabaci increased as temperature increased. At 20°C, 25°C, 27.5°C, and 30°C, the average numbers of eggs laid per female per day were 6.01, 8.30, 10.59, and 10.27, respectively. Daily oviposition of B. tabaci observed in the present study was higher than the value cited by Fekrat & Shishehbo (2004), where the daily ovipositions of B. tabaci on aubergine were 3.9, 5.0, and 5.8 eggs/day/female at the temperature of 20°C, 25°C, and 30°C, respectively. Khan & Wan (2015) reported that the mean daily number of laid eggs ranged from 4-5 on tomato and 5-6 on cotton at 25°C. Sohani et al. (2007) found that at 20°C, 25°C, and 30°C on cucumber B. tabaci laid 4.24, 9.92, and 12.75 eggs/day/female. The most favorable temperature for the development and reproduction of B. tabaci on cassava was 25-27.5°C.

Sex ratio varied in B. tabaci from 1/1 (female/male) at 20°C, 25°C, and 27.5°C and 1/1.26 at 30°C. This result is consistent with the results of previous research of Sohani et al. (2007), whereby the sex ratio from 1/1 (male/female) at 20°C to 1/1.49 at 30°C. Khan & Wan (2015) reported at 25°C, B. tabaci sex ratios were 52:48 and 55:45 female to male ratio on tomato and cotton hosts, respectively.

Conclusions

The present study is one of the few studies on biological characteristics of B. tabaci on cassava in Vietnam. The ideal temperature for whitefly survival on cassava was between 25 and 27.5°C, which explains why they can build up population and play a key role on the transmission of SLCMV in the Southern and Central parts of Vietnam. Based on our results, the whitefly lower developmental threshold was 11.2°C and it was estimated that 14.31 generations could occur within 1 year on cassava, suggesting that B. tabaci is a potential threat in developing whitefly population and spreading SLCMV on cassava in the Northern part of Vietnam. In addition, global warming could promote B. tabaci invasion by increasing their survival, which increases negative impacts to the new agroecosystem.

Acknowledgments

We thank the Department of Entomology, Faculty of Agronomy, Vietnam National University of Agriculture for providing us with facilities to conduct the research. This work was

918 Vietnam Journal of Agricultural Sciences
supported by the grants from the Vietnam National University of Agriculture, Code T2019-01-01. We also thank the reviewers for their helpful comments which helped to improve our manuscript.

References

Bosco D. & Caciagli P. (1998). Bionomics and ecology of *Bemisia tabaci* (Stenorrhyncha: Aleyrodidae) in Italy. European Journal of Entomology. 95: 519-527.

Buxton J. (2005). Control of whiteflies on protected ornamental crops. Factsheet 14/05. Horticultural Development Council in coop. with DEFRA. Bradbourne House. UK.

Carabali A, Belloti AC & Montoya-Lerma J. (2010). Biological parameters of *Bemisia tabaci* (Gennadius) biotype B (Hemiptera: Aleyrodidae) on *Jatropha gossypifolia*, commercial (Manihotesculenta) and wild cassava (*Manihot flabellifolia* and *M. carthaginesis*) (Euphorbiaceae). Neotropical Entomology. 39(4): 562-567.

Dam Ngoc Han (2013). Study on the composition of whitefly, biological and ecological characteristics of soybean *Bemisia tabaci* (Gennadius) and control in Hanoi. PhD thesis. Vietnam Academy of Agricultural Sciences (in Vietnamese).

Dam Ngoc Han, Pham Thi Thu & Ho Thi Thu Giang (2012). Some biological characteristics of *Bemisia tabaci* (Gennadius) biotype B (Hemiptera: Aleyrodidae) harmful to soybean in Hanoi. Journal of Plant Protection. 2: 3-5 (in Vietnamese).

Fekrat L. & Shishehbo P. (2004). Biological Characteristic and life table of cotton Whitefly *Bemisia tabaci* Gennadius on aubergine at different constant temperatures. The Scientific Journal of Agriculture. 27: 21-31.

General Statistics Office of Vietnam (2019). Statistical Yearbook of Vietnam 2019. Chapter: Agriculture, Forestry and Fishing. Statistical publishing house, Hanoi, Vietnam (in Vietnamese).

Gerling D., Horowitz A. R. & Baumgartner J. (1986). Autecology of *Bemisia tabaci*. Agriculture Ecosystem and Environment. 17: 5-19.

Jones D. R. (2003). Plant viruses transmitted by whiteflies. European Journal of Plant Pathology. 109:195-219.

Khan I. A. & Wan F. H. (2015). Life history of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) biotype B on tomato and cotton host plants. Journal of Entomology and Zoology Studies. 3(3): 117-121.

Legg J. P., Shirima R., Tajeeb L. S., Guastella D., Boniface S., Jeremiah S., Nsami E., Chikoti P. & Rapisarda C. (2014). Biology and management of *Bemisia* whitefly vectors of cassava virus pandemics in Africa. Pest Management Science. 70(10): 1446-1453.

Le Thi Lieu & Tran Dinh Chien (2004). Research on biological characteristics and chemical measures in prevention of *Bemisia tabaci*. Journal of Plant Protection. 3: 3-9 (in Vietnamese).

Le Thi Tuyet Nhung (2014). Study on the composition of the whitefly Aleyrodidae (Homoptera) and the characteristics of biology, ecology, and measures to control *Bemisia tabaci* (Gennadius) tobacco in Hanoi. PhD thesis. Vietnam Academy of Agricultural Sciences (in Vietnamese).

Oliveira M. R. V., Henneberry T. J. & Anderson P. (2001). History, current status, and collaborative research projects for *Bemisia tabaci*. Crop Protection. 20: 709-723.

Perring T. M. (2001). The *Bemisia tabaci* species complex. Crop Protection. 20: 725-737.

Plant Protection Department of Vietnam (2018). Report on the situation of cassava leaf mosaic and disease prevention and control. Conference "Solutions to prevent and control cassava leaf mosaic disease (cassava). Ho Chi Minh City on August 28, 2018 (in Vietnamese).

Plant Protection Department of Vietnam (2020). Report on the situation of pest and diseases on major crops. Report No. 10/TBSB-BVTV on March 6, 2020 (in Vietnamese).

Powell D. A. & Bellows T. S. Jr. (1992). Preimaginal Development and Survival of *Bemisia tabaci* on Cotton and Cucumber. Environmental Entomology. 21(2): 359-363.

Raveesh K. G. & Charu G. (2018). Lifecycle, Distribution, Nature of Damage and Economic Importance of Whitefly, *Bemisia tabaci* (Gennadius). Acta Scientific Agriculture. 2(4): 36–39.

Sohani N. Z., Shihelbor P. & Kocheli F. (2007). Thermal effect on the biology and life table of *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae). Pakistan Journal of Biology Science. 10(22): 4057-4062.

Swati T., Seema S. & Kamlesh M. (2017). Life parameters of whiteflies *Bemisia tabaci* Genn. on different host plants. Indian Journal of Scientific Research. 16(1): 34-37.

Touhidul I. M. & Ren S. (2007). Development and Reproduction of *Bemisia tabaci* on three Tomato Varieties, Journal of Entomology. 4(3): 231-236.

Tran Dinh Pha, Nguyen Hong Son, Pham Van Hoan, Cu Thi Thanh Phuc, Dang Thi Phuong Lan, Le Xuan Cuoc & Le Thanh Giang (2008). Preliminary research results on *Bemisia tabaci* (Gennadius) (Hom.: Aleyrodidae) on tomato and cucumber crops. Proceedings of the 6th National Conference of Entomology. Hanoi, Vietnam: 689-694 (in Vietnamese).

Uke A. & Trinh X. H. & Quan M. V. & Liem N. V., Ugaki Mai & Natsuaki K. (2018). First Report of Sri Lankan Cassava Mosaic Virus Infecting Cassava in Vietnam. Plant Disease. 102(12): 2669.
Virachack H., Giang T. H., Giang H. T. T. & Takatoshi U. (2018). Temperature effects on the development of Vietnamese cotton bollworm *Heliothis armigera* (Hübner). Journal of Faculty of Agriculture, Kyushu University. 63(2): 303-309.

Wang D., Yao X. M., Huang G. X., Shi T., Wang G. F. & Ye J. (2018). First report of Sri Lankan cassava mosaic virus infected cassava in China. Plant Disease. 103(6): 1437.

Zalom F. G., Natwick E. T. & Toscano N. C. (1985). Temperature regulation of *Bemisia tabaci* (Homoptera: Aleyrodidae) populations in Imperial valley cotton. Journal of Economical Entomology. 78: 61-64.