# AGE-STAGE, TWO-SEX LIFE TABLE OF *Tetranychus urticae* KOCH (ACARI: TETRANYCHIDAE) REARED ON FIVE COTTON VARIETIES

**A THESIS**

**BY**

**MD. ASIF HELAL**

Registration No. 2205088

Session: 2022-2023

Thesis Semester: July-December, 2023

**MASTER OF SCIENCE (M.S.)**

**IN**

**ENTOMOLOGY**

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**HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY**

**DINAJPUR-5200**

**DECEMBER 2023**

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**Submitted to The Department of Entomology**

**Hajee Mohammad Danesh Science and Technology University, Dinajpur**

**in partial fulfillment of the requirements for the degree of**

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**HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY**

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**DECEMBER 2023**

Dedicated

To My

Beloved Parents

and

Teachers

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The Authors

## ABSTRACT

*Tetranychus urticae* Koch (Acari: Tetranychidae) is an important cotton pest in Bangladesh and other cotton growing countries. The effect of five varieties of cotton (CB-12, CB-14, CB-15, HC-1 and M-1) on the life history and demographic parameter of *T. urticae* studied at 25 ± 2°C temperature, 50-70% RH and a photoperiod of 16:8 h (L:D). The life history parameters were estimated using the age-stage, two-sex life table method. The shortest female development time was (15.00 days) on the M-1 variety and the longest (16.17 days) on the CB-15 variety. The *T. urticae* fecundity ranged from 24.66 to 16.87 eggs/ female, with the CB-15 variety having the highest and the HC-1variety having the lowest values. The shortest female longevity was observed on the CB-12 variety (26.55 days) and the longest on the CB-15 variety (32.24 days). The net reproductive rate ($R_0$) varied from 12.16 on HC-1 to 18.33 eggs per individual on the CB-15 variety. The finite rate of increase ($\lambda$) was highest on the M-1 variety (1.1362 days) and lowest on the HC-1 variety (1.1146 days). The lowest (0.1085 day) value of the intrinsic rate of increase ($r_m$) was on the HC-1 variety and the highest was on the M-1 variety (0.1277 days). The mean generation time ($T$) was lowest (22.05 days) on the M-1 variety and highest (26.05 days) on the CB-14 variety. This finding indicates that the HC-1 variety is a less suitable variety for *T. urticae* than the other tested varieties. Therefore, this study provides new information for developing a comprehensive integrated pest management plan for *T. urticae* on cotton.

**Keywords:** *Tetranychus urticae*, quality, cotton, two-sex life table antibiotic resistance

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# CHAPTER I

# INTRODUCTION

Cotton (*Gossypium* spp.) is a shrub native to tropical and subtropical regions throughout the world, including the Americas, India and Africa. Cotton is a basic resource for millions of consumers and commercial items manufactured around the world and its contribution to the food and fiber industries is becoming increasingly important (Mondal and Ara 2006). Cotton is an economically and strategically important plant in Bangladesh. The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch is a polyphagous, parenchyma cell feeding spider mite with over 150–200 host plant species, especially in field crops and fruit trees (Vacante 2016; Migeon and Dorkeld 2019). It feeds by sucking the contents from plant cells (Helle and Sabelis, 1985). This mite is regarded as a main pest of cotton and has serious effects on the crop yield (Wilson et al. 1991). It reduces the number and size of bolls, seed weight and germination in cotton. *Tetranychus urticae* also affects boll period and fiber characteristics (Wilson 1993). Canerday and Arant (1964) found that mite infestations increased the proportion of immature fibers.

Each year two-spotted spider mites infest a considerable portion of cotton growing area. Thus, it is necessary to control two-spotted spider mites. It can be employed in systemic as well as contact applications of pesticides. However, due to the recurrent use of pesticides, the two-spotted spider mite now has the resistant capability against several pesticides or acaricides (Whalon et al. 2008; Kwon et al. 2010 and Nicastro et al. 2010). Furthermore, consistent pesticide or acaricide spraying resulted in the destruction of natural enemies in the field and increased environmental hazards (Thistlewood, 1991, Kumral and Kovanci 2005). In recent years, predatory mites of the phytoseiid family have been commercially developed and utilized as an alternative to chemical pesticides to control *T. urticae*, particularly in greenhouses (Kilincer et al. 2010). Combined IPM (Integrated Pest Management) approaches, rather than a single application, may increase mite control success. As a result, one of the most critical components of the approaches is the usage of plant resistance varieties or cultivars to pests. Understanding the processes of host plant resistance and identifying the origins of specific insect species is the first step in developing an insect-resistant cultivar (Jyoti et al. 2001; Darvishzadeh and Jafari, 2016).

Host plant resistance is especially effective for controlling arthropods that are not harmful to the environment and it can minimize grower financial investment (Li et al. 2004). As a result, it is critical to determine which host plant cultivars or types do not tolerate pest infestation. This would reduce the dependency on pesticides while also benefiting natural enemies. For a better understanding, life table parameters are a good measurement of population growth of a given species under a certain set of conditions. Chi and Liu (1985) as well as Chi (1988) developed a two-sex, age-stage life table model with different development rates for both sexes. The female-based life table (Carey, 1982) and the two-sex life table (Chi, 1988) are the two basic approaches for determining life table parameters. In the female-based age-specific life table, only females are counted and any variable developing rate of other individuals is ignored. Males and females, on the other hand, differ significantly in terms of survival, lifespan, predation, and susceptibility to pesticides (Chi and Liu, 1985). The two-sex life table can thoroughly calculate the age and stage structure of a two-sex population completely (Chi, 1988), as well as provide the actual control efficiency of the entire population, i.e., both sexes (Chi and Su, 2006). The age-stage, two-sex life table method provides more accurate and useful data than the only female-based age-specific life table method (Yu et al. 2013). As a result, using a two-sex life table in biological control decisions can be quite beneficial. Furthermore, life table factors show the host plants sensitivity (Bonato et al. 2000; Adango et al. 2006). In this context, the objective of the study was to determine the effect of five cotton varieties on the population growth characteristics of *T. urticae* to assess their level of resistance or susceptibility to *T. urticae*. This finding, in particular, might be used to successfully build a comprehensive pest management program for *T. urticae*.

# CHAPTER II

# LITERATURE REVIEW

Mites are small insects which constantly cause an extensive amount of economic damage. The hierarchical classification of mite *T. urticae* is shown below:

Kingdom: Animalia

Phylum: Arthropoda

Sub-phylum: Chelicerata

Class: Arachnida

Sub-class Acari

Super-order: Acariformes

Order: Prostigmata

Family: Tetranychidae

Genus and species: *Tetranychus urticae* (Koch, 1836)

Whenever it relates to spider mite nomenclature, or their scientific name, there are always misconceptions. Acarologists and applied entomologists have already discovered that some spider mites go by the name *Tetranychus bimaculatuas* Harvey or *Tetranychus telarius* (Linnaeus). Boudreaux (1956) had been studied the so-called "Two-spotted spider mite complex" which determined that multiple species were involved. The two-spotted spider mite, *Tetranychus urticae* Koch and the carmine spider mite *Tetranychus cinnabarinus*, where the two main species in this case reviewed the taxonomy of tetranychid mites (Boudreaux, 1956; Jeppson et al., 1975; McGregor, 1950; Pritchard and Baker, 1955). These reports provide references to the original taxonomic description, synonym and distribution information, and keys to the genus and species. The *Tetranychus urticae* (TSSM) genome was entirely sequenced in 2011 which resulting in the first arachnid genome worldwide (Grbié et al., 2011).

## 2.1 Biology and reproductive behavior of *Tetranychus urticae*

Fahim et al. (2020) was observed *T. urticae's* biology and life table parameters have been for four cultivars of strawberries: Wanter star, Markez, Fortona, and 029. They found that, on studied cultivars, the developmental periods of the females varied significantly, although no such difference was seen for the males. Compared to the other stars, Wanter star and Fortona had a significantly longer developmental period (P = 0.00). In this research, the female *T. urticae* showed the shortest oviposition period and the longest adult lifetime on Fortona and Wanter star, with the longest periods on 029 (P = 0.00). On Wanter star, female fertility and daily egg production were the lowest. In contrast to other cultivars, 029 had the highest of reproductive rate; as a result, Wanter star was released as a resistant cultivar against *T. urticae* infestation.

Osman et al. (2019) researched the biological responses of the two-spotted spider mite, *Tetranychus urticae,* to various host plants and found that for mite females obtained on beans, cucumber, eggplant, tomato, and pepper, the average total immature stages were 6.31, 6.06, 6.27, 6.59, and 6.49 days, and the average life cycle was 9.78, 10.39, 10.73, 10.31, and 10.03 days. When mites grew on pepper and then tomato, there was a decrease in their life span. When comparing mites growing on beans to other host plants, the intrinsic rate of natural growth ($r_m$) and the finite rate of increase (k; day$^{-1}$) were highest. The highest net reproductive rates were recorded by cucumbers and beans, with each female yielding 55.45 and 55.65 off-spring/female/generation, respectively.

Havasi et al. (2018) also studied how diflovidazin affected the life table characteristics of the two-spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae) in a sublethal process. The results of the study showed that the net reproductive rate ($R_0$) in the control and LC20 groups were 48.88 and 31.14 off-spring/individual respectively, at its highest and lowest values. The study found that the highest intrinsic rate of increase ($r_m$) was 0.234 day$^{-1}$ in the control treatment, whereas the lowest value was 0.216 day$^{-1}$ in the LC20 concentration.

Additionally, Uddin et al. (2017) observed the life table parameters of *Tetranychus urticae* Koch (Acari: Tetranychidae) on various bean types, such as Kartica, BARI Seam-1, and IPSA Seam-1. With $r_m$ = 0.230 and 0.223 (offspring/female/day), respectively, the results indicated that the Kartica and BARI SeaM-1 were the most favorable hosts for *T. urticae*. With $r_m$= 0.197, IPSA SeaM-1 had the slowest population growth. In contrast with the other two kinds, IPSA SeaM-1 is less conducive to two-spotted spider mites, according to the results of the current study.

Golizadeh et al. (2017) studied ten rose cultivars, including Bella Vita, Cool Water, Dolce Vita, Maroussia, Orange Juice, Pink Promise, Roulette, Tea, Valentine, and Persian yellow, in order to determine the population growth characteristics of *Tetranychus urticae* Koch. The results showed that the mite survival rate on Bella Vita varied between 66.5% to 85.9% on Persian yellow. Among the evaluated rose cultivars, the immature development period varied; it was 9.35 days for Orange Juice and 12.30 days for Bella Vita. Pink Promise had the highest fecundity rate ever observed.

Maleknia et al. (2016) studied how the life history and demographic characteristics of the two-spotted spider mite (TSSM) (*Tetranychus urticae* Koch) were impacted by twelve cultivars of cucumber grown in greenhouses: Royal, Amitral, Ariya, Sultan, Vida, Bahman, Storm, Nasim, Negin, PS-29, Tornado, and Caspian. On Caspian, the greatest development time was 8.28 ± 0.09 days, whereas on Vida and PS-29, the shortest times were 5.45 ± 0.12 and 5.54 ± 0.07 days, respectively. The average TSSM fecundity per female varied between 64.83 ± 5.33 to 98.38 ± 5.65 eggs, with the lowest value observed on Negin and the highest value on Amitral. Negin had the shortest female longevity (16.08 ± 1.15 days), while Amitral had the longest (26.82 ± 1.36 days). Between Negin and Amitral, the net reproductive rate ($R_0$) ranged from 42.30 ± 4.90 to 75.72 ± 6.64 eggs per individual. The values of the finite rate of growth (λ) and the intrinsic rate of increase ($r_m$) were highest on Vida (0.331 ± 0.010 and 1.389 ± 0.014/day, respectively) and lowest on Caspian (0.249 ± 0.006 and 1.282 ± 0.008/day, respectively). The cultivars show varying mean generation times (*T*), which varied from 11.68 ± 0.170 to 16.71 ± 0.266 days.

Najafabadi and Zamani (2013) examined the impact of common bean cultivars, including Chiti Khomein, Chiti Ks21189, red Akhtar, red Ks31169, white Pak, and white G11867, on the life table characteristics of *Tetranychus urticae* (Acari: Tetranychidae). The results of the study revealed that white Pak had the lowest intrinsic rate of growth ($r_m$) at 0.129 ± 0.048 days-1, while red Akhtar had the highest at 0.269 ± 0.031 $days^{-1}$. Additionally, the red Akhtar exhibited the greatest values for the TSSM's net reproductive rate ($R_0$) and finite rate of increase (λ), with 62.38 ± 1.05 female offspring and 1.30±1.02 day-1, respectively. The white Pakistani population had the lowest values of these measures, 1.13 ± 1.10 day-1 and 27.37 ± 1.40 female offspring, respectively. Different cultivars revealed considerable variations in Doubling Time (DT), with the smallest and longest values observed in red Akhtar and white Pak, respectively.

According to Khanamani et al. (2013) seven cultivars of eggplant Isfahan, Dezful, Shend-Abad, Neishabour, Bandar-Abbas, Jahrom, and Borazjan have different life table parameters for the two-spotted spider mite (TSSM), *Tetranychus urticae* Koch. Among the previously mentioned cultivars, "Neishabour" had an intrinsic rate of increase ($r_m$) of 0.022 days, whereas "Isfahan" had a $r_m$ of 0.157 days. One eggplant cultivar, "Neishabour," produced 1.425 offspring, while "Isfahan" produced 11.585 offspring. Those numbers represent the net reproductive rate ($R_0$) of TSSM. In addition, there were significant variances in the gross reproductive rate (GRR) values among the cultivars evaluated; "Isfahan" (29.574 offspring) had the lowest GRR value, while "Neishabour" (2.867 offspring) had the greatest GRR value. The previously mentioned cultivars' respective mean generation times ($T$) for TSSM were 15.415, 15.102, 14.191, 15.110, 16.117, 15.187, and 14.736 days.

El-Wahed et al. (2012) studied how *Tetranychus urticae* Koch's biology and life table parameters were affected by temperature variations in two different pear cultivars. When *T. urticae* was fed the Lacont pear variety, they observed that the longest developmental phases reached 30.6 and 30.1 days for the female and male at 15°C, while it was 34 and 32.1 days at the same temperature when it was reared on the Hood pear category. At 30°C, the highest generally mean fecundity rate (156.8 and 143.6 eggs/female) was observed.

Sedaratian et al. (2010) was analysis the comparative life table of *Tetranychus urticae* (Acari: Tetranychidae) on 14 genotypes of soybeans, including Sari, Sahar, Tellar, Zane, Ks3494, L17, Dpx, 032, 033, Clark, Hill, I27, Tms, and Williams. Here, they discovered that L17 (0.392) had the highest intrinsic rate of development ($r_m$), while Tms (0.233), Hill (0.236), 032 (0.236), I27 (0.237), and Clark (0.240) had the lowest values of this parameter. Also, the TSSM's finite rate of increase ($\lambda$) and net reproductive rate ($R_0$) attained their maximum values on L17, at 1.475 and 45.521, respectively. These metrics lowest values 12.149 and 1.258, respectively were noted on Tms. The doubling time ($DT$) varied significantly during genotypes; L17 and 032 yielded the shortest and longest values of this period, respectively. The genotypes Tms, Hill, 032, I27, and Clark were found to be less appropriate, indicating a higher resistance to the TSSM compared to the other genotypes.

Marcic (2007) worked on sublethal effects of spirodiclofen on life history and life-table parameters of two-spotted spider mite (*Tetranychus urticae*). They found that the intrinsic rate of increase ($r_m$) and finite rate of increase ($\lambda$) were significantly reduced in treated females ($r_m$ = 0.141, $\lambda$ = 1.156 and $r_m$ = 0.214, $\lambda$ = 1.232; 12 and 6 mg/l, respectively), compared to control ($r_m$ = 0.251, $\lambda$ = 1.276).

# CHAPTER III

# MATERIALS AND METHODS

## 3.1 Maintenance of mites under laboratory conditions

*Tetranychus urticae* were collected from infested beans at the Faculty of Agriculture of Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh in June 2023. The stock colonies were kept on whole bean leaves in controlled climatic conditions 25 ± 2°C temperature, 60% ± 10% RH, 16: 8 h (L: D) approximately two months before the beginning of the experiment.

## 3.2 Plant culture

Seeds of five commercial cotton varieties (CB-12, CB-14, CB-14, HC-1 and M-1) were collected from the Bangladesh Cotton Development Board, Dinajpur. The seeds were separately sown in 20-cm plastic pots filled with fertilized soil and cow dung (Figure 1). No pesticides were used during the studied and all the plants were watered simultaneously. Fresh cotton leaves were used in the experiment.

## 3.3 Experiments

For each variety, three-centimeter diameter discs were cut from the cotton leaf and placed upside down on water-soaked cotton in a plastic Petri dish (9 cm diameter). Every three to four days, the mites were transferred to new arenas. Each unit was considered a replication (N = 175 for five varieties). The duration of the female and male immature stages in five cotton varieties was measured in controlled climatic conditions 25 ± 2°C temperature, 60% ± 10% RH and 16:8h (L: D). To calculate the developmental time, a cohort of 175 identical aged eggs was employed. The newly mated females were placed into 175 new experimental units and after six hours, the females and additional eggs were removed, leaving only one egg in each unit, which was monitored throughout the developmental period. The immature developmental periods were observed at 12-hour intervals until the mite reached adulthood. Newly emerged adults were used to calculate the sex ratio percentage for each variety. To investigate the adult characteristics of the same varieties the newly emerged female was paired with males obtained from a stock colony. Males that had died or been lost were replaced with new ones from the stock colony. The experimental units were observed twice a day and any changes were documented until the last female died. This monitoring allowed us to determine the parameters of premature duration stage, survival, pre-oviposition, oviposition, and post-oviposition periods, female and male longevity and fecundity.


**Figure 1: Tested different cotton varieties in the experiment**

**Figure 2: Experimental arenas for studying the biological stages of *T. urticae***

### 3.4 Population growth parameters

The data were analyzed according to the age-stage, two-sex life table theory (Chi and Liu, 1985) and the method Chi (1988) by using the TWO SEX-MS Chart program (Chi, 2018). The age-stage survival rate ($S_{xj}$; where x = age and j = stage), which is the probability that a newly laid egg will survive to age x and stage j, and the age-stage fecundity ($f_{xj}$), which is the number of hatched eggs produced by female adult at age x, were calculated. The age-specific survival rate ($l_x$), age-stage life expectancy ($e_x$), age-stage reproductive value ($v_{xj}$) and the age- specific fecundity ($m_x$), as well as the population parameters, include the intrinsic rate of increase ($r_m$), the finite rate of increase ($\lambda$), the net reproductive rate ($R_0$), and the mean generation time ($T$) were estimated in sequence.

Age-specific survival rate ($l_x$) was calculated by:

$$\boldsymbol{lx} = \sum_{j=1}^{m} \boldsymbol{s_{xj}}$$

Where, m is the number of stages. Age-specific fecundity ($m_x$) was calculated as:

$$\mathbf{m_x} = \frac{\sum_{j=1}^{m} \mathbf{s}_{\mathbf{xj}} \mathbf{f_{xj}}}{\sum_{j=1}^{m} \mathbf{s_{xj}}}$$

The intrinsic rate of increase ($r_m$) was calculated by using the iterative bisection method from the Euler–Lotka equation with age indexed from zero (Goodman, 1982):

$$\sum_{x=0}^{\infty} \mathbf{e}^{-\mathbf{r}_{\mathbf{m}(x+1)}} \mathbf{l_x} \mathbf{m_x} = \mathbf{1}$$

The net reproductive rate represents the mean number of female offspring that an individual can produce during its lifetime and was calculated as:

$$\mathbf{R_0} = \sum_{x=0}^{w} \sum_{j=1}^{k} \mathbf{s_{xj}} \mathbf{f_{xj}}$$

The mean generation time ($T$) and is calculated as:

$$= \frac{\ln R_0}{r}$$

Age-stage-specific life expectancy ($e_{xy}$) is the time that an individual of age $x$ and stage $y$ is expected to live. This parameter was calculated according to the method described by Chi and Su (2006) as:

$$\mathbf{V_{xy}} = \sum_{i=x}^{n} \sum_{j=y}^{m} \mathbf{S'_{ij}}$$

Where, $S'_{ij}$ is the probability that an individual of age $x$ and stage $y$ will survive to age $I$ and stage $j$. Fisher (1930) defined the reproductive value as the contribution of individuals of age $x$ and stage $y$ to the future population. According to Tuan *et al.* (2014), reproductive value in the age-stage, two-sex life table is calculated as

$$\mathbf{V_{xy}} = \frac{\mathbf{e^{-r(x+1)}}}{\mathbf{S_{xy}}} \sum_{i=x}^{n} \mathbf{e^{-r(i+1)}} \sum_{j=u}^{m} \mathbf{S'_{ij} f_{if}}$$

Where, the subscript i-boot represents the it bootstraps and $l_x$ and $m_x$ are calculated from the n individuals selected randomly with replacement. Generally, the data on the same individual are repeatedly selected. This procedure was repeated m times (m = 10,000) and computed the mean of these m bootstraps as:

$$\mathbf{r_B} = \frac{\sum_{r=1}^{m} \mathbf{r_{i-boot}}}{\mathbf{m}}$$

The variance (VARrB) and standard errors (SErB) of these m bootstraps were calculated as

$$\mathbf{VARr_B} = \frac{\sum_{i=1}^{m}(\mathbf{r_{i-boot}} - \mathbf{r_B})^2}{\mathbf{m-1}}$$

$$\mathbf{SEr_B} = \sqrt{\mathbf{VARr_B}}$$

All the life table parameters were estimated by using TWO SEX-MS Chart software (Chi, 2018). The bootstrap technique was used to estimate the mean, variances and standard errors of the population parameters (Chi and Liu 1985; Efron and Tibshirani 1993). 10,000 replications were used in bootstrap technique to analyze the data. Data concerning adult longevity, adult pre-oviposition period (APOP), total pre-oviposition period (TPOP), oviposition days, fecundity, and population growth parameters ($r$, $\lambda$, $R_0$, GRR and $T$) on tested genotypes were compared using with paired bootstrap test using the TWOSEX-MS Chart program (Efron and Tibshirani, 1993).

# CHAPTER IV

# RESULTS

## 4.1 Developmental time of different stages

The development times of different life stages (males and females) of *T. urticae* on five cotton varieties are presented in Table 1. There were significant differences ($P<0.5$) observed among the biological parameters such as egg, larval, protonymphal and deutonymphal period on different cotton varieties. Total immature development for males and females was significantly different among the five varieties. The total development time of females was the shortest on (15.00 ± 0.13 days) M-1 variety and longest on (16.17 ± 0.20 days) CB-15 variety respectively, which was significantly different than the development time for those reared on other varieties.

## 4.2 Adult longevity and fecundity

The tested cotton varieties significantly affected *T. urticae* pre-ovipositional period (APOP), longevity, total pre-ovipositional period (TPOP) and fecundity. The APOP of *T. urticae* reared on the M-1 variety was significantly shorter compared with those reared on the other varieties. Additionally, the TPOP values on the CB-14 variety were significantly longer than the TPOP for those raised on other varieties. The shortest oviposition days were found on the CB-12 variety and the longest on the CB-15 variety. The total fecundity for *T. urticae* reared on CB-12 and HC-1 was significantly lower than for those reared on other varieties.  CB-15 (24.66 eggs) and CB-14 (24.23 eggs) had the highest fecundity values, respectively. The lowest fecundity value was observed in CB-12 (16.86 eggs) and HC-1 (16.87 eggs) respectively. Cotton variety had a considerable impact on the total longevity of both males and females (Table 2). The longevity of females was longest on the CB-15 variety (32.24 days) and shortest on the CB-12 variety (26.55 days). The female sex ratio of offspring varied from 72.09% on CB-14 and HC-1 to 74.36% on CB-12 and CB-15 varieties respectively (Table 1).

### 4.3 Survival and fecundity

Age-stage survival rates ($S_{xj}$) of *T. urticae* on five cotton varieties are shown in Figure 1. The $S_{xj}$ shows the probability that a new-born individual will survive to age x and stage j. The highest probability that a new born egg survived to the adult stage was 0.74, 0.74, 0.74, 0.72 and 0.72 for females on CB-12, CB-15, M-1, CB-14 and HC-1 and 0.28, 0.28, 0.26, 0.26, and 0.26 on CB-14, HC-1, CB-12, CB-14 and M-1 varieties for males respectively. The age-specific survival rate ($l_x$), age- specific fecundity rates ($m_x$), and age-stage-specific fecundity ($f_{xj}$) of *T. urticae* females were greatly influenced by cotton varieties (Figure 2).

The $f_{xj}$ gives the number of eggs produced by adult females in each stage of age (x), where age x is counted from the egg stage. The age-specific fecundity rate ($f_{xj}$) reached peak on the 28$^{th}$ day on M-1 (4.7eggs), on the 27$^{th}$ day on HC-1 (4.44 eggs), on the 28$^{th}$ day on CB-14 (3.97 eggs), on the 29$^{th}$ day on CB-15 (3.70 eggs) and on the 21$^{st}$ day on CB-12 (2.97 eggs). CB-14, CB-15, M-1, CB-12 and HC-1 the first oviposition occurred on days 17, 16, 16, 15 and 15, respectively. The age-stage reproductive values ($v_{xj}$) for different stages of *T. urticae* on five cotton varieties are presented in Figure 3. On all tested varieties, the lowest and highest value of $v_{xj}$ belonged to egg and female stages respectively. The highest age-stage reproductive value ($v_{xj}$) for females was 13.49 on 21$^{st}$ days on CB-14, 13.13 on 17$^{th}$ days on M-1, 11.56 on 22$^{th}$ days CB-15, 11.18 on 19$^{th}$ days on CB-12 and 9.55 on 18$^{th}$ days on HC-1 (Figure 3).

### 4.4 Age-stage life expectancy

The age-stage life expectancy ($e_{xj}$) curves of *T. urticae* on five cotton varieties are plotted in Figure 4. Based on the results, the age-stage life expectancy of *T. urticae* decreased with ageing. The highest life expectancy of the female was 19.14 on days 13 on CB-15, 17.16 on days 14 on CB-14, 14.48 on days 14 on M-1, 13.55 on days 13 on CB-12 and 13.48 on days 14 on HC-1. The life expectancy for males was 15.67 on days 14 on CB-14, 13.90 on days 15 on CB-15, 13.3 on days 14 on CB-12, 12.18 on days 14 on M-1 11.75 on days 14 on HC-1 respectively (Figure 4).

### 4.5 Population growth parameters

According to Table 3, the net reproductive rate ($R_0$) ranged varied from 18.33 offspring /female on CB-15 to 12.16 offspring/female on HC-1. The M-1 variety had the highest intrinsic rate of increase ($r_m$) which was statistically different from all other varieties except CB-15 but no significant differences were observed among CB-12, CB-14 and HC-1 respectively. The lowest ($r_m$) value was found in the HC-1 variety (0.1085/day). The finite rate of increase ($\lambda$) was highest on the M-1 variety (1.1362/day) and lowest on the HC-1 variety (1.1146/day) and CB-15 variety (1.1246/day) respectively. The mean generation time ($T$) was significantly influenced by tested varieties (Table 3). The mean generation time was longest on the CB-14 variety (26.05 days) and shortest on the M-1 variety (22.05 days). They were statistically different from each other.

**Table 1:** Development duration (days ± S.E.) from egg to adult of *T. urticae* reared on five different varieties of cotton at 25±2°C under a 16L:8D photoperiod (N1 and N2 indicates protonymph and deutonymph, respectively).

| Varieties | Sex | N[a] | Egg | L | N1 | N2 | Egg-to-Adult | F1 Female ratio (%) |
|---|---|---|---|---|---|---|---|---|
| CB-12 | ♀ | 29 | 4.24 ± 0.14ab | 4.31 ± 0.14ab | 3.34 ± 0.10c | 3.31 ± 0.10b | 15.21 ± 0.21b | 74.36 |
| | ♂ | 10 | 4.30 ± 0.15a | 4.60 ± 0.16a | 3.30 ± 0.15c | 3.00 ± 0.00d | 15.20 ± 0.20bc | |
| CB-14 | ♀ | 31 | 4.39 ± 0.14a | 4.52 ± 0.10a | 3.68 ± 0.10ab | 3.55 ± 0.09b | 16.13 ± 0.18a | 72.09 |
| | ♂ | 12 | 4.58 ± 0.15a | 4.50 ± 0.15a | 3.42 ± 0.15bc | 3.33 ± 0.14bc | 15.83 ± 0.32ab | |
| CB-15 | ♀ | 29 | 4.41 ± 0.14a | 4.03 ± 0.06bc | 3.62 ± 0.10abc | 4.10 ± 0.13a | 16.17 ± 0.20a | 74.36 |
| | ♂ | 10 | 3.80 ± 0.13bc | 4.50 ± 0.22a | 3.80 ± 0.13a | 3.80 ± 0.25ab | 15.90 ± 0.28a | |
| HC-1 | ♀ | 31 | 3.55 ± 0.11c | 4.39 ± 0.09a | 3.81 ± 0.11a | 3.29 ± 0.08c | 15.03 ± 0.14c | 72.09 |
| | ♂ | 12 | 3.92 ± 0.15b | 4.08 ±0.29bc | 3.83 ± 0.11a | 3.25 ± 0.13bc | 15.08 ± 0.26bc | |
| M-1 | ♀ | 31 | 3.39 ± 0.09c | 4.23 ± 0.09bc | 3.45 ± 0.10bc | 3.94 ± 0.06a | 15.00 ± 0.13c | 73.81 |
| | ♂ | 11 | 3.45 ± 0.16c | 4.27 ± 0.14abc | 3.36 ± 0.15bc | 3.91 ± 0.09a | 15.00 ± 0.19c | |

[a] Number of individuals tested.
[b] Mean values differ significantly at $P$<0.05 (Paired bootstrap test). Durations followed by the same letters within a column are not significantly different at the 5%

**Table 2:** Average pre-oviposition period (APOP), total pre-oviposition period (TPOP), oviposition days, female longevity (days ± S.E.) and eggs per female (mean ± S.E.) of *T. urticae* reared on five different varieties of cotton at 25±2°C under a 16L:8D photoperiod

| Varieties | N[a] | APOP | TPOP | Oviposition days | Female longevity | Eggs per female |
|---|---|---|---|---|---|---|
| CB-12 | 29 | 3.38 ± 0.18bc | 18.59 ± 0.30c | 5.41 ± 0.31d | 26.55 ± 0.36d | 16.86 ± 1.27b |
| CB-14 | 31 | 4.19 ± 0.11a | 20.32 ± 0.22a | 8.06 ± 0.24b | 31.16 ± 0.32b | 24.23 ± 1.18a |
| CB-15 | 29 | 3.07 ± 0.17cd | 19.24 ± 0.30bc | 8.90 ± 0.24a | 32.24 ± 0.25a | 24.66 ± 1.27a |
| HC-1 | 31 | 2.81 ± 0.19de | 17.84 ± 0.24d | 5.45 ± 0.36d | 27.48 ± 0.64cd | 16.87 ± 1.69b |
| M-1 | 31 | 2.48 ± 0.16e | 17.48 ± 0.18d | 6.90 ± 0.53c | 28.48 ± 0.80c | 22.65 ± 2.35a |

[a] Number of individuals tested.
[b] Mean values differ significantly at $P<0.05$ (Paired bootstrap test). Durations followed by the same letters within a column are not significantly different at the 5% level.

**Table 3:** Demographic parameters (mean ± S. E.) of *T. urticae* reared on five different varieties of cotton at 25±2°C, 50-70 % RH and 16L:8D net reproductive rate ($R_0$), intrinsic rate of natural increase ($r$, day$^{-1}$), mean generation time ($T$, day) and finite rate of increase ($\lambda$)

| Varieties | $R_0$ | $R$ | $T$ | $\lambda$ |
|---|---|---|---|---|
| CB-12 | 12.54 ± 1.50b | 0.1143 ± 0.0058ab | 22.13 ± 0.37c | 1.1210 ± 0.0065ab |
| CB-14 | 17.47 ± 1.86a | 0.1098 ± 0.0046b | 26.05 ± 0.36a | 1.1160 ± 0.0051b |
| CB-15 | 18.33 ± 1.96a | 0.1174 ± 0.0050a | 24.78 ± 0.37b | 1.1246 ± 0.0056ab |
| HC-1 | 12.16 ± 1.66b | 0.1085 ± 0.0061b | 23.02 ± 0.46c | 1.1146 ± 0.0068b |
| M-1 | 16.71 ± 2.29ab | 0.1277 ± 0.0067a | 22.05 ± 0.38c | 1.1362 ± 0.0076a |

[a] Mean value differ significantly at $P<0.05$ (Paired bootstrap test). Durations followed by the same letters within a column are not significantly different at the 5% level.

**Figure legends:**

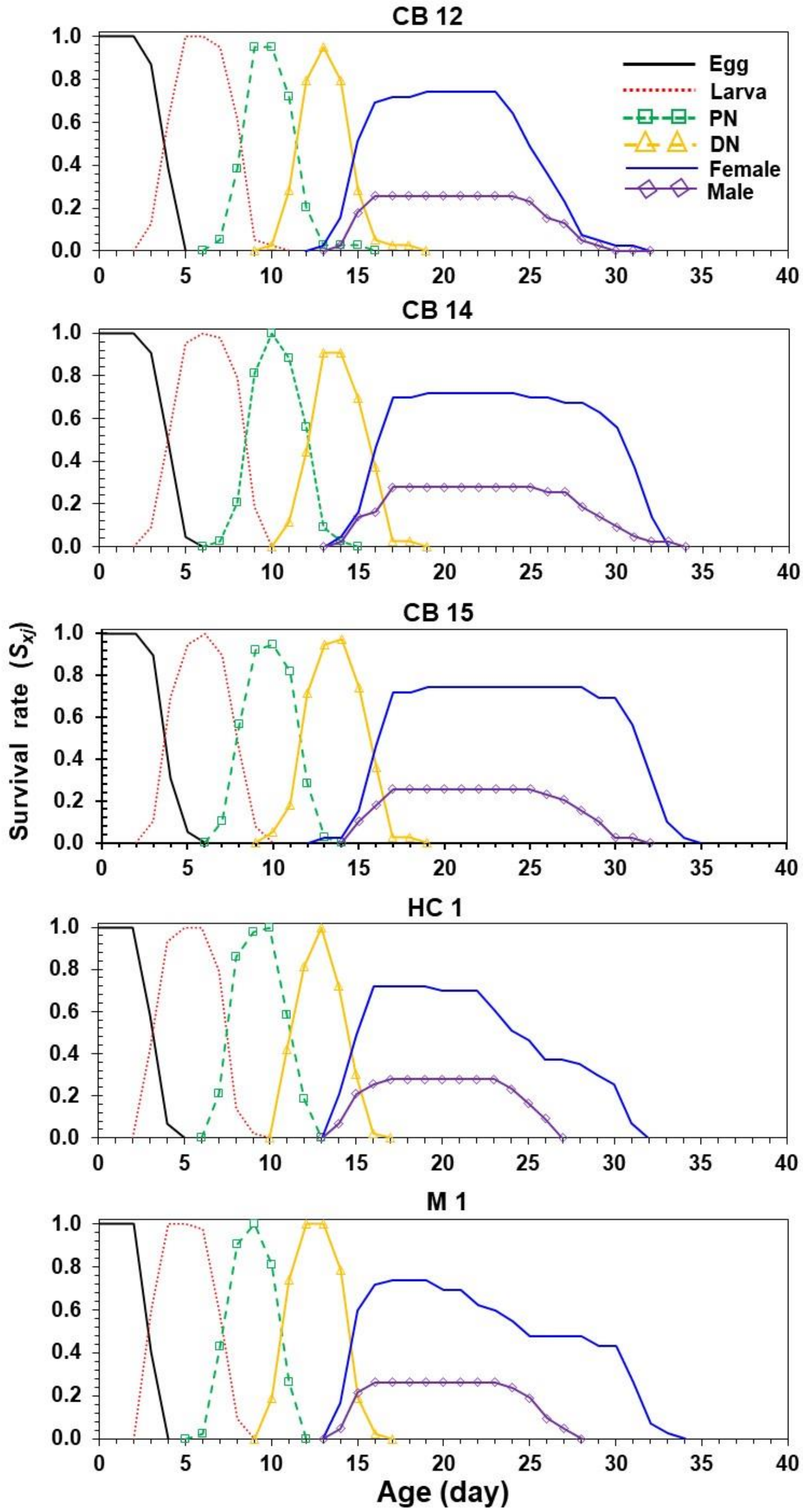


**Figure 1**: Age-stage specific survival rates ($s_{xj}$) of *T. urticea* reared on five different varieties of cotton at 25 ± 2°C temp. RH: 60 ± 10 %, 16L:8D photoperiod (PN and DN indicates protonymph and deutonymph, respectively)

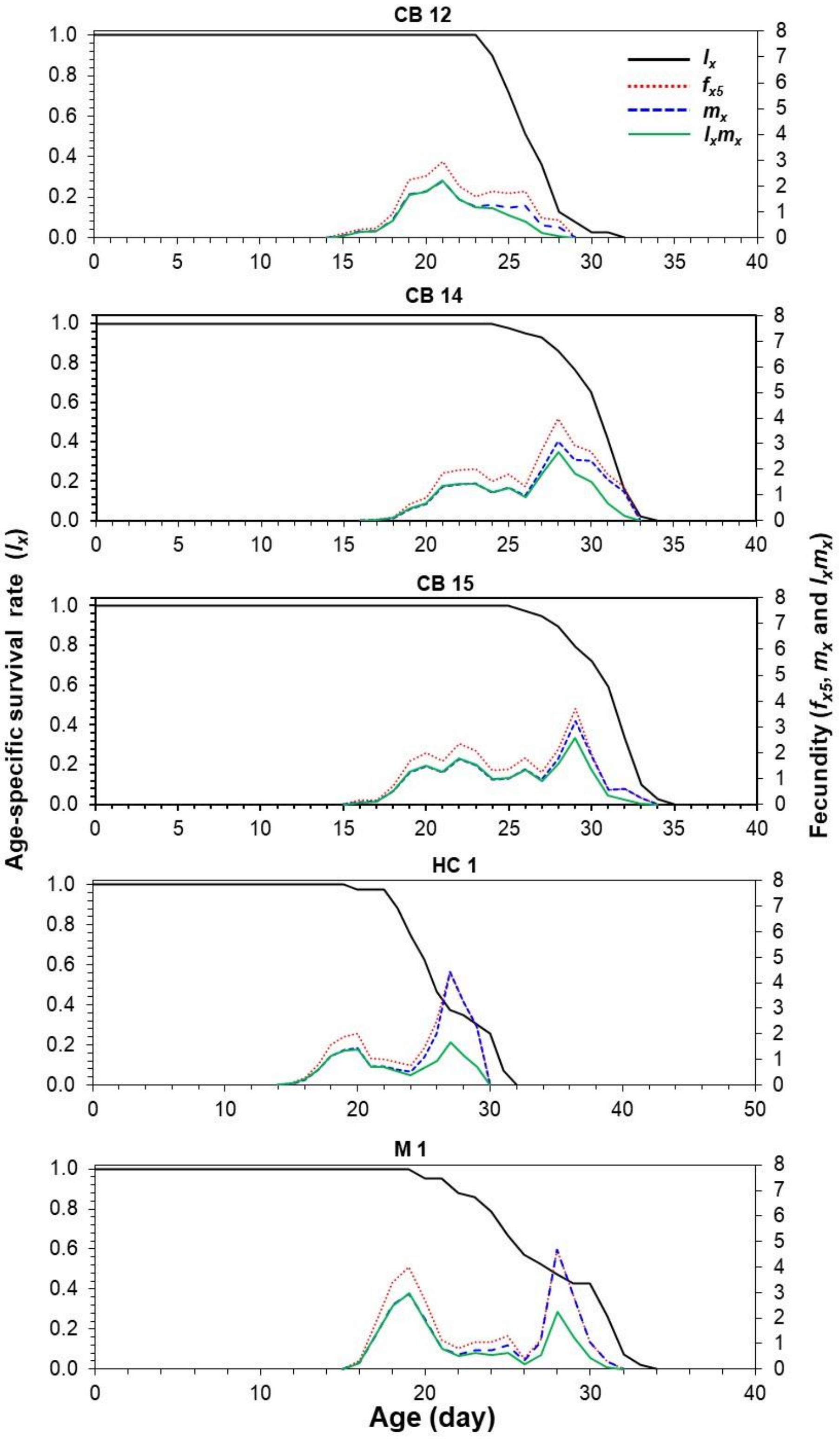


**Figure 2:** Age-specific survivability ($l_x$), age-stage specific fecundity ($f_{x5}$), age-specific fecundity ($m_x$) and age-specific maternity ($l_xm_x$) of *T. urticea* reared on five different varieties of cotton at 25 ± 2°C temp. RH: 60 ± 10%, 16L:8D photoperiod (PN and DN indicates protonymph and deutonymph, respectively)

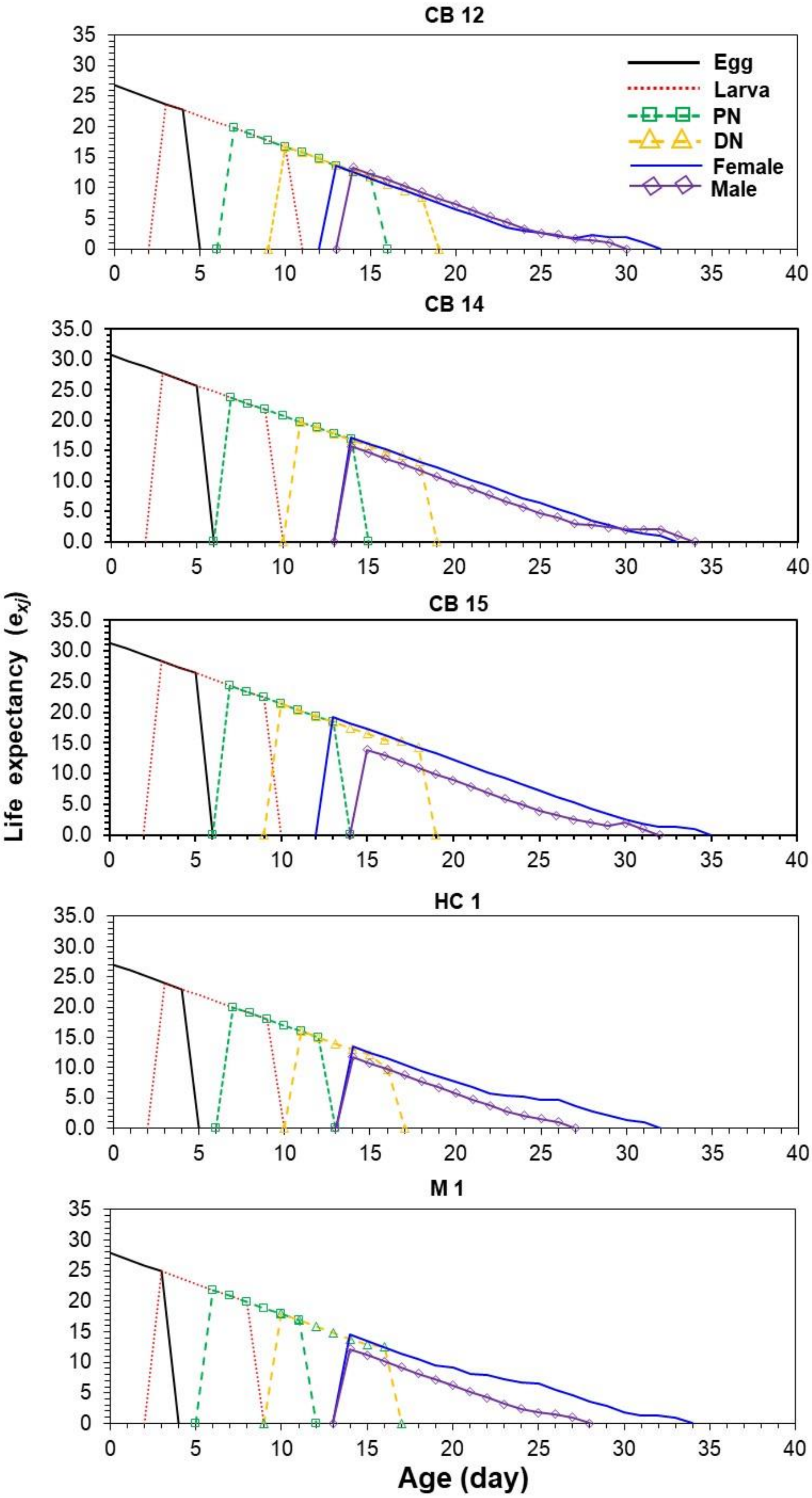


**Figure 3:** Age-stage life expectancy ($e_{xj}$) of *T. urticea* reared on five different varieties of cotton at 25 ± 2°C temp. RH: 60 ± 10%, 16L:8D photoperiod (PN and DN indicates protonymph and deutonymph, respectively)

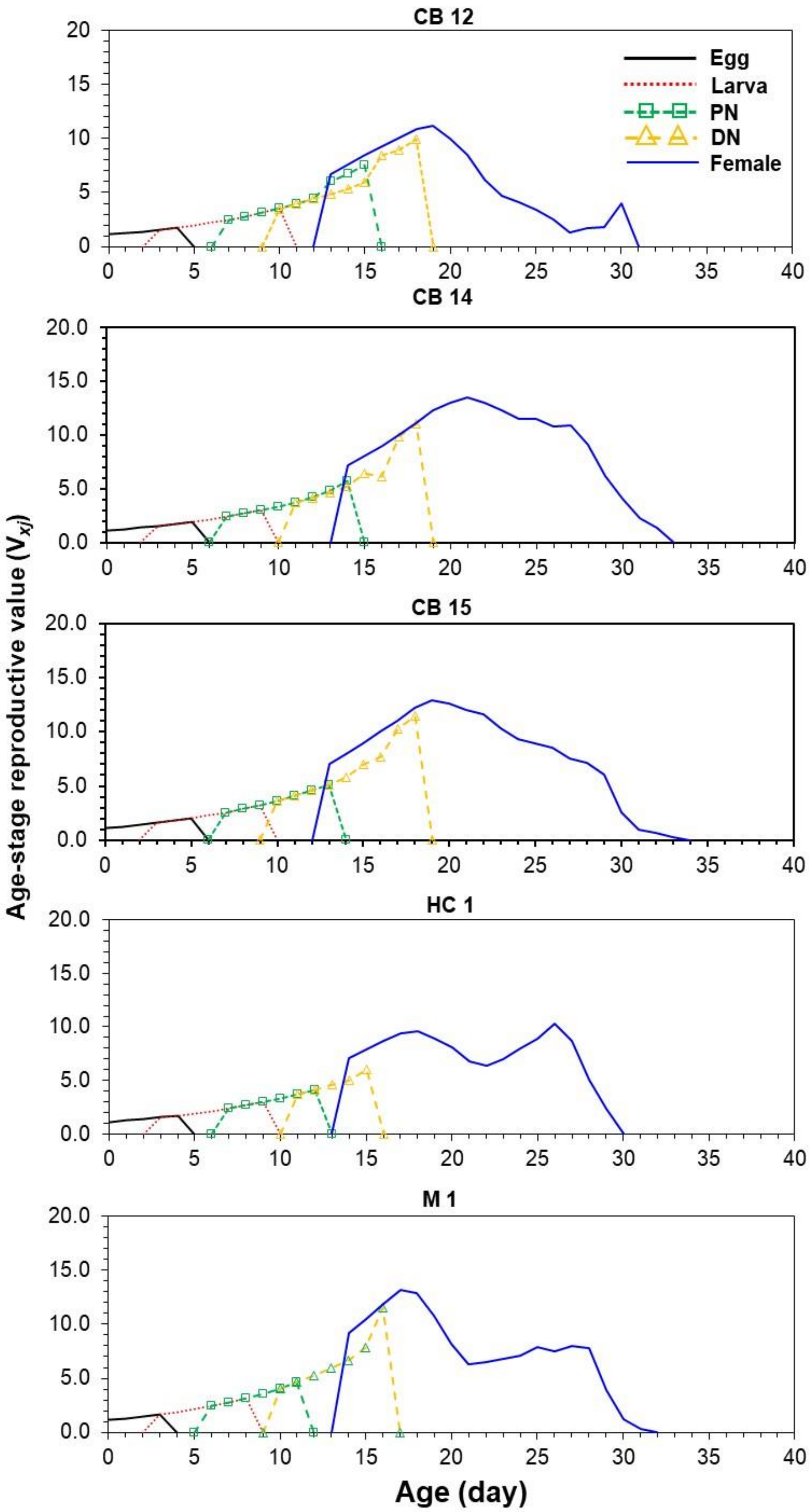


**Figure 4:** Age-stage fecundity ($v_{xj}$) of *T. urticea* reared on five different varieties of cotton at 25 ± 2°C temp. RH: 60 ± 10%, 16L:8D photoperiod (PN and DN indicates protonymph and deutonymph, respectively

# CHAPTER V

# DISCUSSION

The present findings indicated that *T. urticae* could feed, survive, and develop on different cotton varieties. However, variability in different host plants significantly affects their development, fertility and life table parameters. Different varieties had an effect on the fertility life table including net reproduction rate ($R_0$), intrinsic rate of natural increase ($r_m$), mean generation time ($t_G$), finite rate of increase (λ), doubling time (DT) and gross reproduction rate (GRR). In this study, the required time for immature development for adult female *T. urticae* ranged from 15.00 to 16.17 days at 25 ± 2°C and 60 ± 10 % RH on cotton variety. Krips et al. (1998) studied eight cultivars of ornamental gerbera crops at 20-30°C and found 11.40 to 17.00 days which was close to this study. Other studies revealed that the required time for immature development for adult female *T. urticae* varied from 9.75 to 20.42 days at 27°C on pea and bean cultivars, these results were similar to those of other authors (Krips et al., 1998; Razmjou et al., 2009). Abdel-Wahed and El-Halawany (2012) reported 10.00 days at 25°C on pear leaves which were lower than the current study. Conversely, Golizadeh et al. (2017) reported that the developmental time for adult females was 27.25 to 38.90 days at 24°C on different rose cultivars which was higher than the present observation. This is probably due to the higher quality of the plants used for feeding TSSM differences in test conditions or genetic differences of the mite population.

The fecundity of *T. urticae* varied from 16.86 eggs/ female to 24.66 eggs/ female in the current study which was lower than compared with different soybean genotypes which had been reported that the fecundity of TSSM varied from 33.62 to 153.22 eggs/ female

(Sedaratian et al., 2009). In addition, Razmjou et al. (2009) reported that the TSSM fecundity values on soybean, cowpea and bean were 83.16, 65.53 and 34.50 eggs/ female which was also higher than the values obtained in the present findings. Kabiri et al. (2012) revealed that the mean number of eggs laid by a female was significantly higher on the Varamin cultivar (66.20 ± 5.36 eggs/ female) and the minimum number of deposited eggs (48.11 ± 5.88 eggs/ female) was counted on the Bakhtegan cultivar. Fahim et al. (2020) found that the mean total and daily fecundity were significantly higher on 029 cultivars (96.25 and 5.79 eggs, respectively) among four strawberry cultivars. The presence of secondary metabolites that directly affect potential herbivore development and fecundity or the absence of primary essential nutrients for the growth and development of this mite might cause the lower performance of some host cultivars (Potter and Anderson, 1982; Sabelis, 1985; Awmack and Leather, 2002; Pietrosiuk et al., 2003; Razmjou et al., 2009; Sedaratian et al., 2010; Khanamani et al., 2012).

In this study, the population parameters (life table) of *T. urticae* the net reproductive rate ($R_0$) ranged from 12.16 to 18.33 (Table 3) and it was close to those mites on apple varieties (Primula, Pionier, Lodel, Novamac, Freedom) 10.2, 8.9, 12.4, 22.6 and 20.3 at room temperature provided (Skorupska, 1998). Fahim et al. (2020) showed that the values of $R_0$ ranged from 25.642 offspring/ individual on Wanter star to 75.446 offspring/ individual on 029 cultivars. Bounfour and Tanigoshi (2001) reported that population parameters determined on red raspberry leaf discs 24.66, 80.99, 54.86 and 86.01 for *T. urticae* and also 13.54, 23.75, 27.92 and 22.74 for *E. carpini borealis* at 15, 20, 25 and 30°C respectively, which were higher than the current study. On apple leaf discs, this parameter estimated was 19.2 and 14.0, for *T. urticae* and *Eotetranychus pruni* (Grombalia) at 24°C (Grissa-Lebdi et al., 2002). According to Taleb and Sardar

(2008) the net reproductive rate for *T. bioculatus* (Wood-Mason) was 78.69, 37.02 and 53.87 for marigold, rose and cosmos (Ornamental plants) respectively, which was higher than the present findings. In contrast, Kasap (2008) revealed that $R_0$ was 12.54 on Golden Delicious and 17.62 on Starking (two apple cultivars) at 25°C which was close to the current study. The variation of the $R_0$ may be due to variations in relative humidity, plant age or the more nutrition supply in the soil which resided the excised leaves. The present findings revealed that the generation time (*T*) ranged between 26.05 to 22.05 days at 25 ± 2°C and it was close to 20.20 and 19.78 days on two apple varieties (Amasya, Starkimson Delicious) at 25°C (Kasap, 2004). Fahim et al. (2020) found that the mean generation time varied from 15.434 ± 0.056 to 16.707 ± 0.080 on four strawberry cultivars which is lower than the current findings. Razmjou et al. (2009) revealed 13.45 ± 0.67, 13.96 ± 0.89 and 10.59 ± 0.31 at 25 ± 1°C on soybean, cowpea and bean for *T. urticae*. It was determined 23.87 and 26.82 days on two apple cultivars (Golden Delicious and Starking) at 25°C for *B. rubrioculus* (Kasap, 2008). Kafil et al. (2007) recorded this rate at 18.24 ± 0.19, 18.47 ± 0.22 and 19.16 ± 0.17 days on cherry, black cherry and apple for *Amphitetranychus viennensis* (Zacher) and 14.9 days at 25°C for *P. citri* (McGregor) on sour orange leaf (*C. aurantium L.*) (Karaca, 1994). Delhiro and Monagheddu (1986) also reported that the parameter decreased with an increase in temperature, ranging from 158.9 days at 11°C to 11.7 days at 33°C for *P. citri* (McGregor) on sour orange leaves.

The highest sex ratio (% females) found in the current study was 74.36%. Conversely, Adango et al. (2006) reported that the sex ratio percent of females was 72.72 and 78.68 on *A. cruentus* and *S. macrocarpon* L. for *T. ludeni* at 27°C that was close to the current findings. Also, Kasap (2004) reported that the female sex ratio was 82, 80, 78 and 71% on Amasya, Golden Delicious, Granny Smith and Starkrimson Delicious (four different apples) at 25°C for the same mite those were similar or higher than the current study. Razmjou et al. (2009) calculated the sex ratio of *T. urticae* 81.2, 86.0 and 81.0, at 25°C on soybean, cowpea and bean. Imani and Shishehbor (2009) concluded on Lebbek 79.5, 80.9 and 75.0 (% female) of *E. orientalis* (Klein) at 20, 25 and 30°C and immature stages mortality determined 19.61, 22.76 and 43.11%. Bonato (1999) showed mortality of *T. evansi* on tomatoes at 21, 26, 31 and 36°C as 37, 25, 30 and 45%. Fahim et al. (2020) observed that the sex ratio (females/ total) (%) was varied from 67.91 to 76.18 which close to this current study.

In this study, the calculated finite rate of increase ($\lambda$) was varied from 1.1146 ± 0.0068 to 1.1362 ± 0.0076 which was similar to the obtained result 1.17 ± 0.02 on bean leaf discs and 1.26 ± 0.03 on whole bean leaves at 25°C for *T. urticae* (Kavousi et al., 2009). Bonato (1999) found (1.20, 1.27, 1.43, and 1.41) values at (21, 26, 31 and 36) °C, on tomato leaf discs for *Tetranychus evansi* Baker and Pritchard which was close to the current study. Razmjou et al. (2009) determined the finite rate of increase (λ) for *T. urticae* 1.35 ± 0.02, 1.27 ± 0.02 and 1.26 ± 0.02 on soybean, cowpea and bean respectively, at 25°C temperature which was also close to the current study. Intrinsic rate of increase ($r_m$) was obtained from 0.1085 ± 0.0061 to 0.1277 ± 0.0067 at 25 ± 2°C. In contrast, Ahmadi et al. (2007) revealed the $r_m$ value was 0.142, 0.079, 0.095 and 0.038 on four Bean varieties (Talash, Sadaf, Goli, Parastoo) at 25 ± 1°C for *T. urticae* which was similar to this study. Conversely, Skorupska (1998) indicated as 0.093, 0.087, 0.105, 0.119, and 0.112 for *T. viennensis* Zacher and 0.084, 0.078, 0.088, 0.113 and 0.108 for *T. urticae* on five scab-resistant apple varieties (Primula, Pionier, Lodel, Novamac and Freedom) respectively. Kheradpir et al. (2007) reported that

0.313, 0.312, 0.254, 0.290 and 0.299 on cucumber cultivars (Green magic, Nasim, 2502, 2526, Negeen) at 25 ± 0.5°C for *T. urticae* which was higher than this study. Adango et al. (2006) determined that the innate capacity of increase 0.173 on *Amaranthus cruentus* L. and 0.215 on *Solanum macrocarpon* L. for *Tetranychus ludeni* Zacher at 27°C. Silva et al. (2009) revealed the innate capacity of increase as 0.12 and 0.17 on *Gerbera jamesonii* Bolus and Hook (Asteraceae) at 25°C for *T. urticae*. Sabelis (1985) also revealed the $r_m$ values for *Tetranychus* mites range from 0.200 to 0.336/day at 25°C. The $r_m$ value for this mite on an unknown cultivar of soybean and bean at 25°C was reported as 0.303 per day (Hasanvand et al., 2019). The reported $r_m$ for *T. kanzawai* on tea, Hydrangea and Japanese pear was 0.187, 0.224 and 0.229 day (Gotoh and Gomi, 2003). Fahim et al. (2020) found the $r_m$ values ranged from 0.264 to 0.194 (day-1). In another study, it was found that the $r_m$ value ranges from 0.197 to 0.230 (Uddin et al., 2017). Also, Kasap (2004) and Sedaratian et al. (2011) reported that the $r_m$ values of 0.243 and 0.233 to 0.392 on apple and soybean respectively that was higher than the current findings. The ($r_m$) value is an important factor in evaluating the performance of herbivores on various host plants because it reflects many parameters such as survival, development, and reproduction (Southwood, 1978). According to the $r_m$ value in the present study, the M-1 variety had the highest intrinsic rate of increase ($r_m$) and the CB-15, CB-12, CB-14 and HC-1 varieties had the lower $r_m$ values. The highest and lowest ($r_m$) values were 0.1277 and 0.1085/day, respectively (Table 3). *Tetranychus urticae* reared on the M-1 variety exhibited a faster growth rate and also almost shorter generation time than those reared on the other varieties, highlighting its capacity to increase population and outbreaks in the next generations. The significant differences in ($r_m$) values showed extensive variation among the cotton varieties maybe due to the suitability of its host plants for rearing *T. urticae*. The present findings indicated that ($r_m$) value was highest on the M-1 (0.1277) and lowest on the HC-1 (0.1085) variety. So, it is suggested that the HC-1 varieties are less suitable for *T. urticae*. The *T. urticae* has less fecundity when reared on exhibited the lowest $r_m$ value on this variety. This was mainly a result of the low sex ratio, survival rate as well as producing the longer developmental and mean generation times. Consequently, it may be concluded that the mite populations would increase at a lower rate on the HC-1 varieties compared to the other tested varieties of cotton.

Finally, the present findings determined that the HC-1 variety has less susceptibility to *T. urticae*. The presence of secondary metabolites or the absence of primary essential nutrients in these varieties for growth and development can lead to these results. Such laboratory findings may be due to antibiotic or antixenotic effects (or their combinations) of host plants on the life table parameters of reared mites. *T. urticae* reared on the resistant variety HC-1 had the lowest fecundity; therefore, further research is needed to explain the observed differences in life table parameters in our study. Also, investigation into the potential of using the variety HC-1 in combination with other control tactics in the integrated management of this pest in field conditions is necessary.

# CHAPTER VI

## SUMMARY

Biology and two-sex life table analysis of TSSM *T. urticae* were studied on five cotton varieties (CB-12, CB-14, CB-15 HC-1 and M-1) at 25 ± 2°C temperature, 50-70% RH and a photoperiod of 16:8 h (L:D). The egg-adult duration was highest on CB-15 and CB-14 (16.17 ± 0.20 days) and (16.13 ± 0.18 days), lowest on HC-1 and M-1 (15.03 ± 0.14 days) and (15.00 ± 0.13 days). Total larval developmental period was highest on CB-12 (4.60 ± 0.16 days) and lowest on CB-15 (4.03 ± 0.06 days). The female longevity period was longest on CB-15 (32.24 ± 0.25 days) and shortest on CB-12 (26.55 ± 0.36). The female ratio was highest on CB-12 (74.36%) and CB-14 (74.36%) and lowest on CB-14 (72.09%) and HC-1 (72.09%). Highest fecundity (eggs/female) was found on CB-15 (24.66 ± 1.27) and lowest on CB-12 (16.86 ± 1.27). Net reproductive rate ($R_0$) was lowest on HC-1 (12.16 ± 1.66) and highest on CB-15 variety (18.33 ± 1.96). Intrinsic rate of natural increase ($r_m$) was highest on M-1 (0.1277 ± 0.0067) and lowest on HC-1 (0.1085 ± 0.0061). Mean generation time ($T$) was longest on CB-14 (26.05 ± 0.36 days) and shortest on M-1 (22.05 ± 0.38 days). Finite rate of increase (λ) was highest on M-1 (1.1362 ± 0.0076) and lowest on HC-1 (1.1146 ± 0.0068).

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