

***Bemisia tabaci* biological and life table properties are affected by *Bt* and non-*Bt* cotton cultivars (Gennadius)**

Ejazul Haq*, Irsad, Parvez Qamar Rizvi and Syed Kamran Ahmad

ABSTRACT

Bemisia tabaci (Gennadius) (Homoptera: Aleyrodidae) is a common cotton pest that causes massive economic losses yearly, directly or indirectly. This study aimed to investigate the effects of *Bt* cotton on the biological and life table parameters of *B. tabaci* under controlled conditions. The incubation, nymphal, and pupal periods were recorded as shortest on *Bt* and longest on non-*Bt* cultivars. It completed immature stages within 27.8, 28.2, and 28.6 days on *Bt*, whereas it took 30.4 days on the non-*Bt* cultivars. Adult longevity increased in *Bt* cultivars while decreasing in non-*Bt* cultivars. The male lived for a shorter duration and was smaller than the female. Pre-oviposition was higher in non-*Bt* cultivars and lowered in *Bt* cultivars. *Bt* cultivars had longer oviposition periods than non-*Bt* cultivars. Fecundity was relatively higher on *Bt* (57.5, 55.1, and 54.2 eggs/female) but reduced on non-*Bt* (48.2 eggs/female). The life table parameters were also modified using different cotton cultivars. Age-survivorship declined with age, and the highest mortality was recorded at the egg stage, with non-*Bt* having a longer life span than *Bt* cultivars. In the egg stages, life expectancy was similarly greater. The net reproductive rate (R_0) was recorded as the highest, and the intrinsic rate of increase (r_m) was the lowest on *Bt* cultivars. Non-*Bt* cultivars had the highest finite rate of increase, mean generation time, and population doubling time, while *Bt* cultivars had the lowest. The experimental findings showed that *Bt* was slightly more suitable for developing *B. tabaci* than non-*Bt* cultivars.

Keywords: Whitefly, Cotton cultivars, Biology, Life table

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INTRODUCTION

Cotton is a commercial and oldest fiber crop in the tropical and sub-tropical region, and estimated production of cotton in India is accounting for 371.18 lakh tonnes in year 2020-2021 (Anonymous, 2020), and covers approximately 5% of cultivated land in India. It has high industrial value as fabric production, and cotton seed oil is the main component of several processed foods (Singh *et al.*, 2013). A variety of pests, including aphids, green leafhoppers, whitefly, cotton thrips, red cotton bug, dusky cotton bug, spotted bollworms, spiny bollworms, pink bollworms, American bollworms, leaf rollers, armyworms, etc.

which threatened cotton cultivation (Singh *et al.*, 2013). Due to enormous losses caused by the borer complex in the cotton ecosystem, transgenic *Bt* cotton, containing Cry genes of *Bacillus thuringiensis* (*Bt*), has been developed to minimize the infestation. Resisting to many lepidopteron, and coleopteran insect pest species, helps to reduce the strong dependence on synthetic insecticides, and enhances agricultural yields (Morse *et al.*, 2006; Krishna and Qaim, 2007; Carpenter, 2010). However, the toxin secreted by *Bt* cotton has shown selectively to target particularly American bollworm (*Helicoverpa armigera*), spotted bollworm (*Earias vittella*), pink

bollworm (*Pectinophora gossypiella*), and related species to a smaller extent, allowing whitefly to survive freely (Qaim, 2009).

A secondary pest of the cotton crop is the whitefly. The whitefly, *B. tabaci* (Gennadius) (Hemiptera: Aleyrodidae), has still developed into a very major pest for a variety of agricultural and ornamental plants over the past 20 years (Oliveira *et al.*, 2001; Naranjo *et al.*, 2009). The pest causes two types of crop harm. First, by sucking the cell sap from the cotton leaves, producing honeydew, and unintentionally spreading viruses from other plants that infect the plants, the whitefly nymphs directly harm the plants by infecting them (Jones 2003; Naranjo *et al.*, 2009). *B. tabaci* adults are tiny, white insects with a white waxy substance covering their bodies. The females lay their eggs in clusters of 30 to 40. (Martin *et al.*, 2000). While other instars are stationary and adhere to the leaf surface, first instar larvae wander a short distance to find food sources. Their propensity for rapid development, great fecundity, and adaptability to challenging living conditions make control difficult (Barro *et al.*, 2011; Lu *et al.*, 2012). Past crop losses of up to 100% have been caused by its microscopic size, brief life cycle, capacity for fast population growth, short-term development, tolerance to pesticides, and viral transmission in plants (Oliveira *et al.*, 2001). No new information opposing the development of whiteflies has been discovered since the introduction of transgenic cotton. In their studies of *B. tabaci* development on *Bt* and non-*Bt* cotton, Fucai *et al.* (2006) and Chandi & Kular (2014) hypothesised that *Bt* cotton is advantageous for the growth and reproduction of this sucking pest. To establish this reality, more research is necessary. The goal of the current experiment was to examine how *Bt* and non-*Bt* cotton cultivars interact with whiteflies.

MATERIALS AND METHODS

The seeds of *Bt* (NCS 9013 *Bt* II, MRC7365 BGII and BG II 6539-2) and non-*Bt* (Rg-8) cotton cultivars were raised following appropriate agronomic practices and grown in plastic pots (9 cm diameter and 7 cm height) under controlled

conditions (27±2°C, 70-80±5RH, and 10:14 L:D) at the Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, India. In order to prevent a new whitefly infestation, all potted plants were maintained in fine mesh. The leaves-containing *B. tabaci* pupae were taken from a cotton field and nurtured in the lab until they emerged. With the use of aspirators, the pupae that had emerged as adults were collected, and the male and female were visually matched. Typically, the female had a blunt belly and was larger than the male, who was smaller and had a pointed abdomen (Kedar *et al.*, 2014). Paired whitefly adults were released in a clip cage made up of plastic and placed under the side of the leaves of potted plants for obtaining fresh eggs. After 24 hrs of exposure, laid eggs were collected and used for further studies on development and survival. Five eggs per potted plant for biology and ten eggs per potted plant for life table studies were selected and marked with a black nontoxic permanent marker. To help identify the infestation, eggs carrying leaves were marked at the petiole region, and the remaining eggs were thrown away. All potted plants are covered with a fine mesh white cotton cloth once the leaves have been marked and tagged to protect them from further contamination. A hand lens was used to begin the observation each day (20x). When the first instar emerged, it left a mark on the leaves by making a circle when it was positioned there. These initial instars could be distinguished by their transparent colour, diminutive size, and distinctive oval form. A new circle was drawn on the same plant leaf to mark each nymph that had crept past the marked area. The same day that each cohort in each pot was established was also the day that they were all marked.

In the aforementioned clip cages, which were positioned underneath the leaves of newly germinated cotton plants in plastic pots, newly emerged adult *B. tabaci* pairs were released. Using data from Birch (1948), we created female fertility life tables that took into consideration things like female fecundity, pre-oviposition, oviposition,

post-oviposition phases, etc. The Birch (1948) formulas were used to determine adult survival to age x (I_x) and fertility (m_x). This information allowed for the estimation of the intrinsic rate of increase (r_m), net reproduction rate (R_0), mean generation time (T_c), finite rate of increase (λ), and doubling time (DT).

Data analysis

Listed given assumptions were used to construct the age-specific life table available data.

x = age of the insect in days

I_x = number of individuals that survived at the beginning of each age interval x

d_x = number of individuals that died during the age interval x

100_{qx} = per cent mortality, computed through the following equation: $100_{qx} = [d_x / I_x] \times 100$

e_x = expectation of life or mean life remaining for individuals of age x , find out from this formula: $e_x = T_x / I_x$

To obtain e_x , two other parameters L_x and T_x were also computed below

L_x = the number of individuals alive between age x and $x+1$ and compute $L_x = I_x + I_{x+1} / 2$

T_x = the total number of individuals of x age units beyond the age x and obtained by the equation: $T_x = I_x + (I_x + 1) + (I_x + 2) + \dots + I_w$

The computation of female fertility table has been calculated with the help of below given following parameters:

Net reproductive (Ro): The term "carrying capacity" refers to the average insect's net reproduction (R_0) rate under a particular environmental regime. The formula given below may be used to calculate the rate at which a population reproduces in a single generation.

$$R_0 = \sum I_x \cdot m_x$$

Mean length of generation (T_c): The mean time between the birth of a parent and the birth of their offspring is referred to as the mean length of generation (T_c). Since the offspring are born over a period of time rather than at a specific time, this time is an approximate value. The estimate was performed using the (Birch, 1948).

$$T_c = \frac{\sum [I_x \cdot m_x \cdot x]}{\sum [I_x \cdot m_x]}$$

Intrinsic rate of increase (r_m): The intrinsic rate increase (r_m) is the rate at which a population grows under a given set of environmental conditions at any given time (Birch, 1948). The following formula may be used to get a reasonably precise approximation of the intrinsic rate of increase (r_m):

$$(i) r_m = \frac{\log_e R_0}{T_c} \text{ (for rough estimation)}$$

$$(ii) e^{-r_m} \cdot I_x \cdot m_x = 1 \text{ (for accurate estimation)}$$

Finite rate of increase (λ): The frequency of population multiplication in a given period may be determined by the finite rate of increase (λ) (Birch, 1948): $\lambda = e^{r_m}$; $\lambda = \text{Antilog}_e e^{r_m}$

Potential fecundity (Pf): The total number of eggs deposited by an average female throughout her lifecycle is known as potential fecundity (Pf). This was calculated by summing the age-specific fecundity column.

$$Pf = \sum m_x$$

Doubling Time (DT): The following equation may be used to estimate the Doubling Time (DT), where DT is the period it takes for the population to double.

$$DT = \frac{\log_e 2}{r_m}$$

Annual rate of increase (ARI): To calculate the annual rate of increase (ARI), we may calculate the intrinsic rate of increase (r_m), the finite rate of increase (λ), the doubling time (DT), and the net reproduction rate (R_0).

$$ARI = 365 = e^{365 r_m} = 2^{365/DT} = R_0^{365/T_c}$$

Statistical analysis

The varied data in a number of both sexes emerge duration of several life parameters on both cotton cultivars were submitted to analysis of variance (ANOVA) using the software "MINITAB version 11" unless specified otherwise. We compared r_m and other life table characteristics of *Bt* and non-*Bt* cultivars using Tukey's HSD test.

RESULTS

Age-specific survival, life expectancy, and mortality

It is evident from the experimental findings that age-specific survivorship has been seen to decline steadily with increasing age (Fig. 1). The mortality rate varied depending on cultivars and different

stages, with egg mortality being higher than nymphal and pupal stages on both *Bt* and non-*Bt* cultivar. The non-*Bt* cultivar had the greatest mortality during the egg, second nymphal, and pupal stages (Fig. 1).

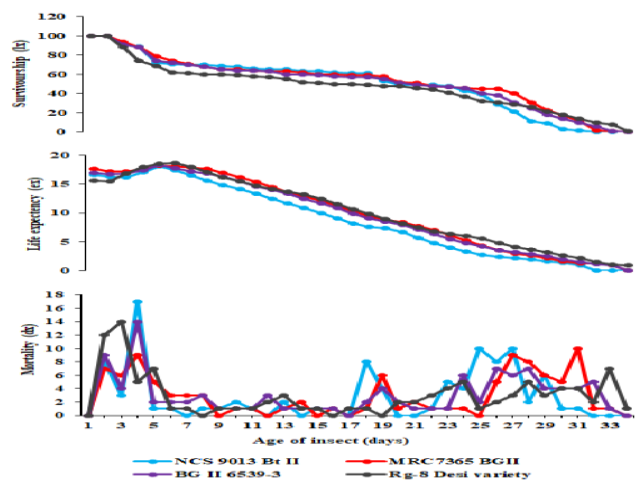


Figure 1. Age-specific survivorship, life expectancy (e_x), and mortality (d_x) of *B. tabaci* on *Bt* and non-*Bt* cultivars

This study indicated that the non-*Bt* cultivar's life cycle took longer to finish a signal generation as compared to *Bt* cultivar, which required a shorter time. On the other hand, life expectancy was shown to be reciprocal to time and declined as time passed; it was greatest in egg stages for non-*Bt* and followed by *Bt* cultivars (Fig. 1). The egg hatching times varied on all cultivars, and they were shorter on *Bt* compared to non-*Bt* cultivar (LSD=0.73; F=1.56; $p>0.01$) (Table 1). Moreover, the non-*Bt* cultivar had the highest egg mortality rate (39%) and the lowest on *Bt*. In contrast, *Bt* had higher egg hatchability compared to non-*Bt* cultivars. Adult females begin to lay eggs after a period known as the pre-oviposition period. It was recorded lowest on *Bt* and highest on non-*Bt* cultivar (LSD=0.39; F=2.40; $p>0.01$). The adult lifespan varies with *Bt* and non-*Bt* cultivars. In general, females outlived males. Male and female lifespans on *Bt* cultivars were found to be the longest and the shortest on non-*Bt* cultivar (Table 2). Adult mortality was likewise rising with age.

Survivorship and development of immature stages

Bt and non-*Bt* cultivars influence the survivorship and development of the immature stages. Newly emerged first instar nymph survived for a more extended period on non-*Bt* than on *Bt* cultivars (Table 1). While *Bt* cultivars had the maximum mortality. Non-*Bt* had the least mortality of the first instars (Fig. 4). During the second instars, the non-*Bt* cultivar had a longer duration, and the *Bt* had a shorter duration (LSD=0.72; F=0.26; $P>0.01$) (Table 1). As a result, the mortality of the second instars was highest on the non-*Bt* cultivar and lowest on the *Bt* (Fig. 4). Third instars were initiated once the preceding stage was finished. During this stage, the nymphal life span was highest on non-*Bt* and lowest on *Bt* cultivars (LSD=0.78; F=0.40, $p>0.01$) (Table 1), whereas mortality was highest on *Bt* compared to non-*Bt* cultivar (Fig. 4). There was a slight variation in pupal duration, and non-*Bt* cultivar took longer than *Bt* (LSD=0.68; F=1.42; $p>0.01$) (Table 1). Non-*Bt* cultivar had the highest mortality. In contrast, *Bt* cultivars had the lowest mortality (Fig. 4). The overall development times of immature stages were found to be the longest on the non-*Bt*, and the shortest on the *Bt* cultivars (LSD=1.94; F=3.37; $p<0.01$) (Table 1).

Life table parameters

The life table parameter attributes were also varied with cultivars. The pivotal age of female was recorded 8 days on the non-*Bt* and the range of 8-9 days on *Bt* cultivars (Fig. 5). The oviposition period was observed longest on the *Bt* cultivars, while followed by non-*Bt* cultivar (LSD=0.54; F=1.93; $p>0.01$) (Table 2). The net reproductive rate (R_0) was found highest on the *Bt* cultivars, while lowest on non-*Bt* cultivar (Table 3). The fecundity was recorded highest on *Bt* cultivars and lowest fecundity recorded on non-*Bt* cultivar (LSD=5.81; F=3.72; $P>0.01$) (Table 2). A little difference was found between intrinsic rate of increase (r_m), It was highest on *Bt* and lowest on non-*Bt* cultivars (Table 3). Population doubling time (DT) was also found to be highest on the non-*Bt* cultivar and lowest on the *Bt* cultivars.

Table 1. Immature stages of *B. tabaci* on *Bt* and non-*Bt* cultivars

Cotton Cultivars	Incubation periods	Nymphal periods			Pupation	Total developmental periods
		I Instar	II Instar	III Instar		
NCS 9013 <i>Bt</i> II	4.1±0.88	4.2±0.79	3.8±0.88	3.8±0.92	4.2±0.63	20.2±2.15
MRC7365 BGII	4.2±0.92	4.5±0.53	4.0±0.82	3.9±0.88	4.2±0.79	20.8±2.44
BG II 6539-2	4.2±0.79	4.6±0.52	4.1±0.74	3.9±0.88	4.3±0.67	21.1±2.02
Rg-8 (non- <i>Bt</i>)	4.8±0.63	5.1±0.74	4.2±0.79	4.2±0.79	4.8±0.92	23.1±2.02
LSD	0.73	0.59	0.72	0.78	0.68	1.94
F	1.56	3.27	0.26	0.40	1.42	3.37
P	0.22	0.03	0.86	0.75	0.25	0.03

The means (±SE) in the same column followed by the same letters are not significantly different at P < 0.01.

Table 2. Female life attributes of *B. tabaci* on *Bt* and non-*Bt* cultivars

Cotton Cultivars	Pre-Oviposition	Oviposition	Post oviposition	Fecundity	Adult Longevity		Total life span	
					Male	Female	Male	Female
NCS 9013 <i>Bt</i> II	1.6±0.52	4.2±0.42	1.8±0.42	57.5±6.77	3.9±0.88	7.6±0.52	24.1±3.03	27.8±2.85
MRC7365 BGII	1.7±0.48	4.1±0.74	1.6±0.52	55.1±7.32	3.6±0.84	7.4±0.71	24.4±3.29	28.2±3.41
BG II 6539-2	1.8±0.42	4.0±0.67	1.7±0.48	54.2±7.45	3.7±0.82	7.5±0.53	24.8±2.85	28.6±3.11
Rg-8 (non- <i>Bt</i>)	2.1±0.32	3.6±0.52	1.6±0.52	48.2±3.65	3.5±0.53	7.3±0.79	26.6±2.56	30.4±2.85
LSD	0.39	0.54	0.44	5.81	0.70	0.81	2.15	2.23
F	2.40	1.93	0.39	3.72	0.48	0.20	2.18	2.12
P	0.08	0.14	0.76	0.02	0.70	0.89	0.11	0.12

The means (±SE) in the same column followed by the same letters are not significantly different at p < 0.01.

Table 3. Life parameters of *B. tabaci* Genn., on *Bt* and non-*Bt* cultivars.

Cotton Cultivars	Life table parameters							
	Net reproductive rate (Ro)	Intrinsic rate of increase (r _m)	Potential fecundity (Pf)	Mean length of generation (T _c)	Finite rate of increase (λ)	Population doubling time (DT)	Annual rate of increase (ARI)	K-value
NCS 9013 <i>Bt</i> II	13.16	0.04	57.29	25.35	1.35	16.19	6093777.38	0.31
MRC7365 BGII	10.75	0.04	54.74	28.20	1.44	18.95	628949.60	0.35
BG II 6539-2	11.13	0.04	54.51	27.59	1.42	18.19	1095175.08	0.37
Rg-8 (non- <i>Bt</i>)	7.68	0.03	50.41	29.57	1.52	20.03	306712.17	0.51

The mean length of generation (T_c) was observed longest on non-*Bt* cultivar and smallest on *Bt* (Table 3). The *Bt* cultivars (Table 3). The finite rate of increase was highest on non-*Bt* and lowest on *Bt* cultivars (Table 3).

Figure 2. Stage-specific survivorship (lx) of *B. tabaci* on *Bt* and non-*Bt* varieties.

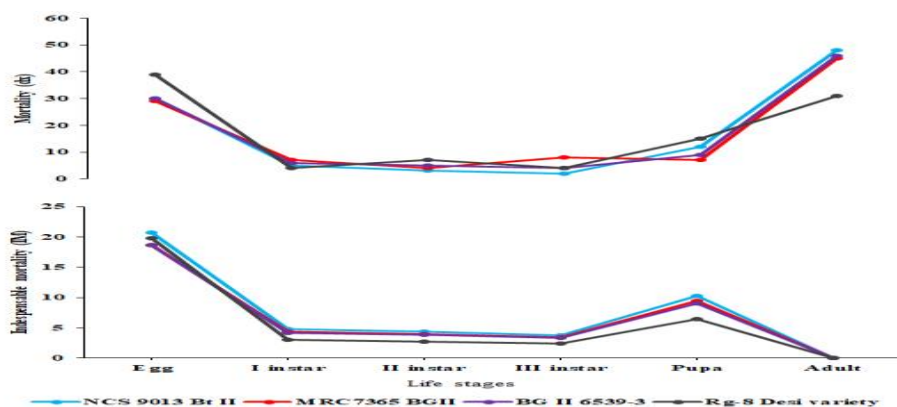


Figure 3. Stage-specific survival fraction (S_x) and Mortality survival ro (MSR) of *B. tabaci* on *Bt* and non-*Bt* cultivars.

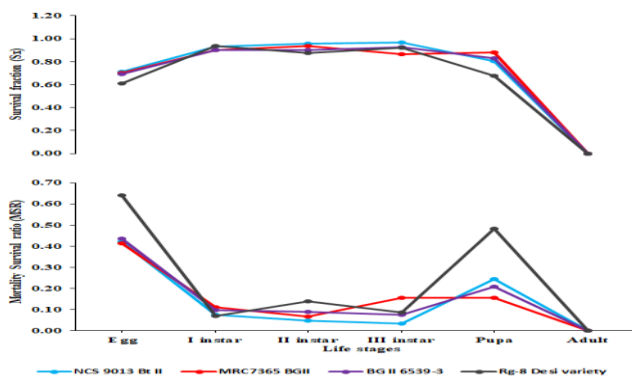


Figure 4. Stage-specific mortality (d_x) and Indispensible mortality (IM) of *B. tabaci* on *Bt* and non-*Bt* cultivars.

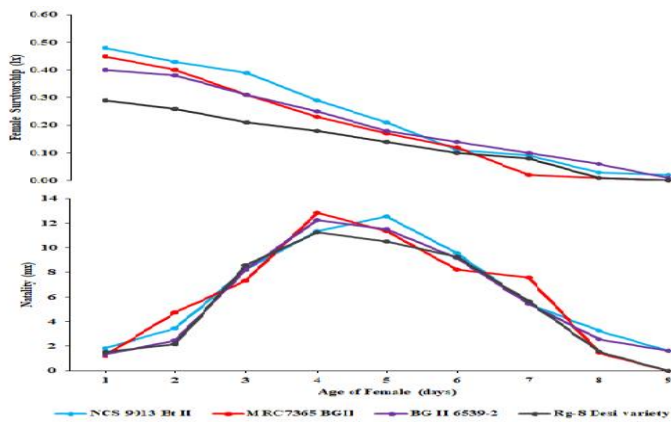
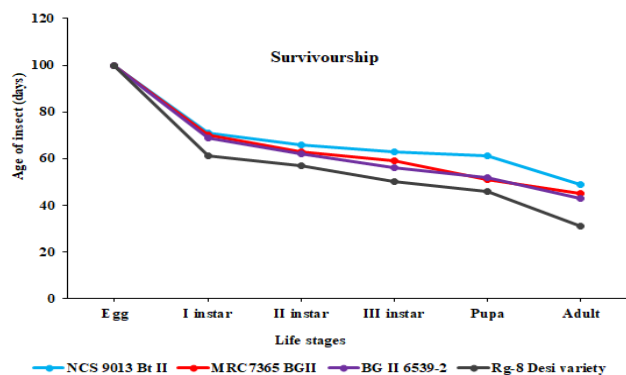


Figure 5. Female survivorship (l_x) and fecundity/natality (m_x) of *B. tabaci* on *Bt* and non-*Bt* cultivars.



DISCUSSION

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Pertaining to this investigation, insect survival and reproduction rates, host plant species vary widely with the suitability of food sources and shelter for certain insects (Lin and Ren, 2005). When *B. tabaci* was exposed to different host plants, it exhibited different responses in terms of life parameters (Lin *et al.*, 2003; Qui *et al.*, 2003). The present study revealed a gradual decline in survival with age (Fig. 1). The variable mortality pattern showed in both *Bt* and non-*Bt* cultivars, the egg, nymphal instars, and pupa being the most vulnerable. The tubular structure on the base of the egg, known as the eggs stalk, promotes the binding of eggs to the surface of the leaves (Lloyd, 1922). It serves as a water transporter, from leaves tissues to eggs (Paulson and Beardsley, 1985; Buckner *et al.*, 2002). This structure maintains the moisture level in eggs. The eggs mortality and failure hatching can be associated with a variety of causes, including inadequate solute absorption through the stalk of the egg (Kakimoto *et al.*, 2007; Iida, 2009), and the egg may have absorbed particular nutrients through the stalk depending on the host plant, which may have damaged eggs (Iida, 2009). On the other hand, *B. tabaci* had the shortest life span on *Bt* and the longest in the non-*Bt* cultivar (Fig. 1). These findings are slightly similar to the findings of Kedar *et al.* (2014); Chandi and Kular (2015). However, the early mortality in the first instar stage might be related to the longer time crawlers need to settle down on host plants (Tsai and Wang, 1996; Lin and Ren, 2007).

According to Van Lenteren and Noldus (1990), *Trialeurodes vaporariorum* (Westwood) host plant selection was directly connected to the biological performance of the plant. The increased rate of reproduction, reduced transience rate, and shorter development period of insects on a certain host plant indicate that the host plant is more suitable (Costa *et al.*, 1991a, b; Awmack and Leather, 2002; Hasan and Ansari, 2011). In the current study, the steady decrease in life expectancy was seen to be greatest on non-*Bt* and lowest on *Bt* cultivars (Fig. 1). The egg survival rate was

observed to be highest on *Bt* and lowest on non-*Bt* cultivars (fig. 4). While, whereas the egg development on both cultivars differed, non-*Bt* having the highest and *Bt* cultivars having the lowest egg mortality (Fig. 4). These findings are agreement with the findings of Azimi *et al.* (2013); Chandi and Kular (2015). With this, the incubation period was the longest on the non-*Bt* cultivar. However, *Bt* cultivars showed considerable variance in incubation periods (Table 1). Whitefly adult life differed substantially among both cotton cultivars, and the females lived longer than males in all-cotton cultivars. A similar finding was observed by Kedar *et al.* (2014); Chandi and Kular (2015).

The significance of the life table element in comparing the whitefly population was stressed by Wang and Tsai (1996). Non-*Bt* cultivars had the longest average duration of egg laying, followed by *Bt* cultivars (Table 2). Both Kedar *et al.* (2014); Chandi and Kular (2015) corroborate our findings. Net reproduction rate (R_0) showed a significant variance, with non-*Bt* cultivars having the highest value as compared to *Bt* cultivars (Table 3). The host plants' net reproduction rate (R_0) was reliant on them. On cotton and rapeseed, researchers found 18.40 and 30.67 females/female; on soybean, 82.15 females/female; and on eggplant, cucumber, sweet pepper, and tomato, respectively, 185.10, 130.70, 73.10, and 36.10 females/female (Kakimoto *et al.*, 2007); 88.94, 45.73, 89.50 and 57.98 females/female on eggplant, chilli, tomato and okra (Ahmad and Rizvi, 2014); 55.29, 56.39, 20.43 females/female on cotton, tomato and pepper (Farooq *et al.*, 2021). Different host plants (Bonato *et al.*, 2007; Islam and Shunxiang, 2007) or varied climatic circumstances (Lin and Ren, 2007) might explain the variance in the net reproduction rate. The highest egg laying was observed on *Bt* and lowest on the non-*Bt* cultivar, similar to the findings of Chandi and Kular (2015) and Kedar *et al.* (2014). In choice assays, Omondi *et al.* (2005) suggested that fecundity is a good predictor of host acceptability. In the present study, the intrinsic rate of increase (r_m) was observed to be higher on *Bt*

and lower on the non-*Bt* cultivar (Table 3). This finding was correlated by Samih *et al.* (2014), who found 0.1010, 0.1286 females/female/day on cotton and rapeseed; Musa and Ren (2015) who reported 0.1875 females/female/day on soybean; Calvitti and Remotti (1998) who ranged between 0.0844 to 0.1121 females/female/day for *B. argentifolii* on six cotton cultivars; Kakimoto *et al.* (2007) who observed 0.168, 0.153, 0.143 and 0.110 females/female/day on eggplant, cucumber, sweet pepper, and tomato; Ahmad and Rizvi (2014) who founded 0.190, 0.114, 0.147 and 0.136 females/female/day on eggplant, chili, tomato, and okra. The population of whitefly was faster growing on *Bt* cultivars than non-*Bt*. There was a considerable variance in mean generation time (T_c) (Table 3). The outcome was the same for Enkegaard (1993), who reported 43.08 days on poinsettia plants, Samih *et al.* (2014), who noted 30.079 and 26.77 days on cotton and rapeseed, and Ahmad and Rizvi (2014), who noted 23.67, 33.57, 30.62, and 29.89 days on eggplant, chilli, tomato, and okra. Non-*Bt* cultivars had the fastest doubling times, while *Bt* cultivars had the slowest (Table 3). Ahmad and Rizvi (2014) noted 8.41, 14.01, 10.87, and 11.74 days on eggplant, chilli, tomato, and okra. Enkegaard (1993) discovered 7.94 days on poinsettia plants. In terms of annual rate of increase (ARI individual/year), the *Bt* cultivar had the highest rate while the non-*Bt* cultivar had the lowest (Table 3). The observed finite rate of increase was lowest for *Bt* cultivars and highest for non-*Bt* cultivars. This result was consistent with measurements made by Samih *et al.* (2014) on cotton, rapeseed, and 1.106; Enkegaard (1993); Musa and Ren (2005); and 1.2041 by Samih *et al.* (2014) on soybeans.

The growth of immature *B. tabaci* is based on the kind of whitefly population or biotype (Muniz and Nobela, 2001; Bonato *et al.*, 2007) or host plants (Zalom *et al.*, 1995; Tsai and wang, 1996; Muniz and Nobela, 1997; Nava-Camberos *et al.*, 2001; Lin and Ren, 2007 Bonato *et al.*, 2007). During nymphal development, the various hosts had distinct effects on the instar duration of *B. tabaci*

(campos *et al.*, 2003; Bonato *et al.*, 2007). *Bt* cultivars overtook the non-*Bt* in terms of immature whitefly mortality and development time (Table 1). The growth rate, survival, and fecundity were substantially different in both cultivars in the current study, Kedar *et al.* (2014); Chandi and Kular (2015) was observed similar findings.

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