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Development and survival of different generations of *Bemisia tabaci* (Gennadius) on brinjal under north Indian conditions

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ABSTRACT: Annual life cycle of *Bemisia tabaci* was studied under screen house conditions at Punjab Agricultural University, Ludhiana, Punjab during 2019-20. The results revealed that *B. tabaci* completed 13 overlapping generations on brinjal in a year. The mean incubation period ranged between 3.60-23.70 days and egg hatchability varied from 80.18 to 95.0 per cent during different generations. The nymphal stage prolonged during winter months and mean duration of nymphal stage varied from 14.83 to 47.22 days during different months. The survival of nymphs ranged from 52.78 to 76.30 per cent, being higher during spring, rainy seasons and lower during summer, winter months. Total development period (egg to adult emergence) of *B. tabaci* varied from 19.38 to 65.30 days during different months. The mean generation survival ranged between 45.0 to 69.2 per cent and it was higher during spring and rainy season, whereas lower in summer and winter season generations. The multiple regression analysis revealed that different weather parameters contributed 37.0 to 63.0 per cent (R^2) variations in survival of different generations of *B. tabaci* on brinjal. This study is the first report on annual life cycle of *B. tabaci* on brinjal under north Indian conditions.

Keywords: *Bemisia tabaci*, brinjal, development period, generations, life cycle, whitefly

INTRODUCTION

Whiteflies are one of the most important pests, which cause severe damage to vegetable, horticultural, agricultural, and ornamental plants worldwide. However, among 1500 reported species of whiteflies, *Bemisia tabaci* (Gennadius), is a destructive polyphagous insect pest, which exhibits a wider host range (over 1000 species) (AbdRabou and Simmons, 2010). This pest causes heavy losses in some plant families such as cucurbitaceae, solanaceae and fabaceae, particularly in tropical and subtropical regions of the world (Martin and Mound, 2007) . *Bemisia tabaci* causes substantial damage and economic losses to susceptible crops through phloem feeding and induction of sooty moulds that reduce photosynthesis (Oliviera *et al.,* 2001). Besides this, *B. tabaci* is able to transmit more than 350 species of plant pathogenic viruses including Begomovirus, Carlavirus, Crinivirus, Ipomovirus, and Torradovirus (Jones, 2003). In favourable environment with warm climatic conditions, whiteflies maintain a high rate of reproduction for the whole year (CABI, 2017) and have the capacity to achieve exceptionally high population size within few generations.

Bemisia tabaci was first reported as a pest of tobacco in 1889 from Greece and named tobacco whitefly, *Aleyrodes tabaci* Gennadius. But, in India, *B. tabaci* was first time reported in 1905 on cotton crops (Misra and Lambda, 1929) and it became a serious pest of cotton in the late 1920s and early 1930s in northern India (Hussain and Trehan, 1933). Recently, an outbreak of *B. tabaci* during 2015 resulted in huge loss to the cotton growers in northern India. In Punjab, 60% of the cotton crop was damaged, leading to reduction in lint yield from 574 kg ha^{-1} in 2014-15 to 197 kg ha^{-1} in 2015-16 (Dhillon and Sidhu, 2016). The potential crop losses by *B. tabaci* are exacerbated by its high reproductive rate, dispersal ability and lack of a diapause stage, which resulted in buildup of pest population throughout the year by shifting to different host plants during different seasons (Lin *et al.*, 2007).So, the appraisal of alternate host plants and their importance in pest build up, survival can be fundamental to manage the polyphagous pest on its main hosts (Tabashnik *et al*., 1991).

Under Punjab conditions, *B. tabaci* is not limited to cotton plants, but it can remain active throughout the year due to the continuous availability of alternative host plants. Moreover, agricultural practices have changed due to fragmentation of farms and sowing of different crops in fields adjoining to cotton is now common. Brinjal is an important host plant of *B. tabaci* which is cultivated throughout the year in Punjab, in an area of 5.47 thousand hectares (Anonymous, 2022). Being cultivated round the year, brinjal played an important role in population build up and carryover of *Bemisia tabaci* under north Indian conditions (Kedar *et al*., 2018). But information pertaining to number of generations completed by *B. tabaci* on brinjal was lacking. Accurate information on biological parameters on specific host plant is required for implementing sustainable management practices, which facilitate the present study to determine the development and survival of different generations of *B. tabaci* on brinjal in a year under Punjab conditions.

MATERIALS AND METHODS

Studies were conducted during 2019 and 2020 in the screen house conditions at Punjab Agricultural University, Ludhiana (Punjab) India. The geographical location of Punjab Agricultural University, Ludhiana has the reference to 75° 80' 45" East longitude and 30° 90' 10" North latitude. To study number of generations of *B. tabaci* on brinjal, the experiment was conducted round the year under screen house conditions. The seedlings of brinjal were transplanted in earthen pots and these pots were kept under screen house. The experiment was started at 15 days after planting, when crop recovered from transplanting shock and started new growth. A pair of whitefly adult was released in a cup cage on undersurface of the fully developed leaf of 15 plants. After 24 h, the adults were removed and leaves were examined for eggs. For this purpose, the leaf portion inside each clip cage was marked with non toxic marker and observed by using stereo zoom binocular microscope. Those leaves which contain eggs were tagged at petiole region and five eggs on each infested leaf were retained for taking observations and remaining were removed with the help of a fine brush. Cup cage were again attached to selected leaves to avoid further infestation of whitefly or other insects. The time period between laying of eggs and appearance of the crawler were taken as incubation period. The observations on incubation period, nymphal and survival of different stages were recorded after 24 hours. Whenever, the first adult emerged in a generation, the next generation of whitefly was initiated by releasing the pair of whitefly adults from stock culture assuming two days pre oviposition period. The next generation was reared on new brinjal plants and development period and survival of eggs and nymphs were recorded. The data was analyzed using mean and standard errors.

RESULTS AND DISCUSSION

When reared round the year, whitefly completed 13 overlapping generations on brinjal from February 2019 to March 2020 (Table 1). Ten overlapping generations were recorded between February 2019 to mid October 2019, whereas, the development of *B. tabaci* during winter months was slower and it completed two generations between November 2019 and March 2020. No published work on annual life cycle of *B. tabaci* on brinjal was observed in literature. However, earlier reports also demonstrated that *B. tabaci* can complete 11 to 15 generations a year under favourable conditions in the laboratory (Avidov, 1956). Our results are in conformity with findings of Aneja (2000), who reported 11 generations of *B. tabaci* during cotton growing season (April to October) in Punjab, India.

Egg: The incubation period varied during different generations and it was influenced by the prevailing weather during different months of the year. The egg stage lasted for longer period in winter generations, being maximum (23.70±0.35days) in generation completed during January 23-March 11, 2020 followed by November 19-January 21 (17.90±0.29 days). The incubation period was shortest (3.60 ± 0.09 days) during August 14-September 2, which was statistically at par with all other generations except four generations during, February 16-March 20, March 22-April 18, November 19-January 21 and January 23-March 11. The egg survival in term of hatchability was recorded and data showed that hatchability ranged between 80.18 to 95.0 per cent during different generations. The hatchability was highest (95.0 %) in whitefly generation during October 22 - November 17, which was at par with generations completed during February 16 - March 20 , April 20-May 1, August 14-September 2 and September 4-September 24. The egg survival was minimum (80.18) in generation during June 8-June 29, being on par with generation completed during May 13-June 6, July 1-21, July 23-August 12, September 26–October 20, November 19-January 21, January 23-March 11 (Table 1).

Nymph: The observations on total nymphal development period (first instar to adult emergence) revealed that nymphal stage prolonged during winter months and temperature has pronounced effect on development of nymphs. The mean development period of nymphs varied from 14.83 to 47.22 days during different generations. It was shortest in generation during April 20-May 11, which was statistically on par with generation during May 13-June 6, June 8-June 29, August 14-September 2 and September 4- September 24. The mean nymphal period of *B. tabaci* generations during winter *i.e* November 19-January 21 (47.22±0.40 days) and January 23-March 11(27.12±0.34 days) was significantly higher and they differ significantly from each other as well as other generations. The nymphs experienced higher mortality than eggs as depicted from the data presented in Table 1. Mean nymphal survival varied from 52.78 to 76.30 per cent as compared to 80.18 - 95.0 per cent egg survival. The nymphal survival was maximum during, July 1-July 21, which was on par with *B. tabaci* generation during February 16-March 20

Table 1. Development and survival of different generations of whitefly, *B. tabaci* on brinjal under screen house conditions at Ludhiana, 2019-20

Generation	Period	Eggs			Nymphs			Total development period			#GT (Days)
		Incubation period (days)		Hatchability (%)	Duration (days)		Survival (%)	Duration (days)		Survival (%)	
		Mean± SE	Range		Mean± SE	Range		Mean± SE	Range		
*I	February 16 – March 20, 2019	16.89±0.23	16-19	93.33	17.48±0.18	16-18	74.20	34.17±0.33	32-38	69.20	32.0
II	March 22 – April 18	9.00±0.15	8-10	87.67	18.00±0.14	17-19	62.60	27.13±0.18	26-29	55.05	26.0
III	April 20– May 11	5.33±0.16	4-6	90.85	14.83±0.23	13-17	53.20	20.18±0.19	20-23	47.50	20.0
IV	May 13 – June 6	5.20±0.14	4-6	82.50	16.56±0.14	15-19	54.50	21.76±0.21	20-25	45.60	21.0
V	June 8– June 29	5.44±0.13	5-7	80.18	16.39±0.16	15-17	57.30	21.83±0.21	20-24	45.70	20.0
VI	July 1– July 21	3.90±0.13	3-5	86.50	17.33±0.13	16-19	67.70	21.23±0.18	19-24	58.50	19.0
VII	July 23– August 12	4.00±0.15	3-6	85.00	17.00±0.24	16-18	76.40	20.06±0.23	19-24	65.00	19.0
VIII	August 14 – September 2	3.60±0.09	4-5	90.83	15.78±0.24	14-18	66.10	19.38±0.21	18-23	60.00	18.0
IX	September 4– September 24	3.88±0.12	4-6	89.33	15.88±0.15	15-18	67.00	20.75±0.19	19-24	59.85	19.0
X	September 26– October 20	4.67±0.09	4-5	85.00	18.25±0.13	17-19	73.60	22.88±0.18	21-24	62.56	21.0
XI	October 22– November 17	4.90±0.13	4-6	95.00	19.75±0.20	18-21	68.30	24.75±0.22	23-27	65.00	23.0
XII	November 19– January 21, 2020	17.90±0.29	17-20	85.00	47.22±0.40	43-51	52.78	65.30±0.48	60-71	45.00	63.0
XIII	January 23– March 11	23.70±0.35	20-27	84.00	27.12±0.34	24-31	55.68	50.82±0.37	46-58	47.50	47.0
	CD (p=0.05)	1.85	-	7.04	1.74	-	6.75	1.53	-	6.39	

*assuming two days pre oviposition period; #minimum generation time

(74.20 %) and September 26-October 20 (73.60 %). The minimum nymphal survival corresponded to November 19-January 21, which was on par with the survival during April 20-May 11 (53.20 %), May 13-June 6 (54.50 %), June 8-June 29 (57.30 %) and January 23-March 11(55.68 %) generations.

Total development period: Total development period i.e. egg to adult emergence of *B. tabaci* varied between 18 and 71 days during different generations on brinjal. It was longer during winter months, being maximum (65.30±0.48 days) during November 19 - January 21, followed by January 23-March 11 (50.82±0.37 days). The shortest development period was recorded in generation completed during August 14-September 2 (19.38±0.21 days) which was statistically on par with July 23-August 12 (20.06±0.23 days), September 4-September 24 (20.75±0.19 days), and April 20-May 11 (20.18±0.19 days) generation. *B. tabaci* experienced varied level of mortality during different generations and total generation survival ranged between 45.00 and 69.20 per cent. The highest survival during February 16-March 20, was statistically on par with survival of the generation completed during July 23-August 12 and October 22 -November 11 (65.0 % each). The minimum survival of 45.0 per cent was recorded in generation occurred during November 19-January 21, which was on par with generation during January 23-March 11 (47.50 %) and three generations during mid April to June (45.60-47.50 %) (Table 1).

Effect of different abiotic factors on development of *B. tabaci* on brinjal: The data pertaining to correlations between major abiotic factors and developmental stages of *B. tabaci* are presented in Table 2. Significant negative correlations were registered (r = -0.83 to -0.89) between egg development period of *B. tabaci* and temperatures, whereas the correlation between egg survival and temperatures were non-significant. The relative humidity (RH) showed positive effects on egg survival (hatchability), but correlations were not significant. The data revealed that temperatures exhibited significant negative correlation with nymphal duration (r = 0.71 to 0.82) as well as total development period (r = 0.83 to 0.87) of *B. tabaci* during different generations. The relative humidity (RH) exhibited non-significant relationship with both nymphal period and total development period. However, relative humidity during evening exhibited positive influence on nymphal survival (r = 0.48) and total generation survival (r = 0.51). The multiple regression equations between development period of eggs, nymphs of *B. tabaci* as dependent variable (Y) and different meteorological parameters as independent variables are also presented in Table 2. The regression analysis revealed that different weather parameters together accounted for 0.84–0.87 (R^2) fluctuations in the development period of *B. tabaci* on brinjal. Similarly,

Table 2. Multiple regression analysis of different developmental stages of *B. tabaci* and meteorological parameters

	Correlation coefficient						Regression equation	R^2
	T max	T min	T avg	RH morning	RH evening	RH average		
Eggs development period	-0.83*	-0.88*	-0.89*	0.49	0.01	0.25	Y = 82.54- 1.58 Tmax + 0.15Tmin -0.19 RHmax -0.21 RHavg	0.87
Eggs survival	-0.23	-0.17	-0.21	0.44	0.12	0.30	Y = 56.75- 0.14 Tmax + 0.26 Tmin + 0.52 RHmax -0.31 RHavg	0.37
Nymphal development period	-0.82*	-0.71*	-0.79*	0.39	0.35	0.39	Y = 171.03- 5.22 Tmax + 3.41 Tmin + 0.23 RHmax -1.16 RHavg	0.85
Nymphal survival	-0.02	-0.19	0.08	0.54	0.48*	0.50	Y = -71.82+ 3.69 Tmax – 2.51 Tmin + 0.03 RHmax +1.07 RHavg	0.63
Total development period	-0.86*	-0.83*	-0.87*	0.45	0.22	0.35	Y = 199.72-4.38 Tmax +1.47 Tmin - 0.60 RHmax -0.26 RHavg.	0.84
Generation survival	-0.13	0.09	-0.12	0.55	0.51*	0.56	Y = -55.35+2.15Tmax – 1.05 TMin+0.56 RHmax+0.33 RHavg	0.54

Tavg: average temperature (°C); Tmax: maximum temperature (°C); Tmin: minimum temperature (°C); RHavg: average relative humidity (%); RHmin: evening relative humidity (%); RHmax: morning relative humidity (%);

the different weather parameters contributed 0.37–0.63 (R^2) variations in survival of different generations of *B. tabaci* on brinjal (Table 2).

Hence it can be concluded that *B. tabaci* completed 13 overlapped generations on brinjal in a year under Punjab conditions. The development of immature stages of *B. tabaci* was slower during winter month and total development period may prolonged up to 71 days as compared to 18 to 24 days during summer and rainy season. The overall generation survival was less than 50 per cent during summer and winter months. So, development of whitefly assorted with temperature variations during different months under Ludhiana conditions. The results were in agreement with earlier reports on variations in development time of immature stages of *B. tabaci* under different temperature regimes. The negative correlation between temperature and development period of *B. tabaci* were in accordance to Nava-Camberos *et al.* (2001) who observed that total development time of *B. tabaci* (egg to adult) at temperature range of 20-32°C varied between 16.3-37.9 days on cotton and generation survival ranged between 37.3-64.4 per cent at different temperatures. Bonato *et al.* (2007) reported that development time of *B. tabaci* was 20 days at 30°C and it prolonged to 56 days at 17°C on tomato. Similarly, Aregbesola *et al.* (2020) also reported that development time of whitefly, *B. tabaci* on cassava decreased from 59.3 days at 16°C temperature to 16.3 days at moderate temperature of 28°C. *tabaci* on cassava decreased from 59.3 days at 16°C temperature to 16.3 days at moderate temperature of 28°C.

The positive relationship between relative humidity and survival of immature stages of *B. tabaci* also got support from previous reports. Anjali *et al.* (2012) reported that infestation of *B. tabaci* exhibited significant positive correlation with relative humidity. Mathur *et al.* (2012) also observed that *B. tabaci* population on brinjal showed positive correlation with mean relative humidity, while significant negative correlation was recorded with temperature. Shera *et al.* (2013) also reported that correlation of *B. tabaci* was significantly positive with evening relative humidity. Kataria *et al.* (2017) reported that hot and humid climate favour the whitefly development and pest population showed positive correlation with relative humidity. Later, Khanday *et al.* (2019) found that *B. tabaci* population was favored by minimum temperature and morning relative humidity. The positive correlation between relative humidity and *B. tabaci* population on brinjal was also reported by Lal *et al.* (2019). The present studies also revealed that abiotic factors accounted for 37-63 percent (R^2) variations in survival of immature stages of *B. tabaci* on brinjal. These results are in close conformity with the findings of Kedar *et al.* (2016), who reported that weather parameters contributed 39 to 59 percent (R^2) variability in nymphal population of *B. tabaci* on *Bt* cotton at Hisar, Haryana. Sitaramaraju *et al.* (2010) observed that abiotic factors wer responsible for 66.1 per cent variability in *B. tabaci* population on *Bt* cotton in Andhra Pradesh. Similarly, Shera *et al.* (2013) observed that all the weather parameters exhibited 50-69 per cent variability in *B. tabaci* population on *Bt* cotton at Ludhiana.

The shorter development period and higher survival was recorded in generations completed during July -September months, where mean temperature of 29.9-30.4°C was recorded. Our results were in close conformity with earlier reports on optimum temperature conditions for *B. tabaci* on different host plants. A favourable range of 29-32°C for development of *B. tabaci* on tomato has been reported (Wang and Tsai, 1996; Qui *et al.,* 2003; Delatte *et al.,* 2009; Guo *et al.,* 2013; Tsueda and Tsuchida, 2011). Similarly, an optimum temperature of 30°C had been reported for *B. tabaci* on cotton (Butler *et al.,* 1983; Nava-Camberos *et al.,* 2001) and on cucurbits (Nava-Camberos *et al.,* 2001; Bayhan *et al.,* 2006; Tsueda and Tsuchida, 2011). Our study is the first report on annual life cycle of *B. tabaci* on brinjal under north Indian conditions. The study also explained the role of different abiotic factors on development and survival of *B. tabaci* on brinjal. This information can be used for monitoring as well as forecasting of this pest and devising effective IPM strategy for *B. tabaci* under north Indian conditions. However, the long term investigations over a wider area are needed for more precise information on this pest.

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