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Biology of whitefly, *Bemisia tabaci* (Gennadius) on tomato

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Abstract
The whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) are small and soft bodied polyphagous pest distributed widely in tropical and subtropical regions of India. Both the nymphs and adults of *B. tabaci* cause direct as well as indirect damages to tomato. The present investigation was conducted to study the whitefly biology on tomato plants under laboratory condition at Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh during 2019-20. The average incubation period, hatching per cent (%), first, second, third & fourth instar (pupal) and total nymphal period of *B. tabaci* were 7.04 ± 0.52, 65.11 ± 7.31, 3.99 ± 0.20, 2.78 ± 0.23, 2.81 ± 0.26 & 3.64 ± 0.41 and 13.22 ± 1.10 days, respectively. The pre-oviposition, oviposition and post-oviposition periods were 1.41 ± 0.20, 2.17 ± 0.27 and 1.11 ± 0.16 days, respectively. The longevity & entire life span of male and female was 3.41 ± 0.37 & 25.16 ± 1.26 and 5.74 ± 0.49 & 27.48 ± 1.30 days, respectively.

Keywords: *Bemisia tabaci* (Gennadius), Biology, tomato, whitefly

1. Introduction
Tomato (*Solanum lycopersicum* Mill.) belongs to family Solonaceae, is one of the most highly praised vegetable crops, widely consumed and grown worldwide under both natural as well as protected conditions. The area under cultivation of tomato is increasing day by day as it is a relatively short duration crop which gives higher yield and so also it is economically attractive. It is an important source of vitamins and an important cash crop for small landholders and medium-scale commercial farmers [9].

Tomato ranks third in priority after potato and onion in India but ranks second after potato in the world. Tomatoes contribute to a healthy, well-balanced diet. They are rich in minerals, vitamins, essential amino acids, sugars and dietary fibres. Tomato contains much vitamin B and C, iron and phosphorus. Tomato fruits are consumed fresh in salads or cooked in sauces, soup and meat or fish dishes. They can be processed into purees, juices and ketchup. Canned and dried tomatoes are economically important processed products. Tomato whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) was described over 100 years ago as a pest of tobacco in Greece. Whiteflies are small, soft bodied homopteran insect belonging to family Aleyrodidae. It rose to international prominence in mid to late 1970's and since then it has risen to the status as one of the most damaging and globally known pests of open field and protected crops. They are the serious economic pests of the crops with worldwide distribution and have extended their damage from tropics and sub-tropics to temperate climates grown under open and protected environment. Both the nymphs and adults of *B. tabaci* cause direct as well as indirect damages to its host plants including tomato and cotton. In direct damages, it pierces and sucks cell contents and excretes huge amounts of honeydew that induces and increase sooty mould fungal development and reduces the photosynthetic efficiency of the plant and thus yields and therefore reducing its value as well as fruit quality. This results in withering, premature dehiscence and defoliation and finally death of the plant. They are reported as vectors of many viral plant pathogens like as tomato yellow leaf curl virus. Therefore, there was need to study life parameters of whitefly infesting tomato in order to gain understanding and valuable insight regarding the development and fecundity so that a management programme might be formulated for this pest on tomato.

2. Materials and Methods
2.1 Biology of whitefly, *Bemisia tabaci* (Gennadius) on tomato
Present investigation on biology of whitefly, *B. tabaci* (Hemiptera: Aleyrodidae) was carried

out in PG laboratory, Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh during 2019-20.

2.1.1 Maintenance of culture
Culture of whitefly was maintained and collected from infested tomato plants, which were maintained as buffer stock of the pest in poly house which was situated at Department of Horticulture, College of Agriculture, JAU, Junagadh with the help of aspirator. The insect free tomato seedlings /plants were raised in earthen pots. They were allowed to grow in laboratory. Such tomato plants were covered with the glass chimney measuring 4.7 cm diameter at the top and 7.2 cm diameter at the bottom with bulging shape in the middle and 21 cm in height. The chimney was gently pressed into the wet soil of pot to hold it firmly.

Twenty adults of both the sexes were collected in aspiratory bottle and introduced into the chimney. The top of the chimney was closed with black muslin cloth and kept in position with the help of rubber band. After 24 hours of exposure, the adults were removed from the plants, eggs on the abaxial surface of leaves were marked by using marker on randomly selected five leaves by using 20X hand lens and such leaves were tagged for further observations. It was again covered with chimney and kept under laboratory. On hatching, the crawlers move on leaves for few hours in search of suitable feeding site was observed. The nymphs, thus developed on tomato were used for studying the biology of this pest on tomato. In the same manner settled down nymphs were encircled by marking a round circle with the help of marker. The plants having marked nymphs were observed daily in the morning till the emergence of adult. The culture was used to study the biology of the whiteflies.

2.1.2 Egg stage
In order to determine the hatching percentage and incubation period, the marked eggs on abaxial surface of tomato leaves were observed till hatching. Observations on incubation period and number of nymphs hatched out were recorded.

2.1.3 Nymphal period
With a view to determine the number and duration of different nymphal instars, nymphs were marked individually and observed under microscope from hatching of eggs till pupation. The observation on nymphal instars, its duration and total period were recorded.

2.1.4 Adult longevity
The adults emerged was introduced individually in to a glass tube to study the fecundity and longevity. Fresh tomato seedlings /plants were provided in to glass box for food and oviposition. Observations on fecundity, longevity and ovipositional period of adults were recorded. In order to study the pre-oviposition, oviposition, post-oviposition periods and longevity of the adults, the freshly emerged male and female adults paired in chimney containing tomato seedlings /plants. To know the fecundity of 25 numbers of female and longevity 25 numbers of adults, freshly emerged flies were paired and transferred in a cage containing tomato seedling. Measurements of different life stage were taken with the help of Leica microscope. The statistical analysis was carried out by mean ± standard deviation method.

3. Results and Discussion
1. Biology of whitefly, *Bemisia tabaci* (Gennadius) on tomato
2. The present investigation on the biological parameters of whitefly, *B. tabaci* was carried out under laboratory condition at Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh during 2019-20. The results are presented here under.

3.1.1 Egg stage
Studies on egg laying pattern under laboratory condition revealed that the female whitefly, *B. tabaci* deposited eggs singly or in the groups. Most of the eggs were deposited on under surface of leaves, whereas few eggs were laid isolated on upper surface of leaves of tomato. The eggs were oval in shape and found somewhat tapered towards the distal end. The broader end had a short stalk that was inserted by the ovipositing female into the leaf. The eggs were pearly white when first laid and darkened over time. The distal end of the egg became dark brown just before the hatching.

3.1.1.1 Incubation period
The required days to hatch the eggs from the date of lay the eggs were considered as an incubation period of whitefly.

The data (Table 1) revealed that incubation period varied from 5.80 to 7.60 days with an average of 7.04 ± 0.52 days at the temperature range of 23.4 to 27.5 °C and relative humidity 82.4 to 91.2 per cent. More or less similar result on incubation period was recorded by [3] (6.30 + 0.65 days) on tomato. The maximum egg period of 12.22 ± 1.34 minimum of 10.22 ± 0.69 days on different tomato cultivars [8]. Incubation period of 6.93 days with range of 5 to 7 days at 30 + 2 ºC temperature [7]. So, present findings are in close conformity with the above findings.

Table 1: Period of different stages of whitefly, *B. tabaci* on tomato

Sr. No.	Particulars		Period (Days)		
			Min.	Max.	Av. ± S.D.
1.	Egg period		5.80	7.60	7.04 ± 0.52
2.	Nymphal period	I instar	3.40	4.20	3.99 ± 0.20
		II instar	2.30	3.10	2.78 ± 0.23
		III instar	2.40	3.30	2.81 ± 0.26
		IV instar /Pupa	2.90	4.50	3.64 ± 0.41
3.	Total nymphal period		11.00	15.10	13.22 ± 1.10
4.	Adult period	Male	2.70	3.90	3.41 ± 0.37
5.		Female	5.00	7.10	5.74 ± 0.49
	Total life period	Male	21.50	26.90	25.16 ± 1.26
6.		Female	23.80	29.80	27.48 ± 1.30
8.	Pre-oviposition period		1.00	1.90	1.41 ± 0.20
9.	Oviposition period		1.70	2.70	2.17 ± 0.27
10.	Post-oviposition period		0.80	1.30	1.11 ± 0.16

3.1.1.2 Hatching percentage
The hatching percentage of whitefly eggs were varied from 55.00 to 77.33 per cent with an average of 65.11 ± 7.31 per cent (Table 2) at the temperature range of 23.4 to 27.5 °C and relative humidity 82.4 to 91.2 per cent [6] recorded 86.5% egg hatching [7]. recorded 89.31, 90.63, 83.07 and 76.9% egg hatching on brinjal, cotton, okra and tomato, respectively. Variation in hatching percentage of whitefly might be due to different hosts on which the pest was reared.

Table 2: Hatching percentage of whitefly, *B. tabaci* eggs on tomato

No. of eggs observed	Hatching percentage		
	Minimum	Maximum	Av. ± S.D.
50	55.00	77.33	65.11 ± 7.31

3.1.2 Nymphal period

Newly hatched nymphs were marked on the leaves and observed individually up to pupation to study the total nymphal duration of this pest. The data on total nymphal period are presented in Table 1. The moulting was confirmed by presence of exuviae on the leaf.

3.1.2.1 First instar

The first nymphal instar was capable of limited movement and so called as crawler which was oval in shape, whitish-green in colour.. It was observed that the crawlers moves a few centimetres in search of a feeding site. The duration of crawler or first instar was varied from 3.40 to 4.20 days with an average of 3.99 ± 0.20 days (Table 1). They initiated feeding on the lower surface of a leaf and after starting feeding, they moulted to the second nymphal instar.

3.1.2.2 Second instar

The freshly moulted second instars nymphs were slightly larger than first instar and immobile. During this stationary stage they looked like soft scale insects, greenish-yellow in colour, oval in shape and had two bright eye spots on the head. It was found that nymphs suck the plant sap throughout the period. They moulted to the third nymphal instar. The data (Table 1) revealed that the duration of second instar nymph was varied from 2.30 to 3.10 days with an average of 2.78 ± 0.23 days.

3.1.2.3 Third instar

Third instar nymph was larger than second instar with bright red eye spots on the head. During this stationary stage they looked like soft scale insects, greenish-yellow in colour, oval, flattened but slightly pointed towards the tail. It was found that nymphs suck the plant sap throughout the period. The data (Table 1) revealed that the duration of third instar nymph was varied from 2.40 to 3.30 days with an average of 2.81 ± 0.26 days. They moulted to the fourth nymphal instar.

3.1.2.4 Fourth instar or pupal period

Late in the third instar and through the fourth instar nymphs developed red eyes and referred as red-eyed nymphs. The nymphs at this stage were yellowish white in colour. In this instar, they stopped feeding and pupated. The so called pupa was thin, flat, oval or elliptical in shape with transparent yellow colour and later it becomes convex. The body was clearly distinguishable into head, thorax and abdomen. The abdominal segments were well developed. The empty white cases, the yellowish white colour adults emerged out. The data (Table 1) revealed that the duration of fourth instar or pupal period was varied from 2.90 to 4.50 days with an average of 3.64 ± 0.41 days.

3.1.2.5 Total nymphal period

The data (Table 1) revealed that the total nymphal period varied from 11.00 to 15.10 days with an average of 13.22 ± 1.10 days at an average temperature of 28.1 °C and 85.3 per cent relative humidity.

So, at an average temperature of 28.1 °C and 85.3 per cent relative humidity, the average nymphal period of *B. tabaci* was found to be 3.99 ± 0.20, 2.78 ± 0.23, 2.81 ± 0.26 and 3.64 ± 0.41 days at first, second, third and fourth /pupal instars, respectively and the average total nymphal period was 13.22 ± 1.10 days. The results are in close conformity with the results of mentioned researchers. The first, second, third and fourth nymphal period was 6.30 + 0.65, 3.65 + 0.22, 2.75 + 0.25, 2.90 + 0.29 and 3.50 + 0.40 days, respectively with total nymphal period of 12.80 + 1.15 days on tomato [3]. The duration of nymphal first instar 4.0 ± 1.0; second instar 2.7 ± 1.1; third instar 2.5 ± 0.7; fourth instar-pupa 5.8 ± 0.3 [6]. Egg, first, second, third nymphal, pupal period was 5.85 to 6.93, 5.38, 2.68, 2.28 and 5.30 days, respectively with total nymphal period of 11.83 days in tomato [7]. Hence, the present finding on various nymphal instars and total nymphal period is in close agreement with the finding of earlier researchers.

3.1.3 Adult longevity

The emerged adults, through a T-shaped slit in the integument of the last nymphal instar, were observed with white wax or white powder on dorsal side of the body. The wings were found held flat over the body in resting position It was observed that the adults feeds by piercing leaves and sucks the plant sap. It was also noticed that adults were moved from older leaves to younger leaves and spent most of their time on the undersides of the leaves. The abdominal difference was observed in case of male and female whiteflies. The bigger and broader abdomen was observed in female flies than the male. While the abdomen was found narrow in male flies which were tapering posterior.

The data in Table 1 revealed that the longevity of male and female adults was varied from 2.70 to 3.90 days with an average of 3.41 ± 0.37 days and 5.00 to 7.10 days with an average of 5.74 ± 0.49 days, respectively at an average temperature of 26.4 °C and 80.1 per cent relative humidity. The longevity of adult male and female was 3.30 + 0.41 and 5.65 + 0.63 days, respectively [3]. So that the present findings are in close agreement with the earlier findings.

3.1.3.1 Ovipositional studies

Most females begin oviposition after mating and that period was considered as oviposition period. The data in Table 1 revealed that the pre-oviposition, oviposition and post-oviposition period varied from 1.00 to 1.90, 1.70 to 2.70 and 0.80 to 1.30 days with an average of 1.41 ± 0.20, 2.17 ± 0.27 and 1.11 ± 0.16 days, respectively at an average temperature of 26.4 °C and 80.1 per cent relative humidity.

Pre-oviposition period of 1.4 ± 0.7 and oviposition 16.7 ± 3.2 days [6]. The pre-oviposition and oviposition period on three tomato cultivars ranged from 1.33 ± 0.33 to 2.88 ± 0.50 days [8]. Pre-oviposition and oviposition period of 1.45 + 0.27 and 2.25 + 0.35 days, respectively on tomato [3]. The pre-oviposition, oviposition and post-oviposition period were 1.70, 5.70 and 1.10 days, respectively on brinjal [7]. So, the present finding is more or less in conformity with the reports of earlier worker.

3.1.3.2 Fecundity

The newly emerged male and female were released in a rearing cage having tomato plants. The female whitefly deposited eggs singly or in the groups. Most of the eggs were deposited on under surface of leaves of tomato and marked eggs were counted. Thus, the fecundity was derived from the number of the eggs laid by female whitefly. The results are summarized in Table 3.

The data in Table 3 revealed that a single female laid on an average 82.68 ± 15.60 eggs with a range of 59 to 117 under laboratory condition at the temperature range of 24.2 to 28.5 °C and 83.0 to 89.3 per cent relative humidity. The fecundity of 194.9 ± 59.1 eggs per female on tomato [6]. The number of

eggs laid by females of *B. tabaci* ranges from about 50 to 400 with an average of about 160 [4]. The female of *B. tabaci* oviposited 51.8, 60.1 and 67.5 eggs on aubergine, tomato and potato, respectively [1]. Higher fecundity of females was on cotton (92.0 eggs/female) than on tomato (78.3 eggs/female) [5]. The fecundity varied from 68.10 to 120.90 eggs per female on tomato [3]. The present findings are more or less in close agreement with the earlier findings. Variation in fecundity of whitefly might be due to different hosts as well different abiotic factors on which the pest was reared.

Table 3: Fecundity of whitefly, B. tabaci on tomato

No. of female observed	Average no. of eggs / female		
	Minimum	Maximum	Av. ± S.D.
25	59.00	117.00	82.68 ± 15.60

3.1.4 Total life span

The duration of entire life span of whitefly, *B. tabaci* from egg to death of adult was recorded and summarized in Table 1. The data (Table 1) revealed that the entire life span of male and female whitefly was observed on an average of 25.16 ± 1.26 and 27.48 ± 1.30 days with a range of 21.50 to 26.90 days and 23.80 to 29.80 days, respectively at an average temperature of 26.8 °C and 80.4 per cent relative humidity.

The total life period of whitefly was 31.56 and 30.16 days for male and female, respectively [7]. The total life period of whitefly was 27.77 + 2.95 days on tomato plants [3]. The whitefly completed its life cycle in 35 days at 18ºC and 18 days at 30 ºC [2]. Hence, the present investigation is more or less similar with findings of earlier researchers.

4. Conclusion

The average incubation period, hatching per cent (%) and total nymphal period of *B. tabaci* were 7.04 ± 0.52, 65.11 ± 7.31% and 13.22 ± 1.10 days, respectively. The longevity & entire life span of male and female was 3.41 ± 0.37 & 25.16 ± 1.26 and 5.74 ± 0.49 & 27.48 ± 1.30 days, respectively.

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