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Morphometrics and annual life cycle of greenhouse whitefly [*Trialeurodes vaporariorum* (Westwood)] in Himachal Pradesh

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Abstract

Morphometrics and life cycle of *Trialeurodes vaporariorum* (Westwood) was studied under laboratory conditions in mid-hill regions of Himachal Pradesh. Eggs measured 0.201 mm in length and 0.096 mm in breadth. There were three nymphal instars with the corresponding average length & breadth of 0.267 & 0.145, 0.370 & 0.217 and 0.658 & 0.377 mm. The second and third nymphal instars possessed setae like projections. The pupa measured 0.728 mm in length and 0.415 mm in breadth. It was flattened and oval like a scale initially and became opaque and expanded with sub-marginal and dorsal setae later. The females were larger (0.963 mm) than the males (0.844 mm). Under laboratory conditions, the pest completed 13 overlapping generations in a year. Total developmental period was of shorter duration (20.7-27.7 days) in summer and rainy-season generations than in winter generations (33.3-43.3 days). The survival in different generations varied from 36.7-74.2 per cent, being comparatively more in winter generations. The females laid 108-373 eggs in different generations, the fecundity being comparatively more during winter generations.

Key words: *Trialeurodes vaporariorum,* greenhouse whitefly, life cycle, developmental biology, morphometrics

Introduction

The greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), is a serious pest in temperate regions under protected cultivation situations and in field crops where the summers are warm enough (Hill, 1987). It is a polyphagous pest and feeds on a large variety of herbaceous plants. The nymphs and adults suck large quantities of phloem sap from the under surface of leaves and also secrete a sticky viscous honeydew, on which sooty mould grows under humid conditions (Byrne and Bellows, 1991). In India, the pest was first recorded from Nilgiri hills of Tamil Nadu on potato (David, 1971) and subsequently it has been reported to infest 102 host plants belonging to 36 plant families (Sood and David, 2012). The pest remained a low density pest in the North-Western Himalayan region and assumed significance only in late nineties when it posed a threat to the cultivation of some vegetable crops and ornamental plants under protected and field conditions (Sood and Sood, 2002). Presently it is categorized as the key pest of tomato, cucumber, french bean, gerbera under protected environment as well as open field situations (Sharma *et al.,* 2006; Sood *et al.,* 2006; Sood *et al.,* 2010).

Though the developmental biology of this pest was studied abroad (Hill, 1987; Byrne and Bellows, 1991; Ghahari and Hatami, 2000), however from India, no published information on this aspect is available except that of Dhillon (1999) who studied some aspects of the biology of the greenhouse whitefly at constant temperature regimes. Present studies were therefore planned to study the annual life cycle of this pest for better understanding of impact of environmental variables on growth and development of this pest.

Materials and Methods

The studies on morphometrics and annual life cycle of the greenhouse whitefly were undertaken at Palampur (1290 m asl) representing the mid-hill zone of North-Western Indian Himalaya. Observations on colour, shape and size of different developmental stages of the greenhouse whitefly were recorded under a stereo-binocular microscope. The length and breadth of the egg, nymph, pupa and adult was measured using an ocular micrometer.

Annual life-cycle of the greenhouse whitefly was studied under laboratory conditions on French bean (cv. Contender) plants raised in plastic pots (9.5×9.5 cm) throughout the year starting from March. The French bean plants (10 days old) (n=3) were exposed for 24 hours to the adults covered with glass chimneys (20×15 cm) at a regular interval. Thereafter, the adults were removed and the plants were shifted to nylon mesh rearing cages (45×45×45 cm) for recording observations on incubation period, hatchability, duration and survival of nymphal and pupal stage, adult longevity and fecundity. A pre-oviposition period of one day was observed for continuing the next generation. A cohort of about one hundred eggs was marked on each plant to record observations on duration of different developmental stages. Mean incubation period was established as the period between oviposition and 50 per cent egg hatching, whereas the mean duration of nymphal instars and pupal stage was established when 50 per cent of the surviving individuals transformed to the next stage. Total number of adults emerged were recorded to establish the total survival. 10 pairs of adults were enclosed in glass chimneys (n=3) on French bean plants and observations were recorded on longevity and fecundity of the adults.

Growth indices for different generations were worked out with the help of following formulae elaborated by Sharma *et al.* (1982) to establish the effect of environmental factors (temperature and relative humidity) on the development of greenhouse whitefly:

$$\text{Nymphal Growth Index (NGI)} = \frac{\text{Nymphal survival (\%)}}{\text{Total nymphal period (days)}}$$

$$\text{Total Growth Index (TGI)} = \frac{\text{Adult emergence (\%)}}{\text{Total developmental period (days)}}$$

Results and Discussion

Description of developmental stages

Egg: The females deposited eggs singly or in clusters of 5-6 eggs on the lower surface of the leaves. The freshly laid eggs were creamish-yellow in colour and turned dark prior to hatching. The eggs were stalked and rounded at the base with apical tapering. The length of eggs ranged between 0.180 to 0.230 mm (average: 0.201 mm) and breadth from 0.07 to 0.105 mm (average: 0.096 mm) (Table 1). The measurements recorded are in proximity to those observed by Dhillon (1999) who reported the length and breadth to be 0.238 mm and 0.094 mm, respectively.

Nymph: The greenhouse whitefly had three nymphal instars which were oval and light greenish yellow in colour. They possessed functional legs on hatching but remained sessile thereafter except during moulting. The last two nymphal instars possessed setae like projections of wax. The features of all the three instars were quite similar except a variation in size. The average length and breadth of the first, second and third instars was 0.267 & 0.145 mm, 0.370 & 0.217 mm and 0.658 & 0.377 mm, respectively (Table 1). The findings of Dhillon (1999) are supportive to the present observations with slight variations.

Pupa: The pupae were flattened and translucent initially and became expanded and opaque with the white lateral and dorsal setae in the later stages. In the

Table 1. Measurements of different stages of *T. vaporariorum*

Stage		Length (mm)		Breadth (mm)	
		Mean±S.E.*	Range	Mean±S.E.	Range
Egg		0.201± 0.014	0.180-0.230	0.096±0.015	0.070-0.105
Nymph					
	I	0.267±0.019	0.228-0.315	0.145±0.015	0.105-0.175
	II	0.370±0.025	0.325-0.420	0.217±0.020	0.175-0.245
	III	0.658±0.023	0.595-0.700	0.377±0.021	0.350-0.415
Pupa		0.728±0.020	0.700-0.770	0.415±0.019	0.385-0.455
Adult				**Wing Expanse**	
	Male	0.844±0.043	0.770-0.938	2.174±0.282	1.824-2.074
	Female	0.963±0.042	0.843-1.083	2.613±0.067	2.450-2.743

* S.E. : Standard error

last stage, red eyes and yellow body pigment was prominently visible below the transparent pupal case. They measured 0.700 to 0.770 mm in length (mean: 0.728 mm) and 0.385 to 0.455 mm in breadth (mean: 0.415 mm) (Table 1). Byrne and Bellows (1991) also recorded similar observations.

Adult: The adults were snowy white with yellow body and a covering of white waxy powder on wings. The females were larger than the males with body length of 0.96 mm and wing expanse of 2.61 mm, whereas in males, it was 0.84 and 2.17 mm, respectively (Table 1). These observations are in close proximity with the observations of Dhillon (1999) who reported the body length of females and males to be 0.88 and 0.82 mm, with the wing expanse of 2.18 and 1.98 mm, respectively, however, it varied slightly with the observations of Byrne and Bellows (1991) who observed the body length of females and males to be 1.06 and 0.09 mm with the wing expanse of 2.65 and 2.41 mm, respectively.

Annual life-cycle of greenhouse whitefly

Under laboratory conditions, the greenhouse whitefly when reared on french bean completed 13 overlapping generations in a year (Table 2), however, Isart (1977) recorded 7-8 generations in open and 8-10 generations in greenhouse on different horticultural crops in Spain. Observations on different aspects of the developmental biology and survival of *T. vaporariorum* throughout the year under laboratory conditions are being presented in Tables 2 and 3.

Egg: The mean duration of incubation period was influenced by the prevailing temperature during different generations and varied between 4.7 to 6.7 and 7.3 to 12.7 days during April-May to September-October and October-November to March-April generation signifying the impact of low temperature in prolonging the incubation period in generations occurring in winter months as compared to summer generations (Table 4). The incubation period was shortest (4.7 days) in June - July generation (V), which in turn was on par to the generations occurring during

Table 2. Developmental biology of *T. vaporariorum* during different generations

Generation	Period of study	Egg (days)	Mean duration of different stages (days)						Adult longevity (days)		Fecundity (number of eggs/ female)*
			I instar	II instar	III instar	Total nymphal period	Pupa	Total developmental period	Male	Female	
I	March 8- April 9	8.3	11.3	6.0	6.3	22.0	4.0	35.3	6.7	8.4	196.5
II	April 11-May 6	6.0	6.0	5.0	6.7	16.3	4.7	27.3	6.4	8.1	181.5
III	May 8- 30	5.3	6.3	4.7	5.3	15.7	3.7	23.7	6.5	7.6	172.5
IV	June 1- 27	5.3	6.0	4.0	5.3	14.3	4.3	24.7	6.1	7.4	128.0
V	June 29-July 17	4.7	4.0	4.3	4.7	13.0	5.0	23.3	5.5	7.1	120.0
VI	July 19-August 11	5.0	5.0	5.0	5.7	15.3	6.0	25.7	6.9	7.3	108.0
VII	August 13-September 4	6.0	6.0	3.7	4.0	13.3	3.7	23.3	6.1	8.8	139.4
VIII	September 6- 24	6.7	3.7	3.3	4.0	11.0	3.0	20.7	13.7	19.7	235.2
IX	September 26-October 18	6.3	5.0	4.0	5.7	14.3	5.7	26.0	15.4	22.3	288.5
X	October 20-November 19	7.3	6.0	6.7	7.0	17.7	7.7	33.3	20.3	35.2	373.0
XI	November 21-December	10.3	9.0	7.7	7.3	23.0	6.7	40.3	26.7	42.6	342.3
XII	January 1-February 13	12.7	8.3	7.7	8.0	23.3	7.3	43.3	17.6	22.6	241.5
XIII	February 15-March 24	11.3	8.3	6.3	5.3	18.7	5.3	35.3	8.0	10.1	189.0
Mean		7.3	6.5	5.3	5.8	16.8	5.2	29.4	11.2	15.9	208.9
CD (P=0.05)		1.25	1.10	0.76	0.75	1.14	0.93	1.84	5.80	4.97	49.32

* Based upon10 pairs replicated thrice

May (III), June (IV), and July - August (VI) generations (Table 2). Hill (1987) also reported a longer incubation period of 9 days at lower temperature of 21°C whereas Ghahari and Hatami (2000) recorded the incubation period to last for 7.3 days at 24°C.

Wide variations in hatchability of eggs was evident during different generations, which ranged between 52.8 to 92.0 per cent (Table 3). Hatchability was comparatively more in the generations occurring during low temperature regimes. Highest hatchability was recorded for March-April generation, which was at par to the generations occurring during September (VIII), November - December (XI) and January - February (XII). It was minimum (52.85%) during July-August (VI) being on par to October-November (X) generation. This can be due to better osmotic potential of leaves during winters owing to lower evaporation rate which checks desiccation and mortality of eggs leading to higher hatchability as observed by Castane and Save (1993) who reported leaf osmotic potential to affect the survival of the eggs of *T. vaporariorum*. Treifi (1986) also reported the mortality to be high at 22-27°C thus supporting the present observations.

Nymph: Duration of the first, second and third instar nymphhs was found to vary between 3.7-11.3, 3.3-7.7 and 4.0-8.0 days, respectively, in different generations. The total nymphal period ranged between 11.0 - 23.3 days in different generations being more in generations occurring during winter months (Table 2). Present studies found support from the findings of Dhillon (1999) who reported the total nymphal period of 30.2 days at 15°C which reduced to 9.8 days with an increase in temperature to 30°C.

Among the three nymphal instars, the first instar experienced the highest mortality as depicted from the minimum mean survival of 86.3 per cent as compared to 92.3 and 98.3 per cent recorded in second and third instar, respectively (Table 3). This can be attributed to the fact that no waxy covering is

Table 3. Survival of different developmental stages of *T. vaporariorum* during different generations

Gener-ation	Period of study	Survival (%)						
		Egg	Nymph				Pupa	Total survival to adult emergence
			Ist instar	2nd instar	3rd instar	Nymphal survival (Total)		
I	March 8-April 9	92.0 (72.70)	92.2 (73.69)	95.4 (80.09)	100.0 (89.96)	80.3 (63.70)	91.9 (75.69)	74.2 (59.62)
II	April 11-May 6	73.6 (59.08)	93.2 (75.66)	93.6 (75.93)	100.0 (89.96)	87.4 (69.34)	100.0 (89.96)	63.9 (53.03)
III	May 8- 30	68.8 (56.06)	83.8 (66.45)	86.7 (68.83)	100.0 (89.96)	52.4 (46.28)	73.9 (59.37)	36.7 (37.24)
IV	June 1- 27	69.5 (56.50)	85.7 (67.95)	89.8 (71.76)	95.4 (82.70)	64.9 (53.64)	89.4 (78.37)	45.0 (42.11)
V	June 29-July 17	70.1 (56.86)	79.6 (63.32)	84.2 (66.62)	94.9 (82.27)	56.3 (48.62)	86.3 (68.91)	40.4 (39.39)
VI	July 19-August 11	52.8 (46.59)	87.6 (69.37)	90.0 (71.74)	96.3 (83.48)	72.6 (58.44)	94.2 (78.92)	38.6 (38.37)
VII	August 13-September 4	82.4 (65.33)	78.0 (62.18)	83.7 (66.24)	97.2 (84.37)	48.4 (44.06)	76.1 (60.74)	40.2 (39.32)
VIII	September 6- 24	86.4 (68.41)	87.2 (69.04)	96.4 (81.01)	99.2 (87.06)	83.3 (65.93)	100.0 (89.96)	71.7 (57.88)
IX	September 26-October 18	64.7 (53.56)	80.8 (64.00)	94.8 (76.90)	100.0 (89.96)	74.6 (59.73)	97.7 (84.85)	49.9 (44.94)
X	October 20-November 19	55.6 (48.23)	84.4 (67.06)	95.0 (79.77)	97.1 (82.27)	78.2 (62.24)	100.0 (89.96)	42.4 (40.63)
XI	November 21-December 30	89.4 (71.03)	86.2 (68.38)	95.9 (78.44)	100.0 (89.96)	82.6 (65.32)	100.0 (89.96)	74.1 (59.56)
XII	January 1-February 13	89.3 (71.76)	87.4 (69.61)	96.7 (83.82)	100.0 (89.96)	81.0 (64.21)	93.9 (79.51)	71.4 (59.55)
XIII	February 15-March 24	81.7 (64.80)	95.5 (78.12)	98.0 (83.61)	97.5 (82.58)	90.5 (73.32)	99.4 (87.47)	73.8 (59.35)
Mean		75.1 (60.84)	86.3 (68.83)	92.3 (75.75)	98.3 (86.50)	73.3 (59.60)	92.5 (79.51)	55.6 (48.54)
CD (P=0.05)		(5.99)	(7.46)	(9.61)	(N.S.)	(4.64)	(11.32)	(5.66)

Figures in parenthesis are the arc sine transformed values.

laid in the first nymphal instar and moreover, the neonates have to crawl over the leaf surface for the selection of suitable site for feeding, thus are therefore prone to more mortality. The nymphal survival was maximum (90.5%) during February-March being statistically on par to April-May generation with the minimum (48.4%) occurring during August - September (Table 3). Dhillon (1999) also found higher survival (74.6%) at lower temperature of 25±1°C.

Pupa: The mean duration of pupal period varied between 3.0 to 7.7 days amongst different generations, being maximum during October-November (X) which in turn was on par to the generation occurring during January-February (XII) (Table 2). The minimum duration of the pupal period was recorded during September (VIII) being statistically on par to the generations in May (III) and August-September (VII). Kim *et al.* (1986) and Ghahari and Hatami (2000) reported the pupal period to last for 7.5 days at 25°C on cucumber and 7.7 days at 24±1°C on brinjal, respectively.

Amongst different developmental stages of *T. vaporariorum*, the pupal stage experienced the least mortality and resulted in survival varying between 73.9-100.0 per cent in different generations (Table 3). No mortality in the pupal stage was recorded in April-May (II), September (VIII), October - November (X) and November - December (XI) generations which being on par to July - August (VI), January - February (XII) and February-March (XIII) generations. The minimum survival corresponded to the third (May) generation and was on par to June – July (V) and August – September (VII) generation. Treifi (1986) also reported higher survival rate of 88.0-90.4 per cent in the pupal stage at 22-27°C and 79-87 per cent relative humidity. Dhillon (1999) reported a comparatively higher survival of pupa which varied between 40-74.6 per cent at constant temperature regimes of 15, 20, 25 and 30°C on tomato. The variations can be attributed to variable temperature and relative humidity conditions during the course of studies.

Total developmental period: The total developmental period from egg deposition to adult emergence indicated a pronounced effect of temperature on the rate of development in different generations. It varied between 20.7-27.7 days in summer and rainy season generations from April to October (generation: II-IX) and 33.3-43.3 days in winter and spring generations (October-April) (Table 2). Amongst the summer and rainy season generations, the duration was minimum in September (VIII) generation and varied significantly to others. This can be attributed to comparatively low temperature during September generation (mean temperature being 26.8°C) (Table 4). Whereas the developmental period was of maximum duration in April-May (II) which in turn was on par to September-October (IX) generation. This also gets

Table 4. Growth indices of *T. vaporariorum* during different generations

Generation	Period	Nymphal growth index	Total growth index	Mean Temperature (°C)			Mean RH (%)
				Minimum	Maximum	Mean	
I	March 8-April 9	3.65	2.10	13.5	25.4	19.5	52.4
II	April 11-May 6	5.36	2.34	22.0	31.3	26.6	80.4
III	May 8- 30	3.34	1.55	24.0	32.1	28.1	63.4
IV	June 1- 27	4.54	1.82	24.2	29.5	26.9	65.1
V	June 29-July 17	4.33	1.73	28.5	28.8	28.7	77.8
VI	July 19-August 11	4.75	1.50	26.4	28.0	27.2	71.7
VII	August 13-September 4	3.64	1.73	26.2	28.2	27.2	72.3
VIII	September 6- 24	7.57	3.46	25.8	27.8	26.8	53.8
IX	September 26-October 18	5.22	1.92	27.4	29.0	28.2	40.9
X	October 20-November 19	4.42	1.27	25.0	27.5	26.2	30.2
XI	November 21-December 30	3.59	1.84	18.3	23.4	20.8	33.6
XII	January 1-February 13	3.48	1.65	15.0	19.9	17.5	38.0
XIII	February 15-March 24	4.84	2.09	17.1	21.4	19.3	39.2

support from the findings of Yano (1981) who observed the development of *T. vaporariorum* from egg to pupa to be of 22 days at 24°C which got prolonged to 32 days at a higher temperature of 30°C.

Generation survival varied between 36.7 to 74.2 per cent, being significantly higher during winter generations of November - December, January - February, February - March and March - April and again in September generation (Table 3). The minimum survival (36.7%) was recorded during May (III) generation being on par to the generations occurring during June to August - September and October- November (generation: V-VII and X).

Adult: The temperature influenced the adult longevity greatly being comparatively more during the winter generations of October – March (Table 3). The females lived longer than the males and lived for 7.1-42.6 days in different generations, whereas the male lived for 5.5-26.7 days. Yano (1989) also observed an increase in life span of adults at lower temperatures. Ghahari and Hatami (2000) also recorded the females to live longer (26.4 days) as compared to males (20.9 days) at 24°C.

Fecundity: The females on an average laid 108-373 eggs during different generations, being comparatively more in winter generations of October to March-April (Table 2). The maximum fecundity corresponded to the October-November (X) generation, being on par to November-December (XI) generation. However, the minimum fecundity corresponded to July - August (VI) generation being on par to the generations occurring during June (IV), June-July (VI), August-September generations (VII). This can be attributed to shorter life span of females during these generations owing to higher temperature.

A perusal of data contained in Table 4 depicting growth indices of *T. vaporariorum* worked out on the basis of survival and developmental period revealed the nymphal growth index (NGI) to vary from 3.34 – 7.57, with the maximum value corresponding to the generation occurring during September (IX) followed by April-May (II) and September – October (IX). The lowest value of NGI was observed for May generation (III), followed by January-February (XII), August-September (VI) and November-December (XI) generations. The maximum value (3.46) of total growth index (TGI) also corresponded to generation occurring in September (VIII) and was followed by April-May (II) (2.34). The TGI value was minimum (1.27) during October-November generation. The relationship worked out amongst the survival (%) and duration of developmental period (days) in different generations revealed a positive correlation amongst both the parameters and resulted in values of 0.4772 and 0.61884 for NGI and TGI, respectively, being significant (P=0.05) for TGI only.

Based upon the observations it is concluded that *T. vaporariorum* can multiply throughout the year in mid-hill regions of Himachal Pradesh under protected situations. The rate of multiplication being higher in spring, early summer and post-rainy season which also corroborates the more incidence of the pest as observed under protected cultivation by different researchers.

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