Indian Journal of Ecology (2025) 52(6) (SI): 1684-1689
DOI: https://doi.org/10.55362/IJE/2025/4712

Manuscript Number: 4712
NAAS Rating: 5.38

Demographic Traits and Population Projection of Solanum Whitefly, *Aleurothrixus trachoides* (Back) on Chilli

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Abstract: Biological traits of solanum whitefly, *Aleurothrixus trachoides* (Back) were determined at 25±3°C, 70±5% relative humidity, and a photoperiod 12:12h (L:D) on Chilli (*Capsicum annuum* L.). The pre-adult development consisted of five stages (egg and four nymphal stages) with the mean duration of 7.52, 6.43, 6.04, 4.65 and 5.03 days, respectively. The mean pre-oviposition period was 2.41 days. Adult longevity averaged 10.84 days in males and 13.63 days in females, with total life span of 40.05 and 43.67 days, respectively. The mean fecundity per female was 104.45 eggs. The intrinsic rate of increase (r) of *A. trachoides* was 0.10 per day. The highest net reproduction rate (R_o) was 53.27 offspring per individual. The mean generation time (T) was 37.91 days. From the life table data, the 60-day projection of population growth revealed the sudden surge in the total population from the 30th day, suggesting that timely control measures are most effective within this specific period to manage this emerging pest.

Keywords: Biology, Life table, Population projection, *Aleurothrixus trachoides*, Solanum whitefly

Whiteflies pose a significant global threat to agriculturists. Over the past 25 years, several exotic whitefly species have invaded numerous countries, resulting in direct losses in agriculture, horticulture and forestry (Sundararaj et al., 2018). Exotic whiteflies are frequently introduced with host plants through international trade, facilitated by their small size, cryptic nature, and tendency to remain attached to hosts during immature stages. These characteristics make them highly transportable and successful invaders in new areas (Simala et al., 2015). In India, 469 whitefly species belonging to 71 genera are reported, including eight invasive species (Sundararaj et al., 2021). Within the last six years alone, nine invasive whitefly species invaded India from Neotropical region *viz.,* solanum whitefly, *Aleurothrixus trachoides* (Back), rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin, nesting whiteflies, *Paraleyrodes bondari* Peracchi and *P. minei* Iaccarino, legume feeding whitefly, *Tetraleurodes acaciae* (Quaintance), palm infesting whitefly, *Aleurotrachelus atratus* Hempel, woolly whitefly, *A. floccosus* (Maskell), Annona Whitefly, *A. anonae* (Corbett) and Invasive Nesting Whitefly, *P. pseudonaranjae* Martin (Sundararaj et al., 2021, Selvaraj and Sushil, 2024, 2025).

The neotropical solanum whitefly, *A. trachoides*, is now invasive in India and is rapidly spreading across South India. It infests economically important solanaceous crops such as brinjal, chilli, and tomato along with several medicinal, ornamental, and weed species (Dubey and Sundararaj, 2015). This species was recorded on 24 host plants across 11 families, with confirmed distribution in Karnataka, Kerala, Maharashtra, and Tamil Nadu (Sundararaj et al., 2018). This species inflicts direct damage to host by feeding and depleting water and nutrients, thereby reducing growth and causing premature leaf drop. They cause indirect damage by excreting sticky honeydew and producing wax, which create a favourable environment for the growth of black sooty mould on infested plants which reduces the photosynthetic efficiency (Kumar et al., 2018). In addition, *A. trachoides* also act as a vector for transmitting plant viruses such as a begomovirus (Chandrashekar et al., 2020, Kamaliah et al., 2024).

The solanum whitefly will soon achieve invasive pest status as it is establishing on economically important vegetable crops and fruit trees. The main objective of the current research was to record the demographic characteristics of the solanum whitefly on chilli. Understanding the biology of this species is essential to identify vulnerable stages in its life cycle which can guide the development of effective and timely pest management strategies.

MATERIAL AND METHODS

Host plants and *A. trachoides* culture: For this experiment, chilli plants (TNAU hybrid Co.1 variety) were used as host plants. The chilli seeds were sown in 25 cm diameter grow bags filled with pot mixture and placed under shade house conditions with 25±3°C, 70±5% RH, and a photoperiod of 12:12 hours (light:dark). Initially, whitefly pupae were collected from chilli field in Sivapuri, Chidambaram and identified as *Aleurothrixus trachoides* based on the morphological key (*Aleurothrixus* Quaintance and Baker 1914), with diagnostic characters of a crenulated margin (6–8 crenulations per 0.1 mm), marginal teeth each with a basal wax gland, rhachis-form abdominal segments, a subcircular vasiform orifice, and a subcordate operculum. Later, sixty unsexed adults of *A. trachoides* were collected from the same field, using an aspirator and these adults were then released onto chilli plants, enclosed in a fine 400 mesh net cage measuring 30 x 30 x 30 cm. Throughout the study period, the plants were regularly watered and fertilized to ensure their proper growth. The homogeneous population of *A. trachoides* was cultured and utilized for subsequent experiments (Fig. 1A&B) (Mercado et al., 2014, Farooq et al., 2021).

Life table: To assess the developmental duration, forty unsexed adult whiteflies were collected from the culture and released into a clip cage (3 cm diameter and 3.5 cm height) attached to the abaxial surface of leaves of potted plant placed under the same shade house conditions (Liu and Stansly 1998). After 24 hours, the abaxial surface of leaves was examined for eggs using a 10X hand lens, and the adult insects were removed. Leaves were detached and inverted in agar Petri dishes for egg hatching. The total cohort of 100 eggs was used, and any remaining eggs on the leaf were gently removed. Once the crawlers emerged, each one was placed individually on a leaf using 000 fine camel brush with the help of a Leica S4E stereo zoom microscope, and a clip cage was placed over the first instar nymph (Fig. 2A). The settled nymphs were later marked with a marker. After the first instar nymphs established themselves on the leaf, they remained immobile until the adults emerged. The moulting and development of each nymph were observed daily using a 10X hand lens (Fig. 2B). At the pupal stage, the leaves were detached and transferred to a plastic container (9 cm width × 13 cm height) covered with a fine mesh net. After the emergence of the adult whiteflies, daily observations were made on both sexes for oviposition and longevity studies until the death of the individuals.

Population projection: The population growth of *A. trachoides* on chilli was estimated using life table data. The projection was carried out based on the method developed by Chi and Liu (1985) and Chi (1990), using TIMING-MSChart (Chi 2017).

Statistical analysis: The data were analyzed using the TWOSEX-MSChart (Chi 2013). The bootstrap technique with 100,000 replications was applied for the estimation of mean and standard errors for each treatment (Efron and Tibshirani 1993). Origin Pro 2022 was used to draw the figures. The following parameters were calculated according to respective equations. The age-specific survival rate (l_x) and age-specific fecundity (m_x) were calculated as:

$$l_x = \sum_{j=1}^{k} s_{xj} \, m_x = \frac{\sum_{j=1}^{k} s_{xj} f_{xj}}{\sum_{j=1}^{k} s_{xj}}$$

Where *k* exhibits the number of stages.

The net reproductive rate (R_0) was computed as:

$$R_0 = \sum_{x=0}^{\infty} l_x m_x$$

The intrinsic rate of increase (*r*) with age indexed from 0 was corrected by the Euler-Lotka equation (Goodman 1982):

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

The following equation was used for the finite rate of increase (λ): $\lambda = e^r$

The mean generation time was demonstrated as

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

The life expectancy (e_{xj}) was determined as:

$$e_{xj} = \sum_{i=x}^{\infty} \sum_{y=j}^{\beta} s_{iy}$$

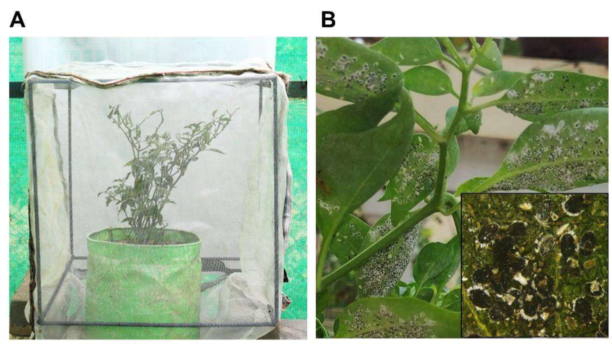

Fig. 1. Host plants and *A. trachoides* culture (A) Chilli plant maintained in mesh cage for adult whitefly collection (B) Symptom showing heavy infestation on abaxial surface of leaves on chilli (*Insert*: microphotograph of crowded nymphal instars)

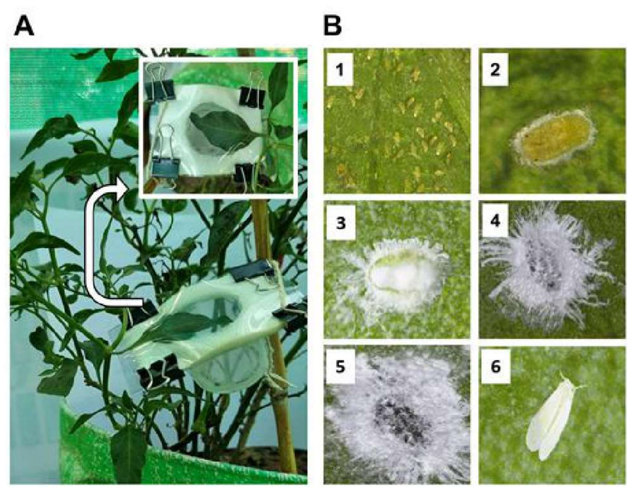

Fig. 2. Developmental stages of *A. trachoides* reared on chilli (A) Clip cage [*insert:* dorsal view of clip cage] and (B) Life stages: (1) Egg; (2) First instar; (3) Second instar; (4) Third instar; (5) Fourth instar / pupae and (6) Adult whitefly

Where S_{iy} shows the probability of survival of each individual of age x and stage j to age i and stage y by assuming $S_{xj} = 1$.

The reproductive rate (v_{xj}) was assessed according to (Tuan et al., 2014a, b).

$$v_{xj} = \frac{e^{r(x+1)}}{s_{xj}} \sum_{i=x}^{\infty} e^{-r(i+1)} \sum_{y=j}^{\beta} s_{iy} f_{iy}$$

RESULTS AND DISCUSSION

The total longevity was 43.67 days for females and 40.05 days for males (Table 1). Eggs required an average of 7.52 days for emergence. The duration of first, second ,third and fourth instar nymphs was 6.43 , 6.00, 4.65, and 5.03 days. The total nymphal duration was 22.16 days. The incubation period of eggs was longer than the duration of each post-embryonic stage, a trend also reported in other aleyrodidae species (Liu and Stansly 1998, Hoddle and Soliman 2001). Kumar et al. (2020) reported similar duration of the development stage for *A. trachoides* eggs and four nymphal stages were 8, 7, 6, 4 and 4 days, respectively.

The adult pre-oviposition period (APOP) was 2.41 days and the total pre-oviposition period (TPOP) was 32.45 days. The female adults oviposit for 10.25 days with a mean fecundity as 104.45 eggs. Comparable pre-oviposition periods were reported for *A. floccosus*, which was 2.45 days by Mercado et al. (2014). In other whitefly species, total was 70 days for *Aleurocanthus woglumi* (Pena et al., 2009), 35–37 days for *Bemisia argentifolii* (Liu and Stansly, 1998) and 41 days for *Tetraleurodes perseae* (Hoddle, 2006).

The age-stage specific survival rate (s_{xj}) of *A. trachoides* shows the variability of developmental rate and survival patterns of different life stages over their entire life cycle (Fig. 3A). The variable developmental rates among individuals result in overlapping stage survival curves (s_{xj}). By ignoring stage differentiation, an age-specific survival rate (l_x) provides the probability of an egg surviving until age x (Fig. 3B). The age-stage specific fecundity (f_x) gives the number of eggs produced by adult females of age x, where the age x is counted from the egg stage. The curve of age-specific fecundity (m_x) (Fig. 3B) shows that reproduction of *A. trachoides* began at the age of 21 days on chilli. Based on the two-sex life table, the age-stage specific life expectancy (e_{xj}) gives the expected life span an individual of age x and stage j can live after age x (Fig. 3C). The life expectancy of a newborn was 39.09 days on chilli (Fig. 3C). The reproductive value (v_{xj}) is the contribution of individuals of age x and stage j to the future population (Fig. 3D). The peak value of age-specific fecundity (m_x) was 8.35 at the age of 39 days, which indicates at that particular age, individuals were exhibiting the highest level of reproductive potential (Fig. 3D). The peak value of age-stage reproductive value (v_{xj}) was 62.7 at the age of 33 days, which implies that individuals at age of 33 days have a greater likelihood of contributing to the reproductive success of the population compared to other ages/stages.

The results obtained for demographic parameters of *A. trachoides* revealed that the female adult from all generations have the ability to produce an average of 88.57 individuals per generation. *A. trachoides* exhibited a net reproductive rate (R_0) of 53.27 offspring per female, which indicates a high reproductive potential and the ability of the population to increase substantially under these conditions. The intrinsic rate of increase (r = 0.10 day^{-1}) indicates a moderate population growth potential, while the finite rate of increase (λ = 1.11 ± 0.01) implies the population multiplies by ~11% daily under these conditions. The time needed to complete one generation *i.e.* mean generation time (T) was 37.91 day. These parameters suggest a moderate but steady population growth of *A. trachoides* on chilli. Mercado et al. (2014) recorded the mean generation time of 38.77 days for *A. floccosus*. The population of *A. trachoides* takes approximately 6.61 days to double in size *i.e.* the doubling time (DT) indicating that under optimal conditions, the population can double within a week (Table 2).

Anticipating the growth of a pest population is crucial for formulating the right timing schedule to develop an efficient

Table 1. Developmental duration, longevity and fecundity of *A. trachoides*

Life stages	n (individual)	Mean ± SE (days)
Egg	100	7.52 ± 0.05
N1	98	6.43 ± 0.05
N2	93	6.04 ± 0.06
N3	89	4.65 ± 0.05
N4 (Pupae)	88	5.03 ± 0.07
Adult longevity (day)		
Male	37	10.84 ± 0.34
Female	51	13.63 ± 0.02
Total longevity (day)		
Male	37	40.05 ± 0.19
Female	51	43.67 ± 0.40
APOP (days)		2.41 ± 0.07
TPOP (days)		32.45 ± 0.20
Fecundity (eggs / female)		104.45 ± 3.77
Oviposition days		10.25 ± 0.32

* Where, N1 = 1st nymphal instar, N2 = 2nd nymphal instar, N3 = 3rd nymphal instar, N4 = 4th nymphal instar (pupae); TPOP = Total pre-ovipositional period; APOP = Adult pre-ovipositional period. Standard errors were measured by 100,000 bootstrap resampling

pest management strategy (Huang et al., 2018, Chen et al., 2025). Mistakes in timing not only result in the failure of pest control measures but also lead to the inevitable wastage of money, labour, and time (Pedigo and Rice 2006, Rogers and Brier 2010, Ali et al., 2025). Therefore, the population projection provides valuable insights into changes in stage structure based on life table data (Reddy and Chi 2015). The population projection also aids in determining changes in the feeding potential of the age-stage structure (Peng et al., 2016, Rajabpour and Yarahmadi 2024). The "log(N+1)" transformation ensures that even small changes in population size are visible on the graph (Fig. 4A & B). The population projection of *A. trachoides*, based on life table data encompassing stage size and total population size, indicated an exponential growth of population starts at 30th day when reared on chilli (Fig. 4A&B). *A. trachoides* populations can complete more than one but less than two generations during 60 days period. These findings highlight a critical window for intervention. Timely pest management measures, ideally initiated within 30 days of initial adult emergence, are therefore essential to suppress outbreaks and prevent significant crop losses.

Table 2. Demographic parameters of *A. trachoides*

Parameters	Mean ± SE
GRR (individuals / generation)	88.57 ± 5.70
R_o (offspring / individual)	53.27 ± 5.54
T (d)	37.91 ± 0.22
r (d^{-1})	0.10 ± 0.01
λ (d^{-1})	1.11 ± 0.01
DT	6.61

* Where, GRR = Gross reproductive rate; R_0 = Net reproductive rate; T = Mean generation time; r = Intrinsic rate of natural increase; λ = Finite rate of increase; DT = Doubling time. Values are mean ± S.E; Standard errors were measured by 100,000 bootstrap resampling

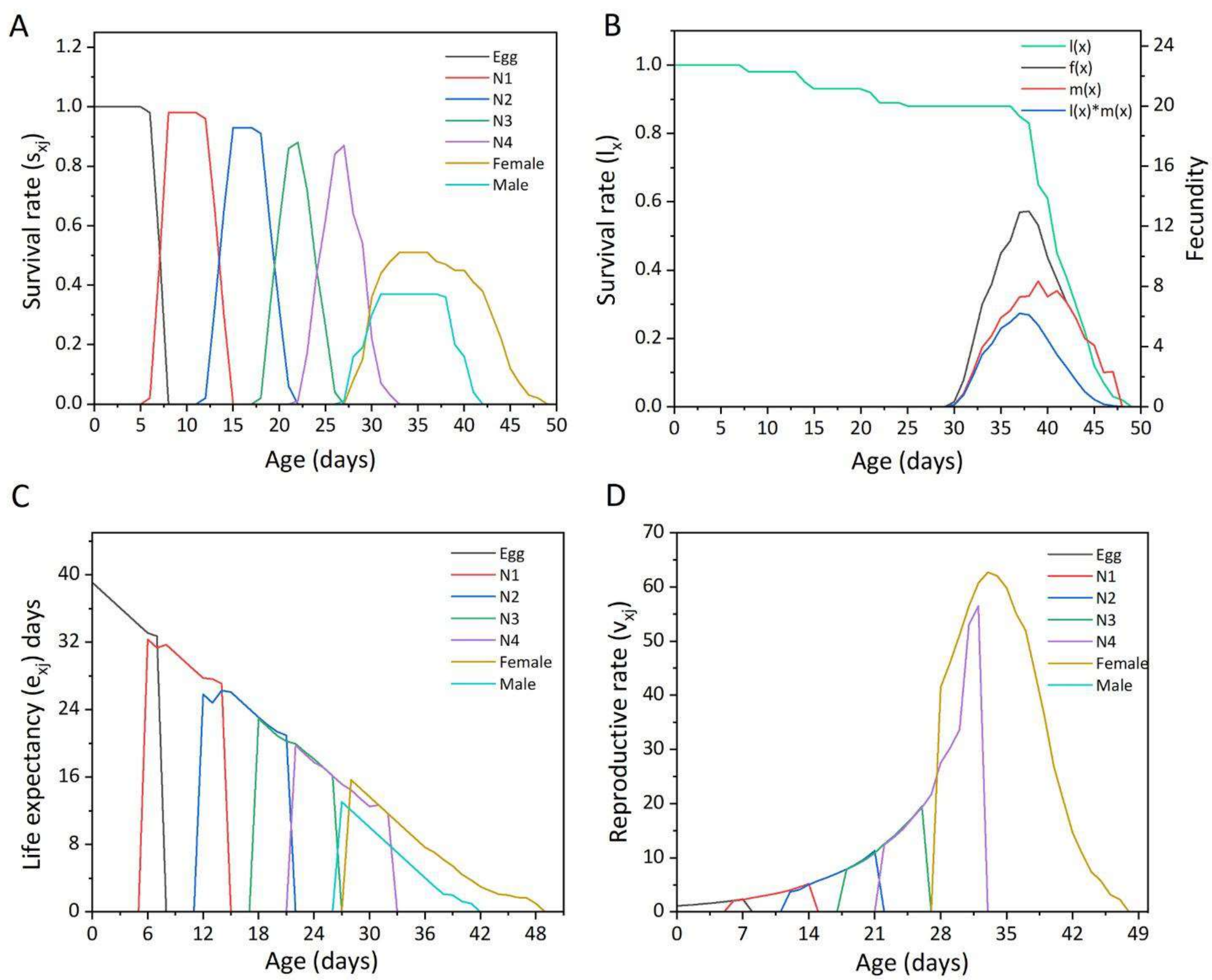

Fig. 3. Age-stage, two-sex life table parameters of *A. trachoides* reared on chilli. (A) Age-stage specific survival rate (s_{xj}); (B) Age-specific survival rate (l_x), Age-stage specific fecundity (f_{xj}), Age-specific fecundity (m_x) and Age-specific maternity ($l_x m_x$); (C) Age-stage specific life expectancy (e_{xj}) and (D) Age-stage specific reproductive rate (v_{xj})

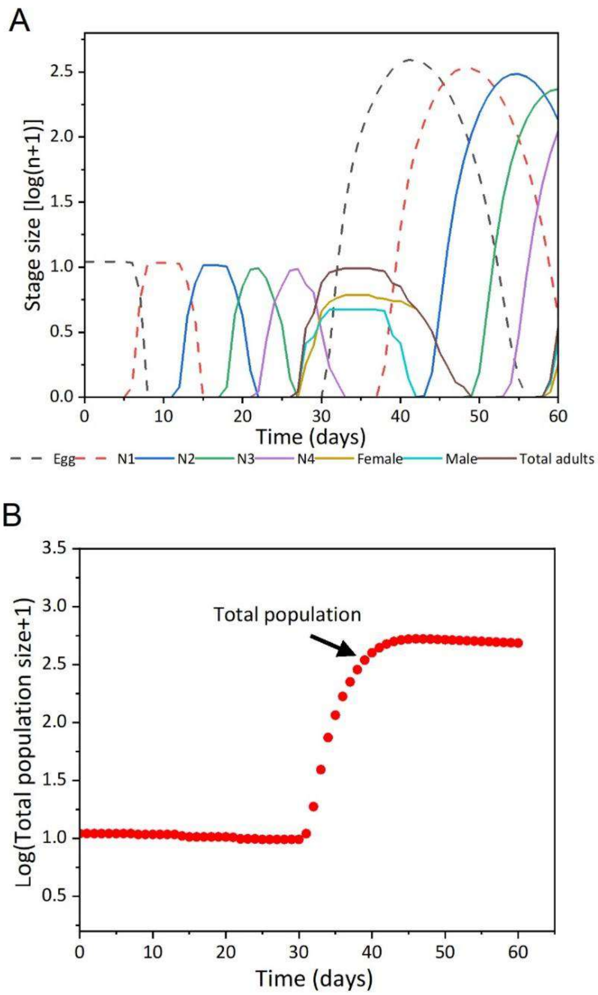

Fig. 4. Population projection of *A. trachoides* reared on chilli, based on (A) stage size and (B) total population

CONCLUSION

The current study provides important insights into the developmental biology and demographic characteristics of solanum whitefly, *A. trachoides* (Back) reared on chili plants. The study confirms that *A. trachoides* is now well-established on chilli crops, posing a potential threat to chilli-growing regions in the near future. The demographic parameters indicate that timely management interventions particularly within the first 30 days of infestation are critical to prevent rapid population build-up. Future research should focus on assessing the influence of climatic factors, host plant variability, and natural enemies on the biology of *A. trachoides* using age-stage and two-sex life table approaches.

ACKNOWLEDGEMENT

The authors are sincerely grateful to the authorities of Annamalai University for permitting us to conduct this research. The first author acknowledges the financial support from the MHRD, UGC Govt. of India for the fellowship received under the RUSA 2.O Project.

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