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Effects of Tomato Leaf Curl Palampur Virus (ToLCPMV) and plant infection status on the fecundity and development of *Bemisia Tabaci* (Gennadius) across seasonal variations

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Abstract
The interaction between plant viruses and insect vectors influences pest dynamics, yet effects on vector fitness remain unclear. This study assessed direct and plant-mediated effects of Tomato leaf curl Palampur virus (ToLCPMV) on fecundity and development of *Bemisia tabaci* across seasons using tomato (susceptible host) and cotton (non-host). On tomato, fecundity varied with virus status, plant condition, and season; viruliferous whiteflies laid more eggs, peaking on healthy plants during SMW 37 (129.80 ± 5.36 eggs), while the lowest occurred in non-viruliferous individuals on infected plants in SMW 51 (16.00 ± 1.22 eggs). Oviposition followed similar trends (4.99 ± 0.25 eggs/female/cm²/day, SMW 37). Developmental durations were primarily temperature-driven, extending under cooler conditions. Female longevity increased in viruliferous individuals. On cotton, viruliferous whiteflies again showed higher fecundity (128.40 ± 2.97 eggs, SMW 28). Temperature and sunshine enhanced fecundity, whereas humidity and rainfall prolonged development, with initial attraction to infected plants shifting later to healthy hosts.

Keywords: Vector fitness modulation, viruliferous dynamics, host–vector–virus interaction, behaviour, environmental drivers

Introduction

Bemisia tabaci (Gennadius) is a globally important pest and efficient vector of begomoviruses, significantly affecting crops such as tomato and cotton (Ghosh and Ghanim, 2021) [10]. Its population dynamics and reproductive success are governed by host plant suitability, plant volatiles, and virus-mediated interactions (Naveed *et al*., 2023; Farina *et al*., 2022) [6, 24]. Host preference studies indicate a tendency to settle on nutritionally superior plants like tomato, although oviposition may occur on suboptimal hosts to balance survival and predation risks (Jiao *et al*., 2012; Shah and Liu, 2013) [14, 32]. Additionally, alternative hosts, including weeds, facilitate persistence and virus transmission across agroecosystems (Sacilotto *et al*., 2022) [30]. The interaction between *B. tabaci* and begomoviruses is highly dynamic, involving behavioural and physiological modifications that enhance virus spread. Viruliferous whiteflies often exhibit altered host preference, favouring healthy plants, while non-viruliferous individuals are attracted to infected plants, promoting acquisition and transmission (Zhao *et al*., 2022; Paris *et al*., 2024) [28, 34]. Viral infections can modulate insect physiology, for instance by increasing fecundity through upregulation of insulin-like peptides (Guo *et al*., 2014) [12]. However, such effects are not uniform; some studies report reduced longevity and fecundity on infected hosts (Rubinstein and Czosnek, 1997) [29], whereas others document enhanced reproduction in invasive biotypes (Guo *et al*., 2012) [11]. Similarly, developmental trade-offs are evident, as certain viruses accelerate immature stages while negatively impacting adult longevity (Mann *et al*., 2008) [22]. Environmental factors further regulate whitefly biology. Optimal reproduction occurs between 24–28°C, while extreme temperatures reduce survival and fecundity (Sengonca and Liu, 1999) [31]. Relative humidity between 30-70% favours survival, whereas excessive humidity and rainfall suppress populations (Lin Kejian *et al*., 2004; Balabantaray *et al*., 2018) [1, 17]. Seasonal conditions, particularly temperature and sunshine, positively influence fecundity, whereas humidity and rainfall prolong developmental stages and reduce population growth (Chaudhuri *et al*., 2001) [5]. Within this framework, the present study evaluates the direct and plant-mediated effects of Tomato leaf curl Palampur virus (ToLCPMV) on *B. tabaci* across seasonal variations, using tomato as a susceptible host and cotton as a non-host system. By integrating host–virus–vector interactions with environmental drivers, it provides a comprehensive understanding of how viral acquisition influences fecundity, development, and behavioural responses, thereby contributing to improved pest and disease management strategies.

Material and Methods

Experiments were carried out at the Vegetable Research Farm and Plant Virology Laboratory, Punjab Agricultural University, Ludhiana, India (30°45′ N, 75°40′ E). The study examined the effects of Tomato leaf curl Palampur virus (ToLCPMV) acquisition on the fecundity, development, and behaviour of the whitefly *B. tabaci* on tomato and cotton hosts.

Two-month-old tomato plants were used to evaluate indirect virus effects mediated through the host plant. Twenty plants were assigned to four treatments with five replications (one plant per replicate): (i) viruliferous whiteflies on ToLCPMV-infected plants, (ii) non-viruliferous whiteflies on ToLCPMV-infected plants, (iii) viruliferous whiteflies on healthy plants, and (iv) non-viruliferous whiteflies on healthy plants. Virus-infected plants were obtained through inoculation by viruliferous adults and confirmed by symptom expression, while healthy plants were maintained

under insect-proof conditions. Viruliferous whiteflies were produced following a 48h acquisition access period on infected tomato plants, whereas non-viruliferous colonies were maintained continuously on virus-free cotton plants. For fecundity assessment, two pairs of newly emerged adults were confined to a 4.9 cm² leaf area per plant using clip cages fitted with fine mesh. Oviposition was allowed until adult mortality, after which eggs were counted under a stereo microscope (ZEISS Stemi series) equipped with a digital camera (ZEISS Axiocam 208). Oviposition rate was calculated as eggs per female per cm² per day. For developmental studies, twenty eggs per replicate were individually marked and observed daily through egg, four nymphal instars, pupal stage and adult emergence. Male and female longevity were recorded separately. Observations were made using a macro mobile camera lens (Adcom 12×/24×). Experiments were conducted monthly from July to December 2024, corresponding to the 3rd standard meteorological week, to capture seasonal variation. Parameters recorded included total eggs laid, oviposition rate, incubation period, nymphal and pupal duration, adult longevity, and total developmental period.

Parallel experiments were conducted on two-month-old healthy cotton plants to evaluate the direct effects of virus acquisition independent of plant infection. Two treatments, each with five replications, were assessed: viruliferous and non-viruliferous whiteflies on healthy cotton plants. Two pairs of adults were confined to 4.9 cm² leaf areas for 48 h using clip cages. Eggs laid during this period were counted, and twenty eggs per replicate were followed through successive developmental stages as described for tomato. Observations were recorded from July to December 2024 [28]. The same biological parameters were measured as in the tomato experiments.

$$Oviposition\ Rate = (No\ of\ Eggs)/(Leaf\ Area * No\ of\ Female * Time)$$

Feeding preference of viruliferous and non-viruliferous whiteflies was evaluated in mesh cages (47.5 × 47.5 × 47.5 cm) containing one ToLCPMV-infected and one healthy tomato plant of similar age and size. Forty adults were released at the centre of each cage, and the number of whiteflies settled on each plant was recorded at 3, 6, 9, 12, and 24 h after release. Individuals not settled on either plant were excluded from analysis. Each assay was replicated three times using fresh insects and plants. Experiments were conducted at 25 ± 2 °C, 60-70% relative humidity, and a 16:8 h (light: dark) photoperiod.

All data were analysed using R software (version 4.4.2). Treatment effects in tomato experiments were evaluated using one-way analysis of variance (ANOVA) at a 5% significance level. For cotton experiments, differences between viruliferous and non-viruliferous whiteflies were analysed using two-tailed independent t-tests ($\alpha = 0.05$). Correlation analyses were conducted to assess relationships between whitefly biological parameters and environmental variables. Meteorological data were recorded regularly, and weekly means corresponding to each standard meteorological week were used for analysis.

Result and Discussion

Whitefly fecundity was significantly influenced by virus acquisition, host plant condition, and seasonal variation (Table 1). Viruliferous whiteflies consistently laid more eggs than non-viruliferous individuals across most SMWs. On healthy tomato plants, both viruliferous and non-viruliferous whiteflies exhibited higher fecundity compared with those on ToLCPMV-infected plants. For instance, the maximum egg deposition was recorded for viruliferous whiteflies on healthy plants during SMW 37 (129.80 ± 5.36 eggs). In contrast, the lowest fecundity occurred in non-viruliferous individuals on infected plants during SMW 51 (16.00 ± 1.22 eggs). At SMW 28, non-viruliferous whiteflies laid 122.20 ± 7.66 eggs on healthy plants, statistically comparable to viruliferous whiteflies (115.80 ± 7.12 eggs), but significantly higher than those on infected plants (94.20 ± 5.67 and 94.00 ± 7.00 eggs, respectively). These patterns are further depicted in Fig. 1. Oviposition rates followed a similar trend (Table 2), with significantly higher values on healthy plants compared to those infected with ToLCPMV. Across most SMWs, viruliferous and non-viruliferous whiteflies on healthy plants exhibited comparable oviposition rates, except SMW 41, where viruliferous whiteflies surpassed all groups. The highest oviposition rate (4.99 ± 0.25 eggs/female/cm²/day) was observed for viruliferous individuals on healthy plants during SMW 37, while the lowest was for non-viruliferous whiteflies on infected plants during SMW 51 (0.70 ± 0.03 eggs/female/cm²/day). Fig. 1 illustrates these oviposition dynamics.

The highest fecundity on the cotton plant (Table 3) was observed at SMW 28, where viruliferous whiteflies deposited 128.40 ± 2.97 eggs in 48 hours compared with 111.80 ± 4.92 eggs in non-viruliferous individuals. Conversely, the lowest egg count was recorded during SMW 51 (22.00 ± 3.32 vs. 11.80 ± 2.04 eggs). Exceptions occurred at SMW 41, where non-viruliferous whiteflies (123.40 ± 3.05 eggs) surpassed viruliferous ones (101.00 ± 2.95 eggs). Oviposition rates followed similar seasonal trends, with the highest rate in viruliferous whiteflies during SMW 37 (5.82 ± 0.40 eggs/female/cm²/day) and the lowest in non-viruliferous whiteflies during SMW 51 (0.62 ± 0.06 eggs/female/cm²/day).

Correlation analysis (Fig. 2) revealed strong positive associations of temperature with fecundity (r = 0.89) and oviposition rate (r = 0.92), and strong negative correlations with incubation, pupal, and total developmental periods. Relative humidity had weaker effects, but on cotton showed positive associations with incubation (r = 0.63) and pupal period (r = 0.56). Rainfall exhibited minor negative effects on fecundity but slightly prolonged nymphal and pupal development. Sunshine hours correlated positively with fecundity and ovipositio but negatively with developmental stages. Overall, warmer conditions and increased sunshine favoured reproduction, while higher humidity and rainfall extended developmental durations.

Settling behaviour indicated an early preference for ToLCPMV-infected plants, with higher numbers recorded at 3 hours (15.4 ± 1.6 vs. 12.3 ± 1.4 whiteflies). This trend persisted at 6, and, 9 hours post-release. However, by 24 hours, a significant shift occurred, with more whiteflies settling on healthy plants (18.6 ± 1.2) compared to infected ones (15.9 ± 1.5). These findings suggest that while ToLCPMV infection initially attracts whiteflies, long-term settlement favours healthy plants.

The study on *B. tabaci* (Gennadius) elucidates the complex interplay among Tomato leaf curl Palampur virus (ToLCPMV), host plant condition, vector physiology, and seasonal variability, highlighting how these factors collectively regulate whitefly fecundity, development, and

behaviour. The results strongly support the concept that begomoviruses can manipulate both their host plants and insect vectors to enhance transmission efficiency, although the outcomes remain highly context dependent. Viruliferous whiteflies consistently exhibited higher fecundity than non-viruliferous individuals, particularly on healthy tomato plants, aligning with earlier reports that virus acquisition enhances reproductive output through physiological modulation. Guo *et al*. (2014) and Zhao *et al*. (2022) [12, 34] demonstrated that begomoviruses upregulate insulin-like peptides (BtILP1), thereby improving nutrient assimilation and egg production. Similar findings by Jiu *et al*. (2007) and Luan *et al*. (2014) [15, 21] further suggest that virus-induced suppression of plant defence pathways, particularly jasmonic acid-mediated responses, indirectly enhances host suitability for the vector. However, fecundity declined markedly on ToLCPMV-infected tomato plants, indicating that virus-induced deterioration of host quality can offset these benefits. This observation is consistent with Rubinstein and Czosnek (1997) and Shi *et al*. (2018) [29, 33], who reported reduced amino acid availability, altered phloem composition, and increased oxidative stress in infected plants, ultimately impairing whitefly reproduction. Oviposition rates closely paralleled fecundity trends, reaching a maximum of 4.99 eggs per female per cm² per day during SMW 37, supporting the hypothesis that virus acquisition enhances feeding activity and salivation, thereby stimulating oviposition and transmission (Liu *et al*., 2013; Moreno-Delafuente *et al*., 2013) [23, 32]. Developmental responses revealed a more nuanced pattern. Virus acquisition tended to prolong developmental duration, particularly the nymphal stage, while also extending female longevity. These findings agree with Mann *et al*. (2008) and Pan *et al*. (2013) [18, 22], who described life-history trade-offs in which delayed development is compensated by increased survival and reproductive lifespan. Seasonal temperature played a dominant role, with cooler conditions extending developmental periods, consistent with Lin Kejian *et al*. (2004) and Bonato *et al*. (2007) [2, 17], who documented reduced metabolic activity at lower temperatures. Notably, pupal duration remained relatively stable, suggesting that this non-feeding stage is less influenced by virus-mediated effects. In contrast to some earlier studies (Nogia *et al*., 2014) [25], host plant infection status did not significantly alter immature stages, highlighting the virus- and host-specific nature of these interactions. Female longevity was consistently enhanced in viruliferous whiteflies, supporting the hypothesis that begomoviruses increase vector lifespan to maximise transmission opportunities (Wang *et al*., 2022; Wei *et al*., 2019) [36, 37]. Male longevity, however, was more strongly influenced by seasonal factors, corroborating findings by Ghosal (2022) and Byrne and Bellows (1991) [3, 9] that males are more susceptible to environmental stress due to physiological constraints. Experiments on cotton, a non-host for ToLCPMV, confirmed that viral acquisition exerts direct effects on whitefly biology independent of host plant infection. Viruliferous whiteflies consistently showed higher fecundity, in agreement with Guo *et al*. (2012) [11], who attributed increased reproduction to enhanced vitellogenin synthesis. The persistence of this effect across seasons, particularly during favourable conditions such as SMW 28, indicates that virus-mediated physiological changes are robust, although occasional reversals under suboptimal conditions suggest context dependency (Mann *et al*., 2008; Luan *et al*., 2014). Rubinstein and Czosnek (1997) [21, 22, 29] similarly reported that viral effects on fecundity and longevity vary with environmental and biological factors. Developmental parameters, including incubation and nymphal periods, were largely unaffected by viral status on cotton, supporting earlier observations that immature stages are less responsive to virus presence under non-host conditions (Pakkianathan *et al*., 2015) [26]. Nevertheless, subtle delays in incubation during certain weeks may reflect metabolic costs associated with viral replication and immune responses (Ghanim *et al*., 2007) [8]. Environmental variables emerged as critical determinants of whitefly performance. Temperature showed a strong positive association with fecundity and developmental rate, consistent with Balabantaray *et al*. (2018) and Khanday *et al*. (2019) [1, 16], who identified 25–30°C as optimal for population growth. Relative humidity exerted weaker effects but prolonged early developmental stages under high conditions (>70%), likely due to reduced desiccation stress (Chandi *et al*., 2021) [4]. Sunshine hours positively influenced fecundity and accelerated development, reflecting increased metabolic activity (Sengonca and Liu, 1999) [31]. Seasonal population trends observed in this study, with higher densities during warmer periods and declines during colder months, agree with Chaudhuri *et al*. (2001) [5]. Importantly, viruliferous whiteflies exhibited enhanced longevity during colder periods, suggesting that viral infection may confer adaptive advantages under environmental stress, as also reported by Rubinstein and Czosnek (1997) [29]. Behavioural observations further revealed that feeding and settling patterns differ between infected and healthy plants. Although virus-infected plants initially attract whiteflies due to altered volatile cues (Zhao *et al*., 2022) [34], reduced settling and oviposition at later intervals suggest the involvement of induced plant defences. The accumulation of defence-related metabolites, such as hydroxy-fatty acids and glycosides, may deter feeding and oviposition by modifying leaf surface properties (Wang *et al*., 2022) [34]. Additionally, reduced nutritional quality in infected plants, as suggested by Wang *et al*. (2020) [35], likely contributes to lower oviposition rates. Overall, the findings demonstrate that ToLCPMV acquisition exerts both direct and plant-mediated effects on *B. tabaci*, enhancing fecundity and longevity under favourable conditions while imposing context-dependent developmental and behavioural trade-offs. The integration of viral, host plant, and environmental influences underscores the complexity of vector–virus interactions and highlights the necessity of incorporating seasonal ecology into pest and disease management strategies.

Table 1: Effect of the virus acquisition on the fecundity (FEC) of whitefly on tomato plants

Treatment	Mean no of eggs laid by whitefly during different standard meteorological week (SMW)					
	28 (1)	**33 (2)**	**37 (3)**	**41 (4)**	**45 (5)**	**51 (6)**
Viruliferous whitefly on ToLCPMV-infected plant	94.00 ± 7.00^{b} (9.69)	115.20 ± 6.38^{b} (10.73)	121.00 ± 5.20^{ab} (11.00)	101.00 ± 4.24^{c} (10.05)	77.00 ± 5.05^{c} (8.77)	20.20 ± 2.49^{c} (4.49)
Non-viruliferous whitefly on	94.20 ± 5.67^{b}	98.00 ± 3.67^{c}	107.20 ± 6.61^{c}	96.00 ± 3.81^{c}	88.00 ± 3.74^{b}	16.00 ± 1.22^{d}

ToLCPMV-infected plant	(9.70)	(9.90)	(10.35)	(9.80)	(9.38)	(4.00)
Viruliferous whitefly on healthy plant	115.80±7.12[a] (10.76)	126.20±5.81[a] (11.23)	129.80±5.36[a] (11.39)	118.60±1.95[a] (10.89)	110.60±6.07[a] (10.51)	27.60±1.82[b] (5.25)
Non-viruliferous whitefly on healthy plant	122.20±7.66[a] (11.05)	121.80±5.85[ab] (11.03)	120.00±5.79[b] (10.95)	111.80±5.45[b] (10.57)	103.40±7.80[a] (10.16)	33.80±0.45[a] (5.81)
LSD (p =0.05)	0.42	0.38	0.41	0.30	0.44	0.23
Cell values are mean±SD; Transformed mean in parenthesis; Treatments with the same letter grouping are not significantly different.						

Table 2: Effect of the virus acquisition on the oviposition rate (OR) of whitefly on tomato plants

Treatment	Oviposition rate of whitefly during different standard meteorological week (SMW)					
	28 (1)	33 (2)	37 (3)	41 (4)	45 (5)	51 (6)
Viruliferous whitefly on ToLCPMV-infected plant	3.69 ± 0.38[b] (1.92)	4.46 ± 0.22[b] (2.11)	4.51 ± 0.27[b] (2.12)	4.05 ± 0.11[b] (2.01)	3.05 ± 0.26[c] (1.75)	0.91 ± 0.07[c] (0.95)
Non-viruliferous whitefly on ToLCPMV-infected plant	3.79 ± 0.24[b] (1.95)	3.92 ± 0.18[c] (1.98)	4.13 ± 0.29[c] (2.03)	3.61 ± 0.28[c] (1.90)	3.37 ± 0.08[b] (1.84)	0.70 ± 0.03[d] (0.84)
Viruliferous whitefly on healthy plant	4.96 ± 0.09[a] (2.23)	4.98 ± 0.34[a] (2.23)	4.99 ± 0.25[a] (2.23)	4.69 ± 0.20[a] (2.16)	4.29 ± 0.10[a] (2.07)	1.19 ± 0.09[b] (1.09)
Non-viruliferous whitefly on healthy plant	4.68 ± 0.08[a] (2.16)	4.79 ± 0.19[ab] (2.19)	4.94 ± 0.12[a] (2.22)	4.11 ± 0.27[b] (2.03)	4.36 ± 0.27[a] (2.09)	1.32 ± 0.06[a] (1.15)
LSD (p =0.05)	0.09	0.08	0.08	0.09	0.07	0.05
Cell values are mean±SD; Transformed mean in parenthesis; Treatments with the same letter grouping are not significantly different.						

Table 3: Effect of the virus acquisition on the fecundity of whitefly on cotton plants

SMW	Mean no of eggs (MEN) laid in 48 hrs		t-value	Oviposition rate (OR)		t-value
	T1: Viruliferous whitefly on cotton plant	T2: Non-viruliferous whitefly on cotton plant		T1: Viruliferous whitefly on cotton plant	T2: Non-viruliferous whitefly on cotton plant	
28 (1)	128.40 ± 2.97 (11.33)	111.80 ± 4.92 (10.57)	*6.46	5.63 ± 0.33 (2.37)	5.47 ± 0.53 (2.34)	0.57
33 (2)	110.60 ± 4.45 (10.51)	107.60 ± 3.05 (10.37)	1.24	5.63 ± 0.49 (2.37)	5.39 ± 0.27 (2.32)	0.97
37 (3)	112.80 ± 4.76 (10.62)	109.80 ± 5.36 (10.48)	0.93	5.82 ± 0.40 (2.41)	5.48 ± 0.26 (2.34)	1.62
41 (4)	101.80 ± 2.95 (10.09)	123.40 ± 3.05 (11.11)	*11.38	5.38 ± 0.20 (2.32)	5.25 ± 0.34 (2.29)	0.71
45 (5)	104.00 ± 5.39 (10.20)	94.60 ± 3.65 (9.72)	*3.23	5.30 ± 0.31 (2.30)	5.03 ± 0.28 (2.24)	1.44
51 (6)	22.00 ± 3.32 (4.68)	11.80 ± 2.05 (3.43)	*5.85	1.13 ± 0.07 (1.06)	0.62 ± 0.06 (0.79)	*12.62
Cell values are mean ± SD; Transformed mean in parenthesis; t-table = 2.36 at p = 0.05; n = 5						

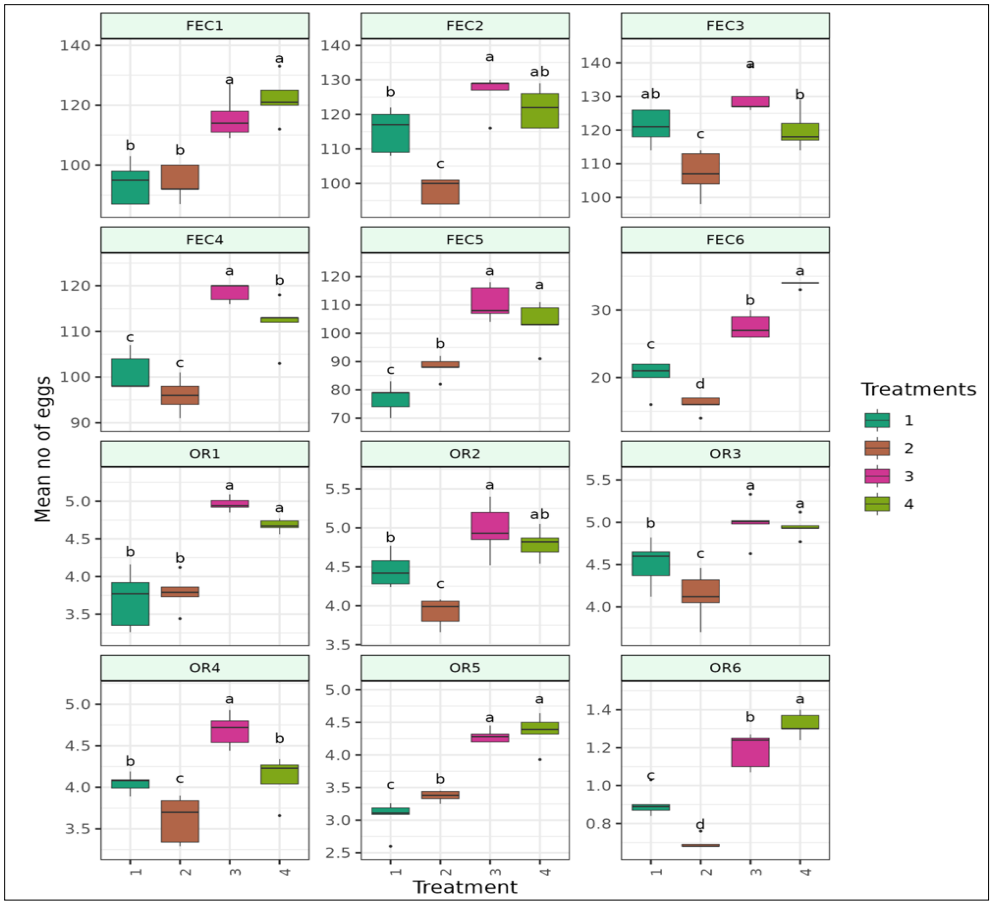

Fig 1: Fecundity (FEC) and oviposition rate (OR) during different standard meteorological weeks (SMW) on tomato

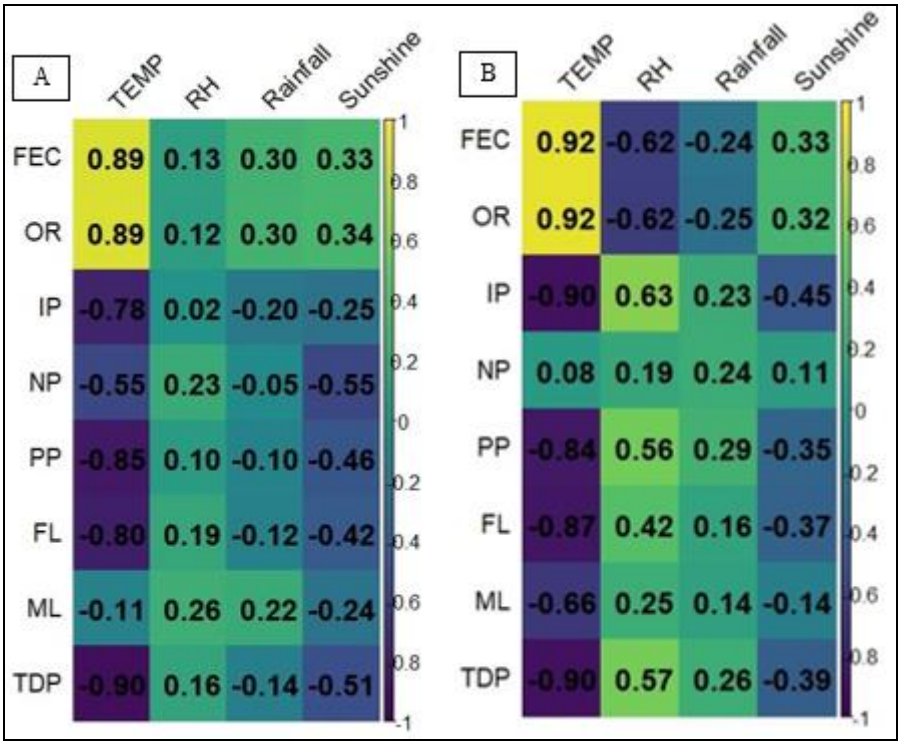

Fig 2: Correlation analysis of whitefly fecundity and developmental parameters with environmental factors of tomato (A) and cotton (B) (TEMP: Mean SMW temperature (°C); RH: Mean SMW relative humidity (%); Mean SMW Rainfall (mm) and Mean SMW Sunshine (hr))

Statements and Declarations

Author's contribution: Conceptualisation and design of the research work, analysis of data and interpretation (RP, HSB, AS): Execution of field experiments and data collection, preparation of manuscript (RP)

References

1. Balabantaray S, Jaglan RS, Dahiya KK. Effects of weather variables on population build up of cotton whitefly (Bemisia tabaci, Gennadius) and its predator natural enemies. Journal of Entomology and Zoology Studies,2018:6:725–727.
2. Bonato O, Lurette A, Vidal C, Fargues J. Modelling temperature-dependent development rate and phenology in insects: Application to Bemisia tabaci. Ecological Modelling,2007:201:77–88.
3. Byrne DN, Bellows TS. Whitefly biology. Annual Review of Entomology,1991:36:431–457.
4. Chandi RS, Kataria SK, Fand BB. Effect of temperature on biological parameters of cotton whitefly, Bemisia tabaci (Gennadius) (Hemiptera: Aleyrodidae). International Journal of Tropical Insect Science,2021:41:1823–1833.
5. Chaudhuri N, Deb DC, Senapati SK. Biology and fluctuation of white fly (Bemisia tabaci Genn.) population on tomato as influenced by abiotic factors under Terai region of West Bengal. Indian Journal of Agricultural Research,2001:35:155–160.
6. Farina A, Barbera AC, Leonardi G, Massimino Cocuzza GE, Suma P, Rapisarda C. Bemisia tabaci (Hemiptera: Aleyrodidae): What Relationships with and Morpho-Physiological Effects on the Plants It Develops on? Insects,2022:13(4):351.
7. Fiallo-Olivé E, Pan LL, Liu SS, Navas-Castillo J. Transmission of begomoviruses and other whitefly-borne viruses: Dependence on the vector species. Phytopathology,2020:110(1):10–17.
8. Ghanim M, Morin S, Czosnek H. Rate of Tomato yellow leaf curl virus translocation in the circulative transmission pathway of its vector, Bemisia tabaci. Phytopathology,2007:97:188–196.
9. Ghosal A. Influence of Abiotic Factors on Whitefly Population Abundance in Cotton. In: Abdurakhmonov Y(ed) Cotton. IntechOpen, 2022.
10. Ghosh S, Ghanim M. Factors determining transmission of persistent viruses by Bemisia tabaci an emergence of new virus–vector relationships. Viruses,2021:13:1808.
11. Guo JY, Dong SZ, Yang X, Cheng L, Wan FH, Liu SS, *et al*. Enhanced vitellogenesis in a whitefly via feeding on a begomovirus-infected plant. PLoS One, 2012,43567.
12. Guo J, Cheng L, Ye G, Fang Q, Guo J. Feeding on a begomovirus-infected plant enhances fecundity via increased expression of an insulin-like peptide in the whitefly, MEAM1. Archives of Insect Biochemistry and Physiology,2014:85:164–179.
13. Guo J, Cong L, Wan F. Multiple generation effects of high temperature on the development and fecundity of Bemisia tabaci (Gennadius) (Hemiptera: Aleyrodidae) biotype B. Journal of Insect Science,2013:20:541–549.
14. Jiao X, Xie W, Wang S, Wu Q, Zhou L, Pan H, *et al*. Host preference and nymph performance of B and Q putative species of Bemisia tabaci on three host plants. Journal of Insect Science,2012:85:423–430.
15. Jiu M, Zhou XP, Tong L, Xu J, Yang X, Wan FH, *et al*. Vector-virus mutualism accelerates population increase of an invasive whitefly. PLoS ONE,2007:2(1):182.
16. Khanday S, Ahmad R, Aziz RU, Sharma GD. Effect of some climatic factors on the population dynamics of silverleaf whitefly Bemisia tabaci infesting cotton plant

Gossypium hirsutum. Acta Entomologica Serbica,2019:24:1–6.
17. Lin K, Wu K, Wei H, Guo Y. Effects of temperature and humidity on the development, survival and reproduction of B biotype of Bemisia tabaci (Homoptera: Aleyrodidae) from Beijing. Acta Phytophysiologica Science,2004:31:166–172.
18. Liu B, Preisser EL, Chu D, Pan H, Xie W, Wang S, *et al*. Multiple Forms of Vector Manipulation by a Plant-Infecting Virus: Bemisia tabaci and Tomato Yellow Leaf Curl Virus. Journal of Virology,2013:87:4929–4937.
19. Liu Z, Chen W, Zhang S, Chen H, Su H, Jing T, *et al*. Behavioral responses of Bemisia tabaci Mediterranean cryptic species to three host plants and their volatiles. Insects,2022:13:703.
20. Lorenzo ME, Grille G, Basso C, Bonato O. Host preferences and biotic potential of Trialeurodes vaporariorum and Bemisia tabaci (Hemiptera: Aleyrodidae) in tomato and pepper. Arthropod-Plant Interaction,2016:10:293–301.
21. Luan JB, Wang XW, Colvin J, Liu SS. Plant-mediated whitefly–begomovirus interactions: research progress and future prospects. Bulletin of Entomological Research,2014:104:267–276.
22. Mann RS, Sidhu JS, Butter NS, Sohi AS, Sekhon PS. Performance of Bemisia tabaci (Hemiptera: Aleyrodidae) on healthy and cotton leaf curl virus infected cotton. Florida Entomologist,2008:91:249–255.
23. Moreno-Delafuente A, Garzo E, Moreno A, Fereres A. A plant virus manipulates the behavior of its whitefly vector to enhance its transmission efficiency. Biology Letters,2013:9(3):20130018.
24. Naveed H, Islam W, Jafir M, Andoh V, Chen L, Chen K. A Review of Interactions between Plants and Whitefly-Transmitted Begomoviruses. Plants (Basel),2023:12(21):3677.
25. Nogia VK, Singh V, Meghwal RR. Effect of Cotton leaf curl virus infected plants on the biology of the whitefly, Bemisia tabaci (Hemiptera: Aleyrodidae): Vector–virus mutualism. Phytoparasitica,2014:42:619–625.
26. Pakkianathan BC, Kontsedalov S, Lebedev G, Mahadav A, Zeidan M, Czosnek H, *et al*. Replication of Tomato yellow leaf curl virus in its whitefly vector Bemisia tabaci is associated with transcriptional changes in the insect. Journal of Virology,2015:89:9521–9533.
27. Pan H, Chu D, Liu B, Shi X, Guo L, Xie W, *et al*. Differential effects of a plant virus on the fitness of an invasive and a native whitefly vector. PLoS ONE,2013:8(6):67819.
28. Paris TM, Johnston N, Strzyzewski I, Griesheimer JL, Reimer B, Malfa K, *et al*. Tomato yellow leaf curl virus manipulates Bemisia tabaci, MEAM1 both directly and indirectly through changes in visual and volatile cues. The Journal of Life and Environmental Sciences,2024:12:17665.
29. Rubinstein G, Czosnek H. Long-term association of tomato yellow leaf curl virus with its whitefly vector Bemisia tabaci: effect on the insect transmission capacity, longevity and fecundity. Journal of General Virology,1997:78:2683–2689.
30. Sacilotto MG, Souza FSF, Baldin ELL, Carbonari CA, Lourenção AL, Faria RD. Preference of Bemisia tabaci MEAM1 (Hemiptera: Aleyrodidae) for weed and cultivated species. Research Square,2022:69:1–23.
31. Sengonca C, Liu B. Laboratory studies on the effect of temperature and humidity on the life table of the whitefly, Aleurotuberculatus takahashi David and Subramaniam (Hom., Aleyrodidae) from southeastern China. Anzeiger für Schädlingskunde, Pflanzenschutz and Umweltschutz,1999:72:45–48.
32. Shah MMR, Liu TX. Feeding experience of Bemisia tabaci (Hemiptera: Aleyrodidae) affects their performance on different host plants. PLoS One,2013:8:77368.
33. Shi X, Pan H, Xie W, Wu Q, Wang S, Zhang Y. Plant virus differentially alters the plant's defense responses to its vector insect. Journal of Integrative Agriculture,2018:17(3):653–660.
34. Wang N, Zhao P, Wang D, Mubin M, Fang R, Ye J. Diverse begomoviruses evolutionarily hijack plant terpenoid-based defense to promote whitefly performance. Cells,2022:12:149.
35. Wang Y, He Y, Liu S, Wang X. Mechanisms of plant virus transmission by the whitefly Bemisia tabaci. Chinese Science Bulletin,2020:65:1463–75.
36. Wang L, Wang X, Wei J, Zhang Y. Begomovirus infection increases survival and reproductive fitness of its whitefly vector. Virus Research,2022:308:198642.
37. Wei J, He YZ, Guo Q, Guo T, Liu YQ, Zhou XP, *et al*. Vector development and vitellogenin expression are manipulated by plant virus to enhance transmission. PLoS Pathogens,2019:15(1):1007817.
38. Wu HY, Li WH, Weng SH, Tsai WS, Tsai CW. Differential effects of two tomato begomoviruses on the life history and feeding preference of Bemisia tabaci. Insects,2023:14:870.
39. Xie M, Wan FH, Chen YH, Wu G. Effects of temperature on the growth and reproduction characteristics of Bemisia tabaci B-biotype and Trialeurodes vaporariorum. Journal of Applied Entomology,2011:135:252–257.
40. Zhao K, Liu SS, Wang XW, Yang JG, Pan LL. Manipulation of whitefly behavior by plant viruses. Microorganisms,2022:10:2410.