Pest Management in Horticultural Ecosystems
Vol. 32, No.1 pp 54-59 (2026)
DOI Number : 10.5958/0974-4541.2026.00006.8

Pest–weather dynamics in tomato: a study from North-Western Punjab

SHAMLI, KAVITA BAJAJ*, JENIA THAKUR and AKASHDEEP SINGH

P.G. Department of Agriculture, Khalsa College Amritsar, Punjab, India

***E-mail:** kavita.bajaj2k9@gmail.com

ABSTRACT: Seasonal incidence of insect pests of tomato was monitored weekly and analysed in relation to key meteorological parameters such as maximum and minimum temperatures, relative humidity, and rainfall. Sucking pests such as *Aphis gossypii* and *Bemisia tabaci*, along with lepidopteran pests viz., the leaf miner *Tuta absoluta* and the fruit borer *Helicoverpa armigera* were first observed during the 41st and 43rd Standard Meteorological Weeks (SMW), respectively. The peak populations of pest were recorded during the 48th SMW, with peak densities of *A. gossypii* (17.78 nymphs/plant), *B. tabaci* (21.8 nymphs/plant), *T. absoluta* (5.2 larvae/plant), and *H. armigera* (4.2 larvae/plant). Correlation analysis showed that maximum temperature had a strong positive association with pest incidence, with correlation coefficient values of 0.719, 0.658, 0.622, and 0.689 for *A. gossypii*, *B. tabaci*, *T. absoluta*, and *H. armigera*, respectively. Minimum temperature exhibited weak, non-significant negative correlations (–0.290 to –0.216). Relative humidity showed negative non-significant correlation for *A. gossypii* (–0.523), *B. tabaci* (–0.565), and *H. armigera* (–0.411), while *T. absoluta* showed a significant negative correlation (–0.580). Rainfall showed significant negative correlations with all four pests. Understanding the seasonal occurrence of insect pests in tomatoes identified the dynamic nature of pest challenges throughout the crop. This awareness may be useful in establishing early and effective control measures and reducing the environmental impact associated with pest management techniques.

Keywords: Tomato, Correlation, Seasonal incidence, Meteorological parameters

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), a prominent member of the Solanaceae family, is among the most widely cultivated and economically significant vegetable crops worldwide. It ranks second after potato in global vegetable production, with an estimated annual output of 213.20 million tonnes (FAOSTAT, 2024). Asia is the leading producer, contributing 60-70 per cent of global output and achieving an average yield of 27 tonnes per hectare. India plays a key role, accounting for approximately 11 per cent of global production. During 2023–2024, tomato was cultivated in India on 870.96 thousand hectares, with a total production of 21.32 thousand metric tonnes and an average yield of 24.48 t ha^{-1}. The principal tomato-producing states- Andhra Pradesh, Tamil Nadu, Karnataka, Madhya Pradesh, among others together account for nearly 90% of national production (NHB, 2020). In Punjab, cultivation covered 11.17 thousand hectares, yielding 291.00 thousand metric tonnes, with a productivity of 26.06 t ha-^{1} (Anonymous, 2024). Meteorological conditions play a pivotal role in shaping the growth, development, and population dynamics of insect pests in tomato crops. Among the most influential factors are maximum and minimum temperatures, relative humidity, and rainfall, all of which affect the life cycles, reproduction, and survival rates of key pest species. Changes in these climatic parameters can either favour or suppress pest incidence and intensity, thereby impacting crop health and productivity (George *et al*., 2019).

Bemisia tabaci (Gennadius) and *Aphis gossypii* (Glover) are two major sucking pests that thrive under warm and moderately humid conditions. Maximum temperatures are positively correlated with their development and population build-up, whereas excessive rainfall or very high humidity tends to suppress their activity by physically dislodging individuals or hampering reproduction (Marabi *et al*., 2017; Sattar *et al*., 2020). The oviposition and egg viability of whitefly population, in particular are highly sensitive to temperature fluctuations with optimal activity observed between 25-30°C (Sharma *et al*., 2018). The outbreaks of aphids are often favoured by rising temperatures combined with moderate humidity, while heavy rainfall may reduce their populations through wash-off effects. Lepidopteran pests such as *Tuta absoluta* (Meyrick) (***Phthorimaea***

***absoluta*)** and *Helicoverpa armigera* (Hubner) are also significantly affected by weather conditions. These pests generally show a strong positive correlation with increasing maximum and minimum temperature. Warmer temperature accelerates their development, increase the number of generations per season, and intensify damage during the fruiting stage (Fathipour and Sedaratian, 2013). Conversely, higher relative humidity and frequent rainfall can negatively influence larval survival by promoting natural enemies and disease outbreaks.

The interaction between temperature, humidity, and rainfall influences the arrival and extent of pest infestation in tomato ecosystems. Understanding these relationships is critical for developing weather-based pest forecasting models and timely integrated pest management strategies to mitigate economic losses in tomato cultivation; therefore, the present investigation was undertaken.

MATERIALS AND METHODS

The research was carried out at Research Farm of P.G. Department of Agriculture, Khalsa College, Amritsar, Punjab, India during 2023.The experimental site has subtropical semi-arid climate with four distinct seasons: winter (December to March), summer (April to June), monsoon season (July to September) and post-monsoon season (October to November). Temperature in Amritsar varies from 4 to 45°C with annual rainfall of around 726 mm. During the experimental period, the maximum temperature varied from 31.4°C and minimum 16.9°C with average rainfall of 14 mm. The total experimental area of 270 square meters was divided into 3 blocks having 0.5 meter space between them and each block served as a separate replication. Further, each block was divided into six plots with individual plot size of 3m × 5m and kept unsprayed throughout the crop season.

A popular tomato variety, Punjab Varkha Bahar-4 was grown in the field during the month of September as per the Package of Practices of Punjab Agricultural University, Ludhiana (Anonymous, 2022). To determine the incidence of insect pests, observations were recorded from the initiation of pest infestation still crop harvest. To record the population of sucking pests, five plants were selected randomly from each untreated plot. The population of nymphs and adults of *A. gossypii* and *B. tabaci* were recorded from per plant whereas, *T. absoluta* and *H. armigera* observations were recorded at weekly intervals right from appearance of the pest till harvesting by direct visual counting of larvae on each plant. The observations from seasonal incidence were correlated with the prevailing weather factors such as maximum and minimum temperature, relative humidity and rainfall. The data on maximum and minimum temperature, relative humidity and rainfall were collected from Agrometeorological Unit, P.G. Department of Agriculture at Khalsa College, Amritsar during 2023. The correlation coefficient of determination was calculated to explore the relation between seasonal incidence of major pests and weather factors using the computer programme OP STAT one factor (Sheoran *et al*., 1998).

RESULTS AND DISCUSSION

The incidence of insects was observed at weekly interval from one month after sowing [41th standard meteorological week (SMW)] till harvesting (52nd SMW).The first appearance of *A. gossypii* was recorded during the 41st SMW, and the last occurrence was observed in the 52nd SMW. The *A. gossypii* population varied from 1.2 to 17.78 per plant with a peak occurrence (17.78 / plant) was observed in the 48th SMW at a maximum temperature of 30.5°C, minimum temperature of 9.5°C, relative humidity of 51.57 per cent and zero rainfall. The lowest aphid population (1.2/ plant) was at 41th SMW when the temperature reached maximum 24.61°C and minimum 18.5°C with a relative humidity of 72.04 per cent and rainfall 2.1 mm (Fig. 1). Correlation analysis indicated that the population of *A. gossypii* had a highly significant positive correlation with maximum temperature, a negative but non-significant correlation with minimum temperature and relative humidity, and a significant negative correlation with rainfall (Table 1).

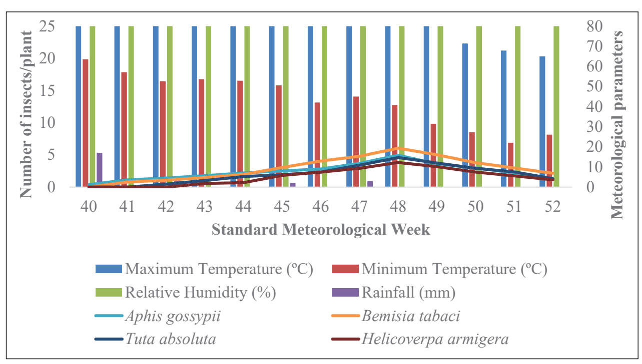

Fig. 1. Seasonal incidence of major insect pests in tomato

Table 1: Relationship between weather parameters and incidence of major insect pests of tomato

Sl. No.	Correlation coefficient (r value)	*Aphis gossypii*	*Bemisia tabaci*	*Tuta absoluta*	*Helicoverpa armigera*
1.	Maximum Temperature (ºC)	0.719**	0.658*	0.622*	0.689*
2.	Minimum Temperature (ºC)	-0.290^{ns}	-0.375^{ns}	-0.396^{ns}	-0.216^{ns}
3.	Relative Humidity (%)	-0.523^{ns}	-0.565^{ns}	-0.580*	-0.411^{ns}
4.	Rainfall (mm)	-0.630*	-0.583*	-0.587*	-0.610*

*values are significant at 5% level of significance, ns – non-significant

The population of *B. tabaci* varied from 0.6 to 21.8 per plant. The first appearance of *B. tabaci* was observed in 41st SMW (0.6/ plant) and remained active up to 52nd SMW (1.1/ plant). The population increased gradually and highest incidence of *B. tabaci* (21.8/ plant) was recorded during 48th SMW when the maximum temperature was 30.5°C and minimum temperature was 9.5°C. Relative humidity recorded was 51.57 per cent whereas rainfall was absent during this week. The activity of whiteflies was declined thereafter and lowest population was recorded during 52nd SMW (1/ plant) when the temperature reached maximum 13.3°C and minimum 8.15°C with relative humidity 61.99 per cent and rainfall 6.2 mm (Fig. 1).The correlation analysis revealed a significant positive association with maximum temperature, a negative but non-significant correlation with minimum temperature and relative humidity, and a significant negative correlation with rainfall (Table 1).

In case of *T. absoluta*, the data revealed that first appearance was during 43rd SMW (0.4 larvae/plant) when temperature maximum temperature 26.6°C minimum during this week was 15.7°C with Relative humidity 67.73 per cent while 4.2 mm rainfall. The population increased thereafter and attained its peak during 48th SMW (5.2 larvae/plant) when the maximum and minimum temperature was 30.5°C and 9.5°C, respectively. Relative humidity was 51.57 per cent while no rainfall was recorded. The population decreased gradually up to 52nd SMW and reached low during 52nd SMW (0 larvae/plant)at maximum temperature of 13.3°C, minimum temperature of 8.15°C, relative humidity of 61.99 per cent and with 6.2 mm rainfall (Fig. 1).The correlation studies revealed that maximum temperature showed significant positive association with the population of *T. absoluta.* On the other hand, negative non-significant correlation with minimum temperature while relative humidity and rainfall exhibited negative significant correlation with the population of *T. absoluta* (Table 1).

The population of *H. armigera* was found during the later stage of growth of crop. Population of *H. armigera* varied from 0.2 to 4.2 larvae. Initiation of this pest was observed during 43rd SMW with a population of 0.2 larvae per plant when the maximum and minimum temperature was 26.6°C and 15.7°C, respectively. Relative humidity was 67.73 per cent with 4.2 mm rainfall. Further, the population increased steadily and acquired its peak during 48th SMW (4.2 larvae/plant) when the maximum temperature was 30.5°C, minimum temperature was 9.5°C, relative humidity was 51.57 per cent with no rainfall. Later, the pest population decreased gradually and minimum population was nil in 52nd SMW when the maximum and minimum temperature was 13.3°C and 8.15°C, respectively. Correlation analysis revealed that maximum temperature showed significant positive association with the *H. armigera* while minimum temperature and relative humidity exhibited negative non-significant. On the other hand, rainfall showed a significant negative correlation with the incidence of *H. armigera* (Table 1).

The multiple linear regression equations presented in Table 2 describe the relationship between pest population (dependent variables) and different weather parameters (independent variables), viz., maximum temperature (X_1), minimum temperature (X_2), relative humidity (X_3) and rainfall (X_4). The coefficient of determination (R^2) indicates the proportion of variation in pest population explained by the combined effect of these weather parameters. For *A. gossypii* (Y1), the regression equation $Y_1 = 2.61 + 0.85\ (T_{max}) - 0.51\ (T_{min}) - 0.16$ (Relative humidity) − 0.16 (Rainfall), with

R^2 = 0.87, indicates that 87 per cent of the variation on aphid population is explained by the selected weather variables. Maximum temperature showed a strong positive influence on population build-up, while minimum temperature, relative humidity and rainfall exerted a negative effect. For *B. tabaci* (Y_2), the equation $Y_2 = -3.03 + 1.22 (T_{max}) - 1.06 (T_{min}) - 0.09$ (Relative humidity) − 0.08 (Rainfall), with R^2 = 0.86 suggests that maximum temperature had a substantial positive association with whitefly population, whereas minimum temperature, relative humidity and rainfall reduced their population levels. The relatively high R^2 value (86%) indicates an excellent fit of the model. For *T. absoluta* (Y3), the regression equation Y3 = 6.19 + 0.71 (T_{max}) − 0.73 (T_{min}) − 0.14 (Relative humidity) − 0.52 (Rainfall), with R^2 = 0.82, reveals that 82 per cent of the variation in pest population is accounted for by the weather variables. Maximum temperature exhibited a positive relationship with population increase, while minimum temperature, relative humidity and rainfall showed negative effects. Notably, rainfall had the strongest negative coefficient (−0.52), indicating that higher rainfall markedly reduced *T. absoluta* infestation, possibly due to disruption of larval stages and adult activity. For *H. armigera* (Y_4), the equation $Y_4 = -4.55 + 0.70 (T_{max}) - 0.53 (T_{min}) - 0.04$ (Relative humidity) − 0.22 (Rainfall), with R^2 = 0.71, implies that 71 per cent of population fluctuation could be explained by the weather parameters. Although maximum temperature positively influenced pest incidence, other parameters exerted negative effects, with rainfall again showing a comparatively stronger suppressive role. Overall, the regression models indicate that maximum temperature is the most influential factor positively affecting pest populations, while minimum temperature, relative humidity, and rainfall generally suppress pest incidence. The high R^2 values (0.71–0.87) confirm that weather parameters play a significant role in regulating population dynamics of insect pests, with maximum temperature being the key driver.

The present results are in agreement with the findings of Kachave *et al.* (2020) who reported the peak population of *A. gossypii* (7.9 nymph/plant) during 46th SMW when temperature reached maximum 33.5°C and, minimum 11°C, with 81 per cent relative humidity. Singh *et al.* (2023) recorded the first incidence of *A. gossypii* in 46th SMW with maximum population in 10th SMW had a negative non-significant correlation between relative humidity and *A. gossypii* population.

First appearance of *B. tabaci* was noticed during 31st SMW with a peak (10.2 nymph / plant), during 42nd SMW when temperature attained maximum 34.4°C and minimum 18°C with relative humidity 74 per cent (Asiry *et al.,* 2022). A non-significant positive correlation was also noticed between the *B. tabaci* population maximum temperature but a significant negative correlation between minimum temperature and relative humidity. Subba *et al.* (2017) also observed a significant positive correlation between the maximum temperature and minimum temperature, whereas, a non-significant negative between rainfall and *B. tabaci.* Likewise, Patel *et al.* (2021) reported the first incidence of *B. tabaci* during 38th SMW (0.2 nymph/plant) and peak population in 48th SMW (5.40 nymph /plant). These variations in the occurrence of the pest are owing to geographical regions and associated abiotic parameters (Dent and Binks, 2020).

Incidence of *T. absoluta* was observed in 32nd SMW with a peak larval population (3.5 larvae/plant) in 41st SMW (Chavan *et al.,* 2013). The when the weather parameters such as maximum and minimum temperature and relative humidity at 36°C, 17.2°C and 64 per cent,

Table 2: Multiple linear regression equation depicting the influence of different weather parameter on pest population

Regression equation	Coefficient of Determination (R^2)
Y_1=2.61+0.85X_1-0.51X_2-0.16X_3-0.16X_4	0.87
Y_2=-3.03+1.22X_1-1.06X_2-0.09X_3-0.08X_4	0.86
Y_3=6.19+0.71X_1-0.73X_2-0.14X_3-0.52X_4	0.82
Y_4=-4.55+0.70X_1-0.53X_2-0.04X_3-0.22X_4	0.71

Where Y_1 = *Aphis gossypii* population, Y_2=*Bemisia tabaci* population, Y_3=*Tuta absoluta* population, Y_4= *Helicoverpa armigera* population; X_1= Maximum Temperature, X_2=Minimum Temperature, X_3= Relative Humidity, X_4=Rainfall respectively play crucial role of the pest. Correlation analysis revealed that minimum temperature and relative humidity indicating negative significant influence on incidence of *T. absoluta*. However, there was a negative non-significant correlation with the population of *T. absoluta* and weather parameter rainfall.

The results of the present study closely match the findings of Singh *et al.* (2025) and Wade *et al.* (2020). They reported the first appearance of *H. armigera* at a low level (0.5 larvae/ plant) during the 32nd SMW. The pest population reached its highest level (3.7 larvae/ plant) in the 41st SMW, when the maximum and minimum temperature was 36.0°C and 17.2°C, respectively and relative humidity was 64 per cent. Their study also showed that *H. armigera* population had a significant negative relationship with relative humidity and a non-significant negative relationship with rainfall. Likewise, Kumar *et al.* (2017) observed the occurrence and peak population of *H. armigera* during the 43rd and 48th SMW, respectively which supports the findings of the present study. Similar observations were also reported by Singh *et al.* (2021). Understanding the seasonal pattern of insect pests in tomato crops helps explain how pest populations change during the crop growth period. This information is important for planning timely and effective pest control measures while reducing negative effects on the environment.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to the P.G. Department of Agriculture, Khalsa College, Amritsar, Punjab-143002, India, for providing the necessary research infrastructure and facilities to carry out the experiment.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests

AUTHOR CONTRIBUTIONS

Conceptualization and designing of the research work (K.B., J.T.); Field experiments and data collection (S.); Data analysis and interpretation (S., K.B.); Preparation of manuscript (S., K.B., J.T., A.S.).

REFERENCES

Anonymous. 2022. Package of practices for cultivation of vegetables. *Punjab Agricultural University, Ludhiana*, pp. 33-41. Available from: https://www.pau.edu

Anonymous. 2024. Selected state-wise area, production, and productivity of tomato in India (2023-2024: 3rd Advanced Estimates). Ministry of Agriculture & Farmers Welfare, Government of India. Available from https://www.indiastat.com/data/agriculture/tomato

Asiry, K. A., Huda, M. N., Mousa, M. A. A. 2022. Abundance and population dynamics of the key insect pests and agronomic traits of tomato (*Solanum Lycopersicon L.*) varieties under different planting densities as a sustainable pest control method. *Horticulturare,* **8**: 976. https://doi.org/10.3390/horticulturae8100976.

Chavan, S. M., Kumar, S., and Arve S. S. 2013. Population dynamics and development of suitable pest management module against major insect pests of tomato (*Solanum lycopersicum L.*) *Journal of Applied Horticulture*, **15**(02): 150-155. DOI:10.37855/jah.2013.v15i02.30.

Dent, D. R. and Binks, R. H. 2020. Insect pest management (3rd edition). CABI Publishing.

Singh, D., Kumar, R., Yadav, S. S., and Meenu. 2025. Population dynamics of major insect-pests on different varieties of tomato (*Solanum lycopersicum L.*) *Journal of Experimental Agriculture International,* **47**(5): 572-579. DOI:10.9734/jeai/2025/v47i53445.

Fathipour, Y. and Sedaratian A. 2013. Effects of temperature and humidity on the development of *Tuta absoluta* in tomato. *International Journal of Pest Management,* **59**: 327–334.

Food and Agriculture Organization (FAO). 2024. FAOSTAT database. Global tomato production and yields by region. Food and Agriculture Organization of the United Nations. Available from: http//www.faostat/en/#home .

George, A., Rao, C. N., Ghike, S. and Dhengre, V. N. Impact of weather on seasonality of phytophagous mites and their natural enemies associated with citrus in vidharbha region of Maharashtra, India. *Journal of Agriculture and Veterinary Science*, 2019; **12**(2): 75-83.

Kachave, D. R., Sonkamble, M. M. and Patil, S. K. 2020. Population dynamics of major insect pests infesting tomato, *Lycopersicon esculentum* (Miller). *Journal of Pharmacognosy and Phytochemistry,* **9**: 344 348.

Kumar, R. and Verma, S. 2022. Nutritional and medicinal properties of tomato: review. *Indian Journal of Horticulture,* **79**: 144–152.

Kumar, V., Meena, R. S., Laichattiwar, M. A. and Singh, P. S. 2017. Seasonal incidence of tomato fruit borer *Helicoverpa armigera* (Hubner) in the Gangetic plain of Uttar Pradesh. *Environment and Ecology,* **35**: 169-171.

Marabi, R. S., Das, S. B., Bhowmick, A. K., Pachori, R., Vibha and Sharma, H. L. 2017. Seasonal population dynamics of whitefly (*Bemisia tabaci* Gennadius) in soybean. *Journal of Entomology and Zoology Studies,* **5**(2): 169-173.

Marabi, R. S., Singh, S., Meena, S. K., Meena, B. L. and Yadav, R. S. 2017. Seasonal dynamics of *Bemisia tabaci* in relation to meteorological factors. *Journal of Basic & Applied Zoology,* **78**: 45–55.

National Horticulture Board (NHB). 2020. NHB Statistics. National Horticulture Board, Ministry of Agriculture and Farmers Welfare, Government of India. Available from https://nhb.gov.in/Statistics.aspx.

Patel, C., Srivastava, R. M., Deeksha, M. G., Kunwar, R., Tiwari, J. and Pal, K. 2021. Influence of abiotic factors on seasonal incidence of *Bemisia tabaci* (Gennadius) on tomato. *The Pharma Innovation Journal,* **10**(10): 1052-1055.

Sattar, A., Addo-Quaye, C. and Tamo, M. 2020. Abiotic influences on the population dynamics of aphid and whitefly on tomato. *Environmental Entomology,* **49**: 622–630.

Sharma, H. C., Archana, S., Thulasi, K., Srilakshmi, K., Gowda, C. L. L. and Warburton, M. L. 2018. Climatic correlates of whitefly biology on tomato. *Crop Protection,* **102**: 120–128.

Sheoran, O. P., Tonk, D. S., Kaushik, L. S., Hasija, R. C. and Pannu, R. S. 1998. Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar. 139-143.

Singh, J. K., Chauhan, S., Kumar, P. and Kumar, R. 2023. Seasonal incidence of insect pests of tomato (*Lycopersicumesculentum* Miller).*International Journal of Environment and Climate Change,* **13**: 1369-1375.

Singh, S. P., Dwivedi, R. K. and Kishor, K. 2021. Population dynamics of tomato fruit borer (*Helicoverpa armigera* Hubner) in relation to abiotic factors in central U.P. *The Pharma Innovation Journal,* **10**: 39-43.

Subba, B., Pal, S., Mandal, T. and Ghosh, S. K. 2017. Population dynamics of whitefly (*Bemisia tabaci* Genn.) infesting tomato (*Lycopersicon esculentus* L.) and their sustainable management using bio-pesticides. *Journal of Entomology and Zoology Studies,* **5**(3): 879-88.

Wade, P. S., Wankhede. S. M., Hatwar, N. K., Shinde, B. D. and Sanap, P. B. 2020. Seasonal incidence of major insect pests infesting tomato (*Solanum lycopersicum L.*). *Journal of Entomology and Zoology Studies,* **8**(3): 1546-1548.

MS Received: 05 February 2026
MS Acceptance: 28 March 2026