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Population Dynamics of *Bemisia tabaci* (Gennadius) on different Brinjal Varieties in Mansehra and Peshawar Regions of Pakistan

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Abstract

The whitefly, *Bemisia tabaci* (Gennadius) is one of the most destructive insect pests of brinjal worldwide, causing significant yield losses through direct feeding and the transmission of plant viruses. This comprehensive study on the infestation of whitefly, in five brinjal (*Solanum melongena* L.) varieties (Twinkle Star, Adventa 305, Shamli, Black boy and Black Nagina) was carried out under field conditions in the Mansehra and Peshawar regions of Pakistan. The results revealed that the brinjal variety Twinkle Star showed comparatively higher resistance, leading to significantly lower mean whitefly numbers (*i.e.*, 5.29 per plant and 4.92 per plant in Peshawar and 1.37 per plant and 2.48 per plant in Mansehra region) compared to other varieties during 2020 and 2021. Weather parameters significantly influenced whitefly abundance, with temperature showing positive associations with population build up, while relative humidity, both in the morning and evening, showed a significant negative association with whitefly populations at district Mansehra, no significant association was observed in district Peshawar. Rainfall displayed a weak negative but non-significant correlation at both locations. Multiple regression analysis demonstrated that abiotic factors explained substantial variation in whitefly populations in selected brinjal varieties at both locations, with R^2 values ranging from 76.30% to 76.80% in both years. The study concluded that the brinjal variety Twinkle Star showed comparatively greater resistance to whitefly infestations, with a significantly lower mean infestation level and suggesting its potential as a component of integrated pest management (IPM) program of whitefly in brinjal fields.

Keywords: Population dynamics; Temperature; Brinjal; Whitefly; Weather parameters

Introduction

Brinjal (*Solanum melongena* L.) is commonly referred to as eggplant, which is a name believed to originate from the resemblance of its fruit to the shape of an egg (Shankar and Venkataraman 2017; Yousafi *et al*. 2018). It is a warm season crop grown for its fleshy fruit and is widely cultivated in tropical and subtropical regions of the world, including Pakistan. It is a rich source of various nutrients, vitamins, proteins, minerals and antioxidants (García-Salas *et al*. 2010). Brinjal is an important vegetable due to its nutritional, medicinal as well as commercial value. In addition, the leaves and seeds also contain certain bioactive compounds with medicinal properties (Watson 2021). The production losses of brinjal crops due to insect pests are very high in South Asia as this important crop is attacked by various insect pests right from the nursery stage till harvesting. Some major pests of brinjal in Pakistan include shoot and fruit borers, Grass hopper, jassids, leaf roller beetles, aphids, Hadda beetle, thrips and whitefly (Iqbal *et al*. 2002; Chandan 2018). Among these insect pests, brinjal whitefly, *Bemisia tabaci* (Gennadius), is one of the most important sucking pests of brinjal crops in Pakistan. It is a small, sap-sucking insect that is notorious for causing severe damage to brinjal and other agricultural crops (Zada *et al.* 2018; Saljoqi *et al*. 2021). Both nymphs and adults of the whitefly suck sap from the plant and secrete honeydew, which disrupts the plant photosynthetic activity (Abbas *et al*. 2022). This pest feeds on the underside of brinjal leaves, sucking plant sap with its specialized mouthparts. The whitefly excretes a sugary fluid known as honeydew while it eats, which serves as a perfect substrate for the formation of black sooty mold (Arif *et al*. 2024). The presence of this mold on the plant's surface impairs its photosynthetic capacity, resulting in decreased growth and production. Moreover, the brinjal whitefly is known vector of several devastating plant viruses, causing additional yield losses and reducing the overall quality of the produce (Pal *et al*. 2021). It has been reported that in Southeast Asia, sucking pests cause up to 67% yield losses (Nadeem *et al*. 2025).

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The only method currently used to manage these pests is chemical control. However, the repeated use of pesticides not only poses environmental hazards (Salim *et al*. 2025), but also leads to the development of resistance in target pests and disturbs the ecological balance (Antignus 2001; Saljoqi *et al*. 2022). Therefore, it is essential to develop an approach that is not only cost-effective but also environmentally safe. Environmental factors, particularly temperature, play a crucial role in the growth, development and reproduction of many insects. They also impact internal and external conditions, encompassing developmental stages, nutritional balance, susceptibility to pathogens and various environmental stimuli. Whiteflies exhibit rapid development in warm conditions and populations increasing quickly in environments where natural predators are eliminated and the weather is favorable. Extended and intense periods of rainfall can significantly reduce whitefly population (Rafiq *et al*. 2008; Anjali *et al*. 2012).

The abundance and distribution of pests undergo changes in response to abiotic factors, and meteorological parameters consequently play a very important role in the biology of many pests (Khan 2019). No doubt temperature stands out as the most critical abiotic factor affecting the pace of growth and development in insects. However, relative humidity and temperature jointly serve as the primary weather parameters that predominantly govern the activity of a specific insect species. The interplay between pest activity and abiotic factors contributes to the formulation of predictive models, facilitating the forecast of pest incidence (Savopoulou-Soultani *et al.* 2012; Salim *et al.* 2022). Considering the economic importance of brinjal and the serious damage caused by *B. tabaci*, the present study was conducted to evaluate the influence of key abiotic factors on the population dynamics of whitefly infestation across different brinjal varieties. The study aimed to identify varietal responses to whitefly infestation under varying environmental conditions and to determine how fluctuations in temperature, relative humidity and rainfall affect whitefly abundance.

Material and Methods

The research regarding the population dynamics of whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) was carried out on different brinjal varieties in selected districts (Peshawar and Mansehra) of Khyber Pakhtunkhwa, Pakistan.

Population dynamics of *Bemisia tabaci* on brinjal varieties

The experiments were conducted in the Peshawar and Mansehra regions of Khyber Pakhtunkhwa over two consecutive growing seasons (2020-21). The experiments were conducted in a randomized complete block design (RCBD). Five different brinjal varieties, namely Shamli, Adventa 305, Black Nagina, Black Boy and Twinkle Star, were selected for the experiment.

Treatments were replicated three times and each plot measured 3 × 3 m². Each treatment consisted of five rows with plants spaced 12 cm apart within rows and 60 cm between rows. Standard agronomic practices, including ploughing, irrigation, fertilizer and weeding were carried out as required. However, no insecticides were applied during the experimental period.

Whitefly population dynamics were monitored at weekly intervals throughout the cropping period in both growing seasons. The whitefly populations were recorded by counting both nymphs and adults visually on whole plant initially and on three leaves per plant, with one leaf selected from the upper, middle and lower portions of each tagged plant in later stage. To record the whitefly population, each leaf was held by its petiole by thumb and forefinger and carefully turned to expose the entire lower surface. The number of whiteflies present on the lower side of the leaf was then counted using magnifying lens. Observations were made on a total of six plants per plot (Nagar *et al*. 2017). Data collection continued until the end of the season or until no whitefly infestation was observed. Data on environmental factors, including maximum and minimum temperatures and relative humidity (RH) during the crop growth period were obtained from the Meteorological Centers in Peshawar and Mansehra regions.

Statistical analysis

The data on whitefly populations (nymphs and adults) and associated weather variables, including maximum and minimum temperature, as well as morning and evening relative humidity were analyzed using SigmaPlot v. 12.0 (Systat Software Inc., San Jose, CA, USA). For comparing whitefly populations among different brinjal varieties, the data were subjected to analysis of variance (ANOVA) under a randomized complete block design and treatment mean were separated using the Least Significant Difference (LSD) test at the 5% probability level ($P \leq 0.05$). The relationship between whitefly abundance and weather factors was determined through Pearson's correlation analysis and simple linear regression analysis.

Results

Population trend of *B. tabaci* in district Peshawar

The mean whitefly population recorded on different brinjal varieties in district Peshawar during 2020 demonstrates that brinjal variety Twinkle Star showed comparatively lower whitefly population (5.29 per plant), followed by Adventa 305 (7.46 per plant) (Fig. 1). The brinjal variety Shamli showed mean whitefly population of 8.64 per plant. The brinjal variety Black boy resulted in whitefly mean population of 9.72 per plant, while the brinjal variety Black Nagina recorded significantly higher mean number of whitefly population (10.92 per plant). The data regarding the weekly mean population trend of whitefly in different brinjal varieties demonstrate that the population of whitefly in the selected varieties started in the last week of April (SMW17; 0.46 per plant) and continued to increase over time. Maximum population of whitefly in selected brinjal varieties were observed in the last week of July *i.e.*, SMW28, where 16.53 mean population of whiteflies was observed. The population of whitefly in different brinjal varieties was declined gradually in the month of August (SMW31; 7.13 per plant) and reached zero at the end of August *i.e.*, SMW33 onward.

The mean population of whiteflies counts in brinjal varieties at Peshawar during the year 2021 indicated that whitefly population was present in all brinjal varieties, although their abundance levels varied among the varieties (Fig. 2). Notably, the brinjal variety Twinkle Star exhibited relatively least whitefly infestations, showing a significantly lower mean population of 4.92 per plant. Following closely was the brinjal variety Adventa 305, with an observed mean number of 7.09 whiteflies. The brinjal variety Shamli displayed a moderate mean population of 8.25 per plant. In contrast, the brinjal variety Black Boy had a mean population of 9.13 per plant, while the brinjal variety Black Nagina recorded a significantly higher mean population of whitefly at 10.14 per plant during the year 2021 in Peshawar. The results regarding the weekly mean whitefly population across different brinjal varieties in Peshawar during the 2021 cropping season indicated that infestations in the selected cultivars initiated during the 4th week of April (SMW18; 2.33 per plant) and subsequently exhibited a consistent upward trajectory. The peak whitefly population within the selected brinjal varieties manifested in the final week of July, specifically SMW27, where the mean number of whiteflies reached 18.93 per plant. Subsequent to this peak, a discernible decline in whitefly population across the selected brinjal varieties occurred throughout the month of July, eventually tapering to zero by the culmination of August, denoted as SMW33.

Effect of weather parameters on whitefly population in Peshawar

The meteorological data recorded at Peshawar during 2020 and 2021 showed weekly fluctuations in the weather parameters throughout the brinjal cropping season (Table 1-2). The data show that in both the years, the temperatures increased from late April, reaching peak levels in June-July (up to 39.64°C to 42.64°C) in 2020 and 2021, respectively. Relative humidity showed an overall declining trend during early summer (May-June), followed by a substantial increase in August in both years. Rainfall generally remained low and sporadic, although occasional peaks were recorded, particularly in late August of 2021. Overall, both seasons were characterized by hot and relatively dry conditions during peak summer months (May-July), which were conducive for whitefly population buildup, whereas increased trend in humidity and rainfall toward the end of the season likely contributed to a decline in population activity.

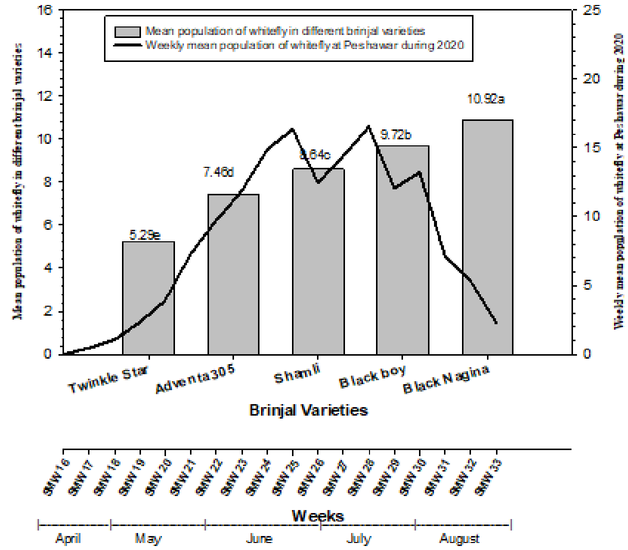

Fig. 1: Mean population of *B. tabaci* per leaf in selected brinjal varieties at Peshawar during growing season 2020

*Bars bearing different letters indicate significant differences according to the LSD test ($P < 0.05$)

LSD value = 0.2867

SMW = Standard Meteorological Week, SMW16 = 3rd week of April, SMW33 = Last week of August

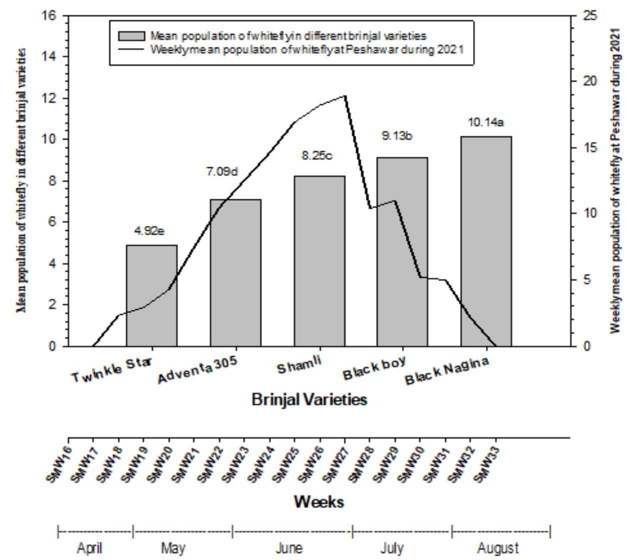

Fig. 2: Mean population of *B. tabaci* per leaf in selected brinjal varieties at Peshawar during growing season 2021

*Bars bearing different letters indicate significant differences according to the LSD test ($P < 0.05$)

LSD value = 0.3788

SMW = Standard Meteorological Week, SMW16 = 3rd week of April, SMW33 = Last week of August

Correlation of *B. tabaci* population with weather parameters in Peshawar

The correlation matrix of whitefly population with weather parameters (Table 3) revealed that, in 2020, the mean maximum temperature had a non-significant ($P > 0.05$) association with the whitefly population in Peshawar.

Table 1: Mean values of temperature, relative humidity and rainfall recorded in weeks for the whitefly population on different brinjal varieties at Peshawar during 2020

Months	Standard meteorological weeks (SMW)	Max. Temp. (°C)	Min. Temp. (°C)	R.H. Morning (%)	R.H. Evening (%)	Rainfall (mm)
April, 2020	SMW16	26.64	16.50	67.57	30.57	27.87
	SMW17	31.76	20.14	60.14	27.29	0.00
May, 2020	SMW18	32.29	20.71	60.29	27.44	0.51
	SMW19	34.00	21.71	54.00	24.43	0.07
	SMW20	31.79	20.43	56.71	25.86	0.76
	SMW21	39.33	23.14	47.29	21.43	0.00
June, 2020	SMW22	34.86	23.86	59.43	27.14	1.12
	SMW23	36.00	25.14	61.00	27.29	0.00
	SMW24	37.93	25.36	56.29	25.57	0.18
	SMW25	39.43	26.29	57.14	25.86	0.00
July,2020	SMW26	37.86	27.79	61.14	27.71	0.15
	SMW27	39.64	26.43	48.43	21.86	0.00
	SMW28	39.14	27.57	54.00	24.57	3.56
	SMW29	38.00	27.29	59.14	27.00	0.00
August, 2020	SMW30	24.64	26.86	69.00	31.43	1.92
	SMW31	38.22	28.61	68.57	42.71	0.00
	SMW32	38.17	35.71	74.57	49.86	0.00
	SMW33	35.16	23.81	82.00	42.71	0.00

R.H. = Relative Humidity

Table 2: Mean values of temperature, relative humidity and rainfall recorded in weeks for the whitefly population on different brinjal varieties at Peshawar during 2021

Months	Standard meteorological weeks (SMW)	Max. Temp. (°C)	Min. Temp. (°C)	R.H. Morning (%)	R.H. Evening (%)	Rainfall (mm)
April, 2021	SMW16	28.70	16.93	58.29	26.29	0.00
	SMW17	34.44	19.93	57.29	27.00	0.00
May, 2021	SMW18	32.79	23.07	56.14	25.86	1.42
	SMW19	34.21	26.43	52.00	23.86	0.00
	SMW20	34.14	22.21	52.57	24.14	0.00
	SMW21	33.50	25.00	49.29	22.71	0.00
June, 2021	SMW22	36.89	25.49	45.29	20.86	0.00
	SMW23	42.64	28.86	50.00	23.00	0.00
	SMW24	39.29	26.36	52.86	24.43	0.00
	SMW25	39.43	25.36	45.14	21.00	0.00
July, 2021	SMW26	41.07	26.90	53.14	24.14	0.00
	SMW27	38.93	27.36	53.71	24.71	0.00
	SMW28	34.21	29.64	62.71	29.43	0.00
	SMW29	28.43	26.71	83.00	38.57	0.00
August, 2021	SMW30	30.29	27.00	81.57	38.29	8.50
	SMW31	35.66	26.08	79.57	43.00	0.58
	SMW32	36.67	26.35	78.00	42.43	0.69
	SMW33	36.03	26.19	74.00	41.57	0.00

R.H. = Relative Humidity

Table 3: Correlation between *B. tabaci* population and weather parameters in Peshawar

Year	Weather parameters				
	Max. Temp.	Min. Temp.	RHM	RHE	PPT
2020	0.411; *P = 0.0906*	0.532; *P = 0.0230**	-0.336; *P = 0.173*	-0.283; *P = 0.255*	-0.300; *P = 0.227*
2021	0.598; *P = 0.00877**	0.551; *P = 0.0178**	-0.375; *P = 0.125*	-0.418; *P = 0.0840*	-0.167; *P = 0.507*

*= Significant ($P < 0.05$), **=highly significant ($P < 0.01$)
Max. Temp. = Maximum Temperature, Min. Temp. = Minimum Temperature
RHM = Relative Humidity in the morning, RHE = Relative Humidity in the evening
PPT = Precipitation (Rainfall): r = correlation coefficient

The data further indicated a positive correlation with both the maximum and minimum temperatures (r = 0.41 and 0.532, respectively). Additionally, non-significant ($P > 0.05$) negative relationships were observed between morning and evening relative humidity and the whitefly population (r = -0.336 and -0.283, respectively), while total rainfall exhibited a non-significant negative correlation (r = -0.300) with whitefly populations in 2020. Similarly, in 2021, the weather parameters also significantly influenced the population of whitefly in Peshawar (Table 3). The mean maximum temperature exhibited a highly-significant ($P < 0.05$) positive relationship with the mean whitefly population (r = 0.598), while the mean minimum temperature showed a significant positive correlation (r = 0.551). The data further indicated a non-significant negative association (r = -0.375) with morning relative humidity and a non-significant negative association (r = -0.418) with evening relative humidity.

Table 4: Multiple Regression equation for *B. tabaci* population in Peshawar

Year	Multiple Regression equation	R^2 Value
2020	Pop = -26.755 + (0.0427 × Max. Temp.) + (1.497 × Min. Temp.) + (0.427 × RHM) - (1.032 × RHE) + (0.145 × PPT)	76.80%
2021	Pop = -61.335 + (1.119 × Max. Temp.) + (0.651 × Min. Temp.) + (1.231 ×RHM) - (2.093 × RHE) - (0.652 × PPT)	76.30%

Pop = Population of whitefly
Max. Temp. = Maximum Temperature
Min. Temp. = Minimum Temperature
RHM = Relative Humidity in the morning
RHE = Relative Humidity in the evening
PPT = Precipitation (Rainfall)

Similarly, rainfall exhibited a non-significant ($P > 0.05$) negative association (r = -0.167) with the mean whitefly population at Peshawar during 2021.

Multiple regression equation of *B. tabaci* in Peshawar

The multiple regression equations (Table 4) illustrated a significant impact of maximum and minimum temperatures, percentage of relative humidity (morning and evening) and total rainfall on the population of whitefly in selected brinjal varieties. The regression equations for brinjal whitefly population indicate that, in the year 2020, the weather parameters caused a 76.80% (R^2) variation in the whitefly population. In 2021, this deviation due to weather parameters accounts for 76.30% (R^2) of the population variation. The overall variation in the whitefly population influenced by weather parameters ranges from 76.30% to 76.80% (R^2) in both years (Table 4).

Population trend of *B. tabaci* in Mansehra

The mean whitefly population recorded in selected brinjal varieties in Mansehra during 2020 illustrates that no single brinjal varieties was devoid of whitefly infection (Fig. 3). The data show that brinjal variety Twinkle Star showed significantly least mean whitefly population of 1.37 per plant, this was followed by brinjal variety Adventa 305, where whitefly population of 2.57 per plant was recorded. Brinjal variety Shamli resulted 3.38 mean whitefly population per plant, this was followed by brinjal variety Black boy where 4.16 whitefly population per plant was recorded. The bars in Fig. 3 further shows that significantly high mean whitefly population (5.07 per plant) was recorded in Black Nagina variety. The weekly mean population of brinjal whitefly in selected varieties in Mansehra during 2020 showed that the population of brinjal whitefly in selected varieties started in the 3rd week of May (SMW19; 1.06 per plant) and continued to increase over time. Maximum population of brinjal whitefly in selected brinjal varieties were observed in the 4th week of June *i.e.*, SMW24 where 14.86 mean number of whiteflies per plant was observed. The line graph further demonstrates that the mean population of whiteflies began to drop in the month of July (SMW28; 6.33 per plant and reached zero at the end of August, *i.e.*, SMW32 onward.

The mean population of brinjal whitefly recorded in selected brinjal varieties at Mansehra during 2021 indicates that whitefly was present in all brinjal varieties, although the population levels varied among the varieties. The data show that brinjal variety Twinkle Star shows significantly least mean whitefly population of 2.48 per plant, followed by brinjal variety Adventa 305 showing 4.03 mean whitefly population per plant. The brinjal variety Shamli resulted in 4.94 mean number of whiteflies per plant was recorded. The bars further illustrated that brinjal variety Black boy resulted in 5.66 mean whitefly population per plant, while the variety Black Nagina showed significantly high mean number of whitefly population (6.44 per plant) during 2021. The weekly mean population of brinjal whitefly in selected varieties at Mansehra during 2021 depicts that the infestation of the brinjal whitefly in selected varieties started in the 3rd week of May (SMW19; 0.80 per plant) and continued to increase over time. Maximum population of whitefly in different brinjal varieties were observed in the 2nd week of June *i.e.*, SMW26 with 10.93 mean number of whiteflies per plant. The line graph further demonstrates that the mean number of whiteflies began to decrease in the month of July (SMW29; 5.99 per plant) and reached zero till the end of August, *i.e.*, SMW33 following heavy rainfall (Fig. 4).

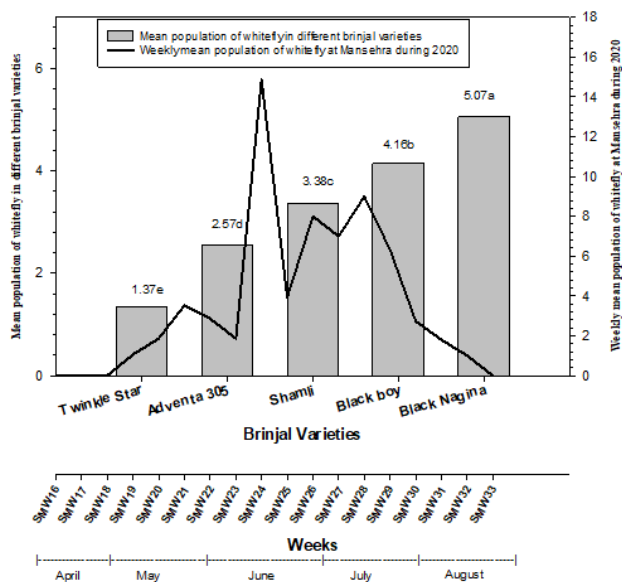

Fig. 3: Mean population of *B. tabaci* per leaf in selected brinjal varieties at Mansehra during growing season 2020
*Bars bearing different letters indicate significant differences according to the LSD test ($P < 0.05$)
LSD value = 0.2829
SMW = Standard Meteorological Week, SMW16 = 3rd week of April, SMW33 = Last week of August

Table 5: Mean values of temperature, relative humidity and rainfall recorded in weeks for the whitefly population on different brinjal varieties at Mansehra during 2020

Months	Standard meteorological weeks (SMW)	Max. Temp. (°C)	Min. Temp. (°C)	R.H. Morning (%)	R.H. Evening (%)	Rainfall (mm)
April, 2020	SMW16	15.01	14.36	62.00	32.80	0.94
	SMW17	22.12	21.47	54.43	28.80	2.75
May, 2020	SMW18	22.37	20.87	59.71	31.59	12.07
	SMW19	26.60	24.95	49.86	26.38	6.17
	SMW20	23.87	22.22	53.14	28.12	4.97
	SMW21	30.68	29.03	31.71	16.78	0.12
June, 2020	SMW22	27.05	25.40	52.00	27.51	1.95
	SMW23	28.26	26.61	53.14	28.12	0.00
	SMW24	31.44	29.79	34.86	18.44	14.82
	SMW25	34.46	32.81	30.00	15.87	0.00
July, 2020	SMW26	32.95	31.30	39.57	20.94	0.60
	SMW27	33.55	31.90	32.29	17.08	0.26
	SMW28	30.83	29.18	47.29	25.02	5.67
	SMW29	28.11	26.46	56.00	29.63	14.09
August, 2020	SMW30	28.71	27.06	57.29	30.31	8.63
	SMW31	28.26	26.61	62.29	32.96	8.29
	SMW32	30.08	28.43	69.14	36.58	17.16
	SMW33	28.26	26.61	76.00	40.21	6.61

R.H. = Relative Humidity

Table 6: Mean values of temperature, relative humidity and rainfall recorded in weeks for the whitefly population on different brinjal varieties at Mansehra during 2021

Months	Standard meteorological weeks (SMW)	Max. Temp. (°C)	Min. Temp. (°C)	R.H. Morning (%)	R.H. Evening (%)	Rainfall (mm)
April, 2021	SMW16	16.73	16.08	62.27	32.07	0.89
	SMW17	23.08	22.43	52.27	26.78	0.21
May, 2021	SMW18	24.70	23.34	57.42	29.50	14.59
	SMW19	28.32	26.67	47.13	24.06	2.45
	SMW20	24.84	23.19	55.42	28.44	8.75
	SMW21	31.95	30.30	31.84	15.97	0.12
June, 2021	SMW22	29.83	28.18	45.13	23.00	1.95
	SMW23	29.68	28.03	52.84	27.08	0.00
	SMW24	32.55	30.90	36.56	18.46	3.25
	SMW25	36.48	34.83	24.27	11.96	11.57
July, 2021	SMW26	34.82	33.17	39.56	20.05	0.60
	SMW27	35.57	33.92	30.99	15.51	0.26
	SMW28	32.55	30.90	43.99	22.39	5.49
	SMW29	31.49	29.84	51.27	26.25	13.69
August, 2021	SMW30	29.22	27.57	56.42	28.97	9.19
	SMW31	30.58	28.93	60.13	30.93	8.12
	SMW32	31.95	30.30	64.70	33.35	17.13
	SMW33	30.43	28.78	74.27	38.42	4.89

R.H. = Relative Humidity

Table 7: Correlation between *B. tabaci* population and weather parameters in Mansehra

Year	Weather parameters				
	Max. Temp.	Min. Temp.	RHM	RHE	PPT
2020	0.586*; *P = 0.0106*	0.591**; *P = 0.00975*	-0.628**; *P = 0.00522*	-0.628**; *P = 0.00522*	0.158; *P = 0.532*
2021	0.695**; *P = 0.00137*	0.696**; *P = 0.00133*	-0.669**; *P = 0.00240*	-0.669**; *P = 0.00240*	-0.185; *P = 0.463*

* = Significant, ** = Highly significant
Max. Temp. = Maximum Temperature, Min. Temp. = Minimum Temperature
RHM = Relative Humidity in the morning, RHE = Relative Humidity in the evening
PPT = Precipitation (Rainfall)

Effect of weather parameters on whitefly population at Mansehra

The meteorological data (Table 5-6) recorded at Mansehra during 2020 and 2021 showed weekly fluctuations in temperature, relative humidity and rainfall data throughout the brinjal cropping season. The data show that in both the years the temperatures gradually increased from early season values (15.01°C to 16.73°C) in late April, reaching peak levels in mid-summer, reaching up to 34.46°C in 2020 and 36.48°C 2021. Relative humidity recorded lower values during early summer (May-July), followed by a substantial increase toward the end of the season in both years. Rainfall generally remained low and sporadic, although occasional peaks were recorded, particularly during mid and late season (up to 17.16 mm in 2020 and 17.13 mm in 2021).

Table 8: Multiple Regression equation for *B. tabaci* population in Mansehra

Year	Multiple Regression equation	R^2 Value
2020	Pop = 7.872 - (1.258 × Max. Temp.) + (1.506 × Min. Temp.) - (0.212 ×RHM) + (0.342 × PPT)	64.40%
2021	Pop = -0.668 + (2.438 × Max. Temp.) - (2.167 × Min. Temp.) - (0.109 × RHM) - (0.103 × PPT)	62.10%

Pop = Population of whitefly
Max. Temp. = Maximum Temperature,
Min. Temp. = Minimum Temperature
RHM = Relative Humidity in the morning
RHE = Relative Humidity in the evening is removed from the equation in Table 8 because it is collinear
PPT = Precipitation (Rainfall)

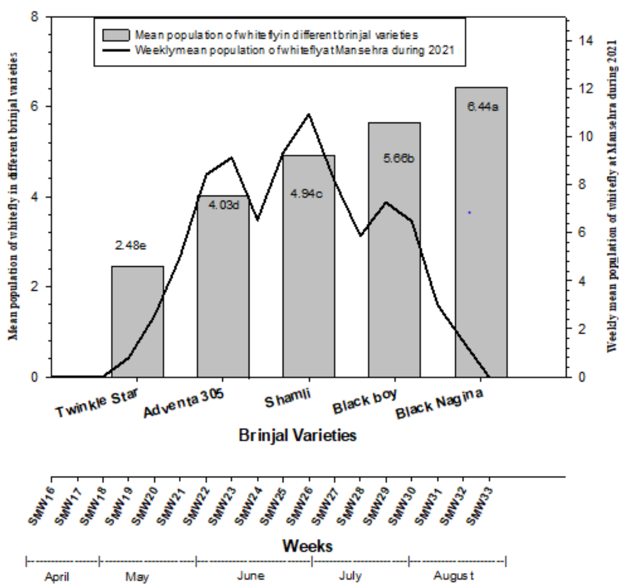

Fig. 4: Mean population of *B. tabaci* per leaf in selected brinjal varieties at Mansehra during growing season 2021
*Bars bearing different letters indicate significant differences according to the LSD test ($P < 0.05$)
LSD value = 0.2848
SMW = Standard Meteorological week, SMW16 = 3rd week of April, SMW33 = Last week of August

Overall, both seasons were characterized by cooler and relatively moist early conditions, followed by warmer and drier periods during peak summer that were favorable for whitefly population buildup, while humidity and rainfall toward the end of the season likely contributed to a decline in population activity.

Correlation of *B. tabaci* population with weather parameters in Mansehra

The correlation matrix of the brinjal whitefly population with weather parameters (Table 7) illustrates that, in the year 2020, the mean maximum and minimum temperatures exhibited a significant ($P < 0.05$) association with the whitefly population in Mansehra in 2020. The data further showed positive correlations (r = 0.586 and 0.591) with both the maximum and minimum temperatures. Additionally, significant ($P < 0.05$) negative relationships were observed between relative humidity in the morning and evening and the whitefly population, with correlation co-efficient of r = -0.628 and -0.628, respectively. However, total rainfall showed a positive but non-significant ($P > 0.05$) correlation (r = 0.158) with the whitefly population in 2020. Likewise, in 2021, the weather parameters also significantly influenced the population of brinjal whitefly in Mansehra (Table 7). The mean maximum and minimum temperatures showed highly-significant ($P < 0.05$) positive relationships (r = 0.695 and 0.696) with the mean whitefly population. The data further showed highly significant ($P < 0.05$) negative associations (r = -0.669 and -0.669) between the whitefly population and relative humidity recorded in the morning and evening respectively. Rainfall, on the other hand, exhibited a non-significant ($P > 0.05$) negative association (r = -0.185) with the mean whitefly population at Mansehra in 2021.

Multiple regression equation for *B. tabaci* population in Mansehra

The multiple regression equations (Table 8) illustrated a significant impact of maximum and minimum temperatures, percentage of relative humidity (morning and evening), and total rainfall on the population of whitefly in selected brinjal varieties at Mansehra during 2020 and 2021. The regression equations for brinjal whitefly population indicate that, in the year 2020, the weather parameters caused a 64.40% (R^2) variation in the whitefly population. In 2021, this deviation due to weather parameters accounts for 62.10% (R^2) of the population variation. The overall variation in the whitefly population influenced by weather parameters ranges from 62.10% to 64.40% (R^2) in both years (Table 8).

Discussion

The population abundance and distribution of insect pests are significantly influenced by the combination of biotic and abiotic factors, along with their intricate interactions. Flourishing in challenging environmental conditions necessitates unique adaptations and flexible responses. Notably, temperature and relative humidity emerge as critical abiotic factors that significantly influence the development, survival, abundance and distribution of insects. Extensive documentation supports the idea that abiotic factors, particularly temperature, play a crucial role in shaping the ecology of insect communities (Savopoulou-Soultani *et al.* 2012). In the present study, the population dynamics of brinjal whitefly on different brinjal varieties were investigated and the fluctuation in population in relation to weather parameters was analyzed under the agro-climatic conditions of Peshawar and Mansehra districts of Khyber Pakhtunkhwa from April to August during 2020 and 2021. The seasonal trend observed in the study indicated that initial infestation of whitefly in the selected varieties began in late April, gradually increased over time with rising temperature, reaching its peak during the last week of July. Thereafter, the whitefly population declined and eventually reached zero by the end of August during both seasons in both districts. This temporal pattern suggests that warm environmental conditions during mid-summer favored rapid multiplication of whitefly populations, while declining temperatures and changes in humidity levels later in the season likely restricted their development. These results are aligned with the observations of Liu's (2000), who reported significant fluctuations in the whitefly adult and nymph populations from April to June during two consecutive seasons. According to their findings, adult whiteflies initially appeared on plants in early April, underwent a rapid increase within a month. The population reached its peak in May, and subsequently declined toward the end of the season in early or mid-June. Furthermore, the presence of whitefly eggs on plants was recorded after the appearance of adults, with a notable concentration on foliage until late May. Similarly, Leite *et al*. (2005) documented the infestation of *B. tabaci* on two okra plantations, reporting a particularly severe infestation on the second plantation. In addition, Michael (2004) reported infestation of *B. tabaci* on okra during two consecutive summer seasons (2001 and 2002), confirming that whitefly population outbreaks are closely associated with climatic variation and host crop phenology.

A key finding of the present study is the differential susceptibility of brinjal varieties to whitefly infestation. None of the tested varieties were completely free from whitefly infestation; however, Twinkle Star recorded comparatively lower mean whitefly population as compared to other brinjal varieties. This was followed by Adventa 305 and Shamli with a moderate level of whitefly population. While the brinjal varieties Black boy and Black Nagina recorded significantly higher mean number of whitefly population in both the year at both the locations. These differences may be attributed to inherent morphological and biochemical resistance mechanisms among the tested varieties. Morphological characters such as thicker leaf surface and cuticular wax layer, increased leaf pubescence and altered leaf texture may reduce whitefly settling, oviposition and feeding preference (Saljoqi *et al.* 2021). Likewise, biochemical factors such as plant secondary metabolites may adversely affect the whitefly feeding efficiency, survival and reproduction (Jafir *et al*. 2018). Such resistance mechanisms have been widely recognized as important contributor to host plant resistance in brinjal and other solanaceous crops. The comparatively lower infestation observed on Twinkle Star may therefore indicate the presence of one or more of these resistances associated characters. These results are aligned with the work of Habib *et al*. (2015) who screened different brinjal genotypes against three sucking insect pests of brinjal and found that brinjal variety Shamli exhibited a comparatively lower density of the three pests, resulting in a significantly higher yield compared to the other two genotypes. Our results further confirm the observation of Jafir *et al*. (2018) whose findings indicated that the Advanta-314 germplasm demonstrated the highest efficacy in mitigating damage caused by the brinjal aphid. In addition, the Twinkle Star germplasm exhibited resistance to the leafhopper. The cultivars Twinkle Star, Dill, and Advanta-314 exhibited notable resistance to whitefly infestation. Moreover, the cultivar KHB-202 was identified as showing a deterrent effect against thrips. The results of the study reported differences in whitefly abundance among the different evaluated brinjal varieties, which have important implications for integrated pest management (IPM). Brinjal varieties that result in reduced whitefly population particularly Twinkle Star and Adventa 305 may possess characteristics that make them less favorable hosts for whitefly population buildup and colonization. Though, resistance modalities were not primarily assessed during the study, the reduced level of whitefly population on these varieties suggests a potential degree of tolerance or reduced susceptibility to whitefly attack. Therefore, varieties demonstrating lower whitefly population build up should be integrated with other IPM components such as biological control, cultural practices and need based selective insecticides to achieve effective and sustainable whitefly management in brinjal. The correlation matrix of the whitefly population with weather parameters revealed that, in both the year, the mean maximum and minimum temperatures exhibited a positive correlation ($r = 0.41$, 0.532) and ($r = 0.598$, 0.551) at Peshawar and ($r = 0.586$, 0.591) and ($r = 0.695$, 0.696) at Mansehra during 2020 and 2021 respectively, indicating that elevated temperatures accelerated pest multiplication. In contrast, the relative humidity and rainfall generally exerted a negative effect, likely through direct interference with the adult activity, oviposition and survival as well as through indirect effects on host phenology. These results are in line with work of Mahore *et al*. (2022), who examined the relationship between meteorological parameters and the whitefly population in different brinjal varieties. The correlation analysis revealed a positive correlation for maximum temperature, minimum temperature, and humidity with values of $r = 0.61$, $r = 0.86$, and $r = 0.55$ respectively during 2021. In the following year, 2022, positive correlations were again noted, with values of $r = 0.72$, $r = 0.93$, and $r = 0.82$ associated with maximum temperature, minimum temperature, and humidity, respectively. The current results are further aligned with previous studies (Devi *et al*. 2015), reporting that climatic factors play a significant role in shaping insect pest population. Although, Devi *et al*. (2015) investigated the population dynamics of jassids rather than whitefly, they similarly observed a significant positive correlation between the jassid population and both maximum and minimum temperatures. In the same way, Pal *et al*. (2019) investigated the population dynamics of major insect pests of brinjal, including jassid and shoot and fruit borer. In their study, jassid population demonstrated a noteworthy positive correlation with maximum temperature (r = 0.77) and minimum temperature (0.79). Additionally, the present findings regarding the effect of weather parameters on whitefly population are in close agreement with the results reported by Sushmetha and Hariprasad (2020) and Ayyanar *et al.* (2022). The results regarding the effect of weather parameters on whitefly abundance are further in line with the work of Sahito *et al*. (2012) whose results regarding the regression analysis indicated a statistically non-significant negative correlation between the whitefly population and temperature, while a highly significant negative correlation was observed with relative humidity. Similarly, Devi *et al*. (2015) and Mahore *et al*. (2022), who examined the relationship between meteorological parameters and the whitefly population in different brinjal varieties and reported positive correlation of whitefly abundance with both maximum and minimum temperature as well as with evaporation. The strong relationship between whitefly abundance and weather parameters highlights the potential for climate-based forecasting models in whitefly management. Such forecasting system when integrated with resistant cultivars and biological control strategies, could substantially improve pest suppression while minimizing indiscriminate insecticide use. Overall, the present findings demonstrate that monitoring of whitefly population, coupled with meteorological parameters, provides a strong foundation for sustainable whitefly management in brinjal. Future studies should focus on the detailed characterization of morphological and biochemical resistance traits in promising varieties such as Twinkle Star and Adventa 305, as well as the development of the robust forecasting models for incorporation into location-specific IPM programs.

Conclusion

The study demonstrated that weather parameters significantly contributed to whitefly infestation across different brinjal varieties. The population dynamics of whitefly were found to be influenced by environmental factors, particularly temperature and relative humidity, with variation in their effects between Peshawar and Mansehra districts. The study further revealed that that the brinjal variety Twinkle Star exhibited comparatively greater resistance to whitefly infestation, with a significantly lower mean infestation level. Overall, the study emphasized the combine role of host plant variation and climatic factors in shaping whitefly population dynamics in brinjal agro-ecosystems. These findings may contribute to the development of integrated pest management (IPM) programs for sustainable brinjal production.

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Authors' Contributions

MN and MS; Methodology, data collection, writing and formal analysis. MS and AURS: Conceptualization, editing and supervised the entire research work. SS and SAK help in revising and editing the manuscript.

Conflict of Interests

All the authors declare that they have no competing interest related to this article.

Data Availability

The data supporting the present study are available from the corresponding author upon reasonable request.

Ethics Approval

Not applicable to this study.

References

Abbas A, J Iqbal, A Zeshan, Q Ali, I Nadeem, H Malik, T Nazir, MF Akhter, BB Iqbal (2022). Lethal and sublethal effects of Flonicamid (50 WG) and Spirotetramat (240 SC) on *Bemisia tabaci* (Homoptera: Aleyrodidae): An age-stage two sex life table study. *Phytoparasitica* 50:727–742 https://doi.org/10.1007/s12600-022-01002-5

Anjali M, NP Singh, M Mahesh, S Swaroop (2012). Seasonal incidence and effect of abiotic factors on population dynamics of major insect pests on brinjal crop. *J Environ Res Dev* 7:431–435

Antignus Y, D Nestel, S Cohen, M Lapidot (2001). Ultraviolet-deficient greenhouse environment affects whitefly attraction and flight behavior. *Environ Entomol* 30:394–399

Arif A, M Salim, HA Shah, AUR Saljoqi, S Sattar, A Usman (2024). Varietal evaluation and testing of synthetic insecticides against peach aphids (*Myzus persicae* Sulzer) under field conditions at ARI, Mingora Swat. *Intl J Agric Sustain Dev* 6:223–237

Ayyanar S, C Chinniah, A Debbarma, N Murugesan (2022). Studies on seasonal incidence of sucking pests as influenced by abiotic factors on brinjal. *J Appl Entomol* 2:1–5

Chandan MK (2018). Incidence and evaluation of newer insecticides against shoot and fruit borer (*Leucinodes orbonalis*). *M.Sc. thesis*, pp:1–104. Department of Entomology, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C.G.), Faculty of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh)

Devi P, TK Sahu, RM Ahirwar, P Bhagat (2015). Population dynamics of major insect pests and natural enemies on brinjal crop and effect of abiotic factors on its dynamics. *Environ Ecol* 21:1421–1425

García-Salas P, A Morales-Soto, A Segura-Carretero, A Fernández-Gutiérrez (2010). Phenolic compound extraction systems for fruit and vegetable samples. *Molecules* 15:8813–8826

Habib K, IA Khan, MSR Akbar, A Farid, I Ali, M Alam (2015). Response of brinjal (*Solanum melongena* L.) genotypes against insect pests in Peshawar, Pakistan. *J Entomol Zool Stud* 3:423–427

Iqbal J, A Sohail, Z Abdin, AH Anjum (2002). Toxicity of tracer 240 SC on haemocytes of last larval instar of brinjal fruit borer *Leucinodes orbonalis* (Guen.). *Pak Entomol* 24:115–119

Jafir M, M Shehzad, Q Abbas, J Nazeer, AA Ahmad, Y Ali, MW Javed (2018). Germplasm screening of brinjal (*Solanum melongena* L.) cultivars for resistance to sucking insect pests. *J Entomol Zool Stud* 6:1134–1137

Khan MMH (2019). Effect of temperature and relative humidity on the population dynamics of brinjal and tomato infesting whitefly, *Bemisia tabaci*. *Jahangirn Univ J Biol Sci* 8:83–86

Leite GLD, M Picanço, GN Jham, MD Moreira (2005). Whitefly population dynamics in okra plantations. *Pesq Agropec Bras* 40:19–25

Liu TX (2000). Population dynamics of *Bemisia argentifolii* (Homoptera: Aleyrodidae) on spring collard and relationship to yield in the Lower Rio Grande valley of Texas. *J Econ Entomol* 93:750–756

Mahore P, P Singh, NS Bhadauria, SS Pippal, D Mahor (2022). Seasonal activity of major sucking insect pests on brinjal (*Solanum melongena* L.) and correlation with abiotic factors. *Biol Forum Intl J* 14:1446–1452

Michael RHG (2004). Ecological studies on the whitefly, *Bemisia tabaci* (Genn.) on some vegetable crops (Homoptera: Aleyrodidae). *Egypt J Agric Res* 82:631–646

Nadeem M, AUR Saljoqi, M Salim (2025). Age-stage two-sex life table study of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) on three brinjal varieties in Pakistan. *Intl J Agric Biol* 34:340608

Nagar J, SK Khinchi, KC Kumawat, A Sharma (2017). Screening of different varieties of okra against sucking insect pests. *J Pharmacogn Phytochem* 6:30–34

Pal S, P Karmakar, A Chattopadhyay, SK Ghosh (2021). Evaluation of tomato genotypes for resistance to whitefly (*Bemisia tabaci* Gennadius) and tomato leaf curl virus in eastern India. *J Asia Pac Entomol* 24:68–76

Rafiq M, A Ghaffar, M Arshad (2008). Population dynamics of whitefly (*Bemisia tabaci*) on cultivated crop hosts and their role in regulating its carry-over to cotton. *Intl J Agric Biol* 10:577–580

Sahito HA, GH Abro, SA Memon, B Mal, R Mahmood (2012). Influence of abiotic factors on population development of *Bemisia tabaci* infesting *Abelmoschus esculentus*. *Intl Res J Plant Sci* 3:12–18

Salim M, A Arif, M Ayaz, AUR Saljoqi, A Gökçe, H Khan, SA Khan (2025). Impact of synthetic insecticides on the life table parameters of *Trichogramma chilonis* under laboratory conditions. *Sci Rep* 15:3900

Salim M, A Gökçe, A Bakhsh (2022). Demographic study of imidacloprid-resistant Colorado potato beetle, *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae) fed on transgenic and commercial potato cultivars. *Phytoparasitica* 50:201–221

Saljoqi AUR, S Amin, M Salim, T Nawaz, F Anjum (2022). Pesticide residue analysis of three different pesticides used against *Helicoverpa armigera* (Hubner) in tomato crop. *Sarhad J Agric* 38:448–455

Saljoqi AUR, M Salim, I Ahmad (2021). Management of garlic thrips, *Thrips tabaci* Linderman (Thysanoptera: Thripidae) through different pest management techniques in garlic crop. *Sarhad J Agric* 37:359–368

Savopoulou-Soultani M, NT Papadopoulos, P Milonas, P Moyal (2012). Abiotic factors and insect abundance. *Psyche* 2012:1–2

Shankar RVR, LV Venkataraman (2017). Eggplant (*Solanum melongena* L.): A versatile vegetable. *Crit Rev Food Sci Nutr* 57:3059–3070

Sushmetha V, Y Hariprasad (2020). Influence of seasonal variation on incidence and population dynamics of whitefly (*Bemisia tabaci*) on brinjal. *Plant Cell Biotechnol Mol Biol* 21:28–32

Watson S (2021). *Health benefits of eggplant*. WebMD.

Yousafi Q, M Afzal, M Aslam, AD Abid (2018). Effect of infested shoot removal and light trap on brinjal shoot and fruit borer (*Leucinodes orbonalis*) infestation on brinjal fruit (*Solanum melongena* L.). *Pak J Zool* 50:2115–2118

Zada H, B Ahmad, E Hassan, AUR Saljoqi, H Naheed, M Salim (2018). Toxicity potential of different azadirachtin against *Plutella xylostella* (Lepidoptera: Plutellidae) and its natural enemy *Diadegma* species. *J Agron Agric Sci* 1:1-7 https://doi.org/10.24966/AAS-8292/100003