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Seasonal Regression analysis of whitefly, *Bemisia tabaci* (Gennadius) on Bt cotton in relation to abiotic factors

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Abstract
The study was conducted on whitefly in Bt cotton at Research Farm of Cotton Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during *kharif* 2014 and 2015. The aim of this study was to quantify the whitefly dynamics on Bt cotton with prevailed weather conditions. To mitigate the loss due to whitefly attack and better yield, regression analysis of pest population and pertinent external climatic information is paramount. Regression analysis was carried out with SPSS software V19. In the present studies, R^2 was found with a range of 0.00 to 0.80 i.e. population of whitefly was influenced up to 80 per cent by the simple, multiple, stepwise and hierarchical linear regression models under Hisar conditions. Simple linear regression model during 2014 and 2015 revealed that morning relative humidity (RH_m) had a higher impact on incidence of whitefly. In the multiple linear regression model, the impact of weather factors on the whitefly in Bt cotton during 2014 exerted 64.90 per cent, 79.50 per cent during 2015 role in the whitefly population fluctuation. In stepwise linear regression model, only morning relative humidity (RH_m) exerted (37.70 and 28.90 per cent) the fluctuation of whitefly population during 2014 and 2015, respectively. Hierarchical linear regression models revealed that the impact on the fluctuation of whitefly population increases with the addition of the influence of weather parameters in both the years.

Keywords: Bt cotton, Pest dynamic, Regression models, Weather impact, Whitefly

Introduction
Whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is an important sucking pest of cotton and was first observed in the late 1920s and early 1930s by [1] in northern India (now part of Pakistan). It is a highly polyphagous insect, has become serious, causing heavy losses during certain years [2, 3]. This pest cause damage by two ways: (a) the vitality of the plant is lowered through the loss of cell sap, in heavy infestation it has the potential to remove significant amounts of phloem sap resulting in the reduction of plant vigour and (b) honeydew excreted by the insect interfere in normal photosynthesis with growth of sooty mould, it also reduces the quality and marketability of harvest products [4]. Cotton leaf curl virus is also transmitted through the whitefly, which causes significant yield losses if occur in the early stages of crop growth [5]. There has been a considerable change in the scenario of whitefly of cotton in Northern India due to increase in area under upland cotton replacing the Asiatic cotton. Large scale cultivation of high yielding varieties/hybrids which are highly susceptible to sucking pests as excessive use of inputs like pesticides and fertilizer are required. Keeping in view, the existing situation of outbreaks of piercing sucking insects on Bt cotton, there is a need to develop an effective and sound pest- management program, that is well suited to the ecological conditions, particularly the weather factors, which play a key role in the multiplication and distribution of pest insects. Keeping this rationale in view, a experiment has been planned to study an overall population situation of sucking insect pests of Bt cotton but also to sort out the exact nature/degree of relationship between pest population and weather factors, with ultimate aim to help the entomologist to develop the best IPM strategy for the control of the notorious insect pests of cotton.

Materials and Methods
The research was conducted at Cotton Research Area, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar during *kharif* 2014 and 2015.

There are 21 Bt genotypes raised in plot size of 5 rows of 5 m under recommended agronomic practices to study the effect of weather factors on the population of whitefly. No plant protection measures were applied throughout the season. The population of whitefly was recorded at weekly intervals with the initiation of pest and continued till the end of crop growth from 5 randomly selected plants with three replicates. Whiteflies were counted from three leaves, each from top, middle and bottom canopies of the plant. Environmental factors data regarding maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, average wind speed, sunshine hours and rainfall were collected from Department of Agricultural Meteorology, CCS HAU, Hisar. Both year's and average data regarding whitefly and weather were subjected to different regression analysis to know the relationship between pest incidence and weather parameters.

Results and Discussion

In order to understand the relative importance of selected weather parameters in explaining the fluctuation of the population of whitefly, the partial regression coefficients of pest population on weather parameters were computed taking the population of whitefly as dependent variables and maximum & minimum temperature, morning & evening relative humidity, rainfall, average wind speed and sunshine hours as independent variables. In a simple regression analysis (table 1) the impact of weather factors on the population of whitefly in Bt genotypes during 2014 showed that morning relative humidity exerted 37.70 per cent role in the whitefly population variation which was the highest than any other factors and which was followed by maximum temperature (33.30 per cent). Similarly, in 2015, the morning relative humidity contributed 28.90 per cent followed by evening related humidity (24.90 per cent) and minimum temperature (24.70 per cent) to the increment of whitefly population. In the pooled analysis, morning relative humidity was most important factor which contributed maximum i.e. 44.90 per cent in the fluctuation of whitefly population followed by maximum temperature (31.30 per cent) and evening relative humidity (30.90 per cent). The impact of morning & evening relative humidity were positive while maximum temperature had a negative impact on the whitefly population during both the years.

The multiple linear regression analysis presented in the table 2 indicated that the total influence of all the weather parameters was high in the population of whitefly. It was upto 64.90, per cent on the population of whitefly during the 2014 and upto 79.50 per cent during 2015. In pooled an analysis, all weather parameters exerted 79.60 per cent of variation in the whitefly population.

The stepwise linear regression model regarding the impact of weather factors on whitefly population in Bt genotypes showe in the table 3. The results revealed that only morning relative humidity was most important factor which contributed 37.70 and 28.90 per cent during *kharif* 2014 and 2015 and in pooled analysis the impact was 44.90 per cent due to the morning relative humidity.

The hierarchical linear regression analysis indicated that the relative importance of weather parameters in explaining the variation of the whitefly population as presented in table 4. The impact of weather factors on the population of whitefly in Bt genotypes during 2014 showed that the maximum temperature exerted 33.30 per cent influence on whitefly population. This fluctuation was increased and reached up to 34.90 per cent when the influence of minimum temperature was added. When, morning and evening relative humidity, average wind speed, sunshine hours and rainfall added, than the impact was 38.60, 41.10, 41.30, 64.70 and 64.90 per cent on the whitefly population fluctuation with the addition of the weather parameters. While, in 2015 season the maximum temperature exerted 17.40 per cent of the fluctuation on whitefly, which was lower than previous year. When the influence of the minimum temperature, morning and evening relative humidity, average wind speed, sunshine hours and rainfall added, than they impact 37.40, 38.40, 46.40, 47.30, 52.40 and 79.50 per cent fluctuation on whitefly population. Under pooled analysis of both the years, weather parameters exerted 31.30 to 79.60 per cent to the variation of whitefly population.

The results of [6] who reported that rainfall showed 8.5 per cent influence in the population of whitefly, increased up to 33.5 per cent when the influence of temperature and if relative humidity influence added than the impact was 66.4 per cent on the variation of whitefly population favors the present study. Similarly, [7-9] who reported that weather factors showed a significant role in population fluctuation of pest. These results are also partially similar to the findings of [10] who reported that the minimum temperature exerted maximum role 31.2 and 11.3 per cent during 2010 and 2011, respectively. [11] Evaluated multiple linear regression analysis and found that the total influence of all the weather parameters was up to 60.26 per cent variation of whitefly population.

Thus, the various meteorological parameters had a profound influence on the incidence and population buildup of whitefly in Bt cotton and the findings will indicate the importance of weather factors in pest forecasting.

Table 1: Simple regression models along with coefficient of determination of individual weather factor on the population fluctuation of whitefly on Bt genotypes

Year	Regression Equation	100 R^2
2014	Y = 254.51 – 5.97Tmax	33.30
	Y = 61.95 – 1.18Tmin	1.10
	Y = -79.71 + 1.51RHm	37.70
	Y = -19.56 + 1.13RHe	23.30
	Y = 37.72 – 0.89WS	0.30
	Y = 24.60 + 0.99SS	0.60
	Y = 30.59 + 0.11RF	0.60
2015	Y = 241.30 – 5.71Tmax	17.40
	Y = -120.62 + 6.45Tmin	24.70
	Y = -121.46 + 1.95RHm	28.90
	Y = -16.80 + 1.03RHe	24.90
	Y = 5.02 + 4.88WS	8.70
	Y = 56.32 – 2.69SS	5.00
	Y = 42.79 – 0.29RF	6.10
Pooled	Y = 301.15 – 7.30Tmax	31.30
	Y = -31.01 + 2.62Tmin	5.40
	Y = -139.73 + 2.25RHm	44.90
	Y = -32.46 + 1.36RHe	30.90
	Y = 26.17 + 1.25WS	0.40
	Y = 49.88 – 2.13SS	2.10
	Y = 41.62 – 0.46RF	7.30

Table 2: Multiple regression models along with coefficient of determination of individual weather factor on the population fluctuation of whitefly on Bt genotypes

Year	Regression Equation	100 R^2
2014	Y = 290.95 – 13.29Tmax + 8.13Tmin – 1.89RHm + 1.78RHe – 2.85WS + 14.69SS – 0.10RF	64.90
2015	Y = -415.68 – 1.23Tmax + 12.69Tmin + 2.81RHm – 1.00RHe + 0.08WS + 3.57SS – 0.77RF	79.50
Pooled	Y = -101.68 – 7.89Tmax + 10.33Tmin + 0.81RHm + 0.73RHe – 3.27WS + 13.05SS – 0.35RF	79.60

Table 3: Stepwise regression models along with coefficient of determination of individual weather factor on the population fluctuation of whitefly on Bt genotypes

Year	Regression Equation	100 R^2
2014	Y = -79.71 + 1.51RHm	37.70
2015	Y = -121.46 + 1.95RHm	28.90
Pooled	Y = -139.73 + 2.25RHm	44.90

Table 4: Hierarchical regression models along with coefficient of determination of individual weather factor on the population fluctuation of whitefly on Bt genotypes

Year	Regression Equation	100 R^2
2014	Y = 254.51 – 5.97Tmax	33.30
	Y = 235.65 – 6.51Tmax + 1.54Tmin	34.90
	Y = -45.86 – 1.27Tmax + 1.13Tmin + 1.30RHm	38.60
	Y = -51.96 – 3.52Tmax + 4.69Tmin + 2.05RHm – 1.23RHe	41.10
	Y = -65.12 – 3.49Tmax + 4.75Tmin + 2.19RHm – 1.36RHe + 0.95WS	41.30
	Y = 323.41 – 14.17Tmax + 8.76Tmin – 2.02RHm + 1.68RHe – 3.47WS + 14.97SS	64.70
	Y = 290.95 – 13.29Tmax + 8.13Tmin – 1.89RHm + 1.78RHe – 2.85WS + 14.69SS – 0.10RF	64.90
2015	Y = 241.30 – 5.71Tmax	17.40
	Y = 70.10 – 4.92Tmax + 5.85Tmin	37.40
	Y = -42.53 – 2.82Tmax + 4.93Tmin + 0.74RHm	38.40
	Y = -73.06 – 6.38Tmax + 11.70Tmin + 1.84RHm - 1.86RHe	46.40
	Y = -106.09 – 6.03Tmax + 11.24Tmin + 2.21RHm – 2.09RHe + 2.18WS	47.30
	Y = -63.73 – 7.84Tmax + 11.38Tmin + 1.69RHm – 1.29RHe – 0.04WS + 4.65SS	52.40
	Y = -415.68 – 1.23Tmax + 12.69Tmin + 2.81RHm – 1.00RHe + 0.08WS + 3.57SS – 0.77RF	79.50
Pooled	Y = 301.15 – 7.30Tmax	31.30
	Y = 233.92 – 8.01Tmax + 3.85Tmin	42.60
	Y = -148.88 – 1.02Tmax + 2.63Tmin + 1.99RHm	49.80
	Y = -169.89 – 3.56Tmax + 7.61Tmin + 2.82RHm – 1.56RHe	52.90
	Y = -182.09 – 3.88Tmax + 7.96Tmin + 3.08RHm – 1.85RHe + 1.77WS	53.30
	Y = -23.01 – 10.08Tmax + 11.47Tmin + 0.28RHm + 0.97RHe – 6.40WS + 15.32SS	77.20
	Y = -101.68 – 7.89Tmax + 10.33Tmin + 0.81RHm + 0.73RHe – 3.27WS + 13.05SS – 0.35RF	79.60

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