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Full Length Research Paper

The correlation of abiotic factors and physico-morphic charateristics of (*Bacillus thuringiensis*) *Bt* transgenic cotton with whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae) and jassid, *Amrasca devastans* (Homoptera: Jassidae) populations

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Nine (*Bacillus thuringiensis*) *Bt* genotypes (Bts-496, FH-113, CP-1401, I-2015, I-2086, CP-1402, VH-255, MG-3 and I-802) and non-transgenic genotype CIM-496 (control), were sown in an RCBD with a plot size of 206 x 170 ft to determine the correlation of abiotic factors and physico-morphic characters of Bt cottons with whitefly, *Bemisia tabaci* (Homoptra: Aleyrodidae) and jassid, *Amrasca devastans* (Homoptera: Jassidae), populations. The results suggest that maximum population of the whitefly and jassid was observed on transgenic genotypes VH-255 and I-2086, respectively; while, the lowest population was recorded on control. The results, showed whitefly and jassid populations to be positively correlated with the temperature. The correlation between the relative humidity was found to be negative for both the whitefly and jassids. The rainfall had a positive effect on the whitefly and negative effect on the jassids. The effect of physico-morphic characteristics of transgenic and non-transgenic varieties had similar kind of varied relationship with the whitefly and jassids. For example, the trichome-density on the leaf-lamina, midrib and veins had positive and significant correlation with the whitefly. In contrast, it is non-significant and negatively correlated with the jassids population. The varieties having thick leaf lamina showed non-significant negative response for the whiteflies population, and significant positive correlation with the jassids.

Key words: Cotton, *Bemisia tabaci*, *Amrasca devastans*; abiotic factors, physico-morphic plant chararters.

INTRODUCTION

Cotton is an important cash crop and a significant source of foreign exchange earnings. It contributes to about 7.5% of the value added goods in agriculture and about 1.6 % to the GDP (Anonymous, 2008). It is vulnerable to attack from a large number of insect-pests, throughout its growth period. The insects damage cotton to the tune of 39.50% (Naqvi, 1975; Chaudhry, 1976).

Large amounts of broad-spectrum chemical insectcides are used to control the key pests of cotton, such as, *Heliothis virescens* (Fabricius), and the pink bollworm, *Pectinophora gossypiella* (Saunders). This not only creates health problems and environmental pollution, but also develops insecticidal resistance in insects (Mohyuddin et al., 1997).

As such, an alternate control-methodology must develop. One option is the use of insect resistant, genetically-engineered (GE) varieties, that express lepidopteron-active Cry proteins, such as, (Cry1Ab) and (Cry1Ac), derived from the soil bacterium, *Bacillus thuringiensis* (Bt). The so-called Bt cotton-plants are presently consider a promising means of managing the

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bollworms (Lawo et al., 2009).

Due to the reduction of broad-spectrum insecticides, in Bt cotton, non-target pests, with piercing-sucking mouth-parts, such as, leaf bugs, cotton spider mites, cotton aphids, and whiteflies, survive better and occasionally, reach a pest status (Xu et al., 2008).

Bemisia tabaci (Genn.) is a key pest of many field and horticultural crops, throughout the subtropical regions of the world (Naranjo, 2001, Bayhan et al., 2006). It damages the plants directly by depriving the host-plants of their nourishment, because it constantly sucks the cell-sap. The result is about a 50% reduction in the boll formation as well as the transmition of the viral diseases. It is found to play a significant role in the spread of CLCuV (Malik et al., 1999). Jassid is very much devastating and creates a considerable loss to the crop by not only by sucking the cell sap but also by inducing toxic materials, into the leaves, which cause a 4.45% reduction in the cotton yield (Bhat et al., 1986).

Keeping in view, the existing situation of outbreaks of piercing sucking insects on Bt cotton, there is a direct need to develop an effective and sound pest-management program, that is well suited not only to the ecological requirements, particularly the weather factors, which play a key role in the multiplication and distribution of insect-pests and but also to evaluate the physico-morphic make up of the Bt cotton-varieties, viz., trichome-density, number of gossypol-glands, the length of hair and thickness of the leaf-lamina in relation to pest-resistance.

But, work done in this regard, is still quite sketchy and needs more extensive research. Thus, owing to the lack of information, on this side, the present study was undertaken to find out the exact nature or degree of relationship between the pest-population and weather factors as well as the physico-morphic traits of different transgenic cotton varieties, in relation to resistance to these non-target pests (whitefly and jassid), with ultimate aim of helping the pest management specialist/breeders to formulate a specific IPM strategy by incorporating specific element(s) in the breeding material.

MATERIALS AND METHODS

The present study was carried out at the Entomological Research Area, University of Agriculture, Faisalabad (Punjab), Pakistan to determine the effect of abiotic factors on the population of jassids and whiteflies, on different transgenic genotypes of cotton and also to determine the degree of antibiotic-resistance of different cotton cultivars, against the sucking pests, based on their physico-morphic traits.

For this purpose, nine Bt genotypes and one non-Bt genotyp of cotton (Bts-496, FH-113, CP-1401, I-2015, I-2086, CP-1402, VH-255, MG-3, I-802, and CIM-496 respecitively), were sown on the 28th May, 2008. The experiment was laid out in a randomized complete block design (RCBD), with ten treatments, having three replications each. The plot-size for each treatment was 206, with a plot size 51.81 m with row to row and plant to plant distance of 0.83 and 0.25 m, respectively. No plant protection measures were applied throughout the season, but only standard and recommended agronomic practices, were given, as and when required.

Population density count

Population of jassids and whiteflies, were recorded, early in the morning at weekly intervals. Fifteen leaves were randomly selected from 15 plants from each plot, in such a way, that one upper leaf from the first plant, one middle leaf from the second and one bottom leaf from third plant, and so on, were considered for the data count.

Meteorological data, regarding the mean daily-temperature, relative-humidity and rainfall, were taken from the Department of Crop Physiology, University of Agriculture, Faisalabad.

Physico-morphological characters

Three plants were selected, at random, from each plot, and one leaf from the top, middle and bottom parts of each, taken to study the trichome-density, number of gossypol-glands, length of hair and thickness of the leaf-lamina on its midrib as well as on its veins counted from the lower side of the leaves, under a binocular microscope from three different places of each leaf. The length of midrib and veins, thus, chosen was 1 cm; whereas, the area of leaf-lamina was 1 cm^2. For this purpose, an iron-dye of 1 cm^2 was used. The cross-section of each leaf was cut with the help of a fine razor and the thickness of leaf-lamina, determined from 3 different sites of each leaf, with the help of an ocular micrometer, under a CARL ZEISS binocular microscope.

Statistical analysis

Data were analyzed statistically and means were compared by Duncan's multiple range test (Steel and Torrie, 1980). The significant level was set at $P<0.05$. Simple correlation was worked out between population-fluctuations of the pests with those of the weather factors as well as with those of physico-morphic characters of the plant.

RESULTS AND DISCUSSION

Whitefly (*B. tabaci*)

Population of the whitefly per leaf on the transgenic genotypes of cotton

Overall mean values for the population of whitefly on different genotypes of cotton being tested is shown Figure 1. The maximum population of whitefly was found to be 3.87 /leaf, on transgenic genotype VH-255 and the minimum was recorded to be 1.68 /leaf, on non-transgenic genotype CIM-496. The population, in other cases, was 2.40 and 2.35 /leaf, on FH-113 and Bts-496, respectively, which were virtually similar. However, genotypes: I-802, I-2015, MG-3, I-2086 and CP-1401 showed an intermediate trend, with a slight variation between them.

Population trend

The mean weekly estimates, on the population of whitefly, from the Ist July to the 26th of November, 2008, are presented in Figure 2. A perusal of this figure indicated that that it started rising from 3.29 insects during first week of July and reached upto 4.51,

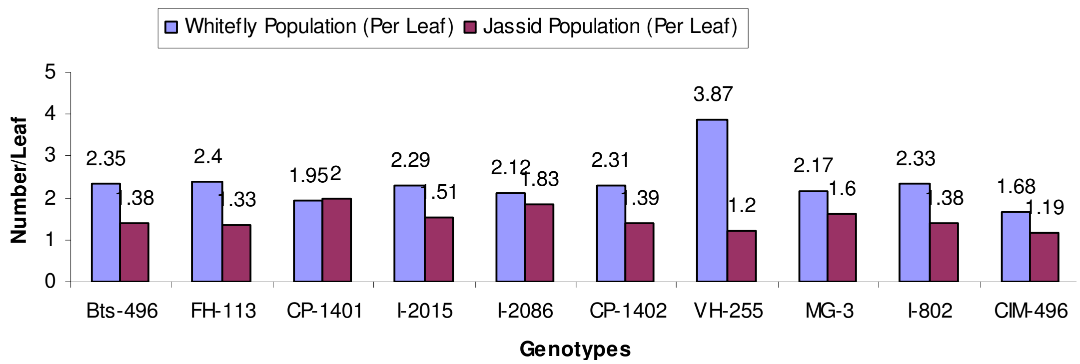

Figure 1. Mean population of the whitefly and jassids, on different transgenic genotypes of cotton.

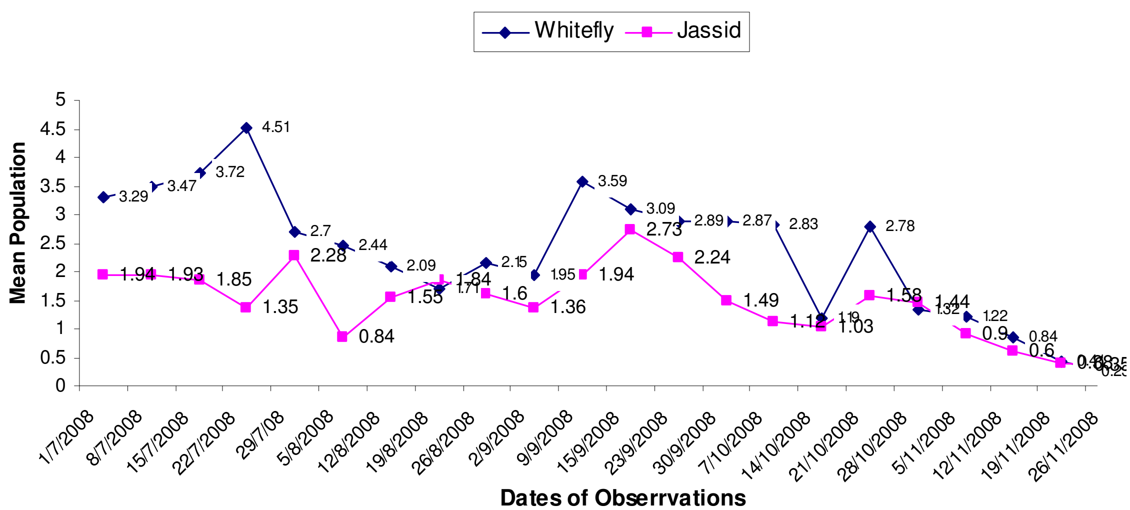

Figure 2. The fluctuations in the populations of whitefly and jassids, per leaf, during different dates, from 1st of July to 26th of November, 2008 on different transgenic genotypes of cotton.

the highest in the third week of July. Population started decreasing continuously from the first week of August till the third week of August. The mean whitefly population started decreasing from the second week of October and reached the lowest in the third week of November, 2008.

Jassid (*A. devastans*)

Population of jassid per leaf on transgenic genotypes of cotton

An overall comparison of mean-values for the population of jassids is presented in Figure 1. A perusal of this figure, shall show maximum population of jassid was 2.00 /leaf, recorded on transgenic genotype CP-1401 and the minimum population was found to be 1.19 /leaf, on non-transgenic genotype CIM-496. There was, however, an intermediate position of population, that is, 1.51 jassids per leaf recorded on I-2015. The genotypes I-2086 and MG-3 had more than an intermediate population of jassids that is, 1.83 and 1.66 individuals, per leaf, respectively.

Population trend

The weekly trend, in the population fluctuation of jassids, like those of whitefly, from Ist July to 26th November, 2008 is displayed in Figure 2. A perusal of this figure, indicated that the population of jassids, started to buildup from the first week of July and continued uptill the third week of November. The maximum population of jassids, was recorded to be 2.73 and 2.24 individuals, per leaf, on the second and third week of September. The lowest population of jassids, was, however, seen to be 0.35 and 0.38, on the third and fourth week of November, 2008, respectively.

Table 1. Correlation coefficient of environmental factors and population of whitefly and jassid on different transgenic genotypes of cotton.

Genotypes	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	
	Whitefly	Jassid	Whitefly	Jassid	Whitefly	Jassid
Bts-496	0.577**	0.597**	-0.085	-0.189	0.529	0.167
FH-113	0.528*	0.470*	-0.357	-0.313	-0.027	-0.093
CP-1401	0.504*	0.722**	-0.356	-0.08	0.101	0.059
I-2015	0.406*	0.496*	-0.326	-0.251	-0.052	-0.074
I-2086	0.476*	0.633**	-0.352	-0.231	0.075	-0.132
CP-1402	0.610**	0.533*	-0.133	-0.306	0.479*	-0.116
VH-255	0.727**	0.432*	-0.401	-0.411	0.207	-0.179
MG-3	0.501*	0.521*	-0.231	0.772	0.182	-0.012
I-802	0.658**	0.582**	-0.178	0.077	0.355	-0.125
CIM-496	0.472*	0.387	-0.336	0.071	-0.094	-0.108

* = Significant (P<0.05), ** = Highly significant (P<0.01).

Table 2. A multiple comparison of means values of different physico-morphic plant characters of different genotypes of cotton.

Genotypes	Trichome density			Gossypol glands			Length of hair			Thickness of lamina (mm)
	Lamina (cm^{-2})	Midrib (cm^{-1})	Vein (cm^{-1})	Lamina (cm^{-2})	Midrib (cm^{-1})	Vein (cm^{-1})	Lamina (mm)	Midrib (mm)	Vein (mm)	
Bts-496	389.5h	825.85c	207.9c	29.00a	20.89c	20.89c	3.80bc	4.08ab	2.73ab	87.22c
FH-113	418.5b	284.3b	237.8b	58.89d	36.12a	36.12a	4.20ab	3.63bc	2.90a	83.88c
CP-1401	205.2g	144.8f	134.9g	38.00c	23.55bc	23.55bc	3.13c	2.20ef	1.66de	45.45f
I-2015	365.2	220.8cd	185.1e	47.44b	31.55ab	31.55ab	3.37c	3.37c	2.00cd	71.38d
I-2086	323.8 f	207.0e	144.8f	38.33c	24.88bc	24.88bc	3.13c	2.33ef	1.90cde	56.05e
CP-1402	324.8f	214.3de	191.0de	43.22bc	27.55bc	27.55bc	3.46bc	3.30c	2.20cd	74.61d
VH-255	464.6a	294.79a	275.8a	62.89a	38.66 a	38.66a	4.60a	4.30a	3.06a	98.56b
MG-3	335.4ef	208.4e	182.0e	43.11bc	25.22bc	25.22bc	3.33c	2.72de	2.00cd	68.77d
I-802	341.7e	221.8cd	198.8d	47.00b	31.11ab	31.11ab	3.66bc	3.20cd	2.36bc	110.3a
CIM-496	130.1h	98.0g	88.55c	50.89b	32.11ab	32.11ab	3.04c	1.93f	1.43e	32.29g

Correlation of the fluctuation in the population of whitefly on transgenic genotypes of cotton; with those of weather factors

The data on the above estimates are displayed in Table 1, which shows that there was a significant and positive correlation between temperature variations and the variations in the population of the whitefly on all genotypes; whereas the humidity had a non-significant and negative correlation with the whitefly population, on all genotypes.

These findings are in agreement with the findings of Rote and Pure (1991) and Wahla et al. (1996) who reported a positive and negative correlation of the whitefly population with temperature and relative humidity, respectively.

A non-significant and positive correlation between the rainfall and whitefly population was found among all genotypes, except among CP-1402, which had a significant positive correlation, while, CIM-496 (non-transgenic genotype), FH-113 and I-2015 had a non significant and negative correlation with the rainfall.

The present finding is in conformity with the result, demonstrated by Jalal et al. (2006) that whitefly population is positively correlated with the rainfall. The results of Bashir et al. (2001), who concluded that rainfall negatively correlated with whitefly population, however, disfavor the present study.

Correlation of the fluctuation in the population of jassid on transgenic genotypes of cotton; with those of weather factors

The data with reference to above estimates are displayed in Table 2, which indicates a positive correlation between air temperature and jassid population, on all genotypes. The relative humidity, however, showed a non-significant and negative correlation with the jassid population on all genotypes except on CIM-496 (control), MG-3 and I-802

Table 3. Correlation coefficient for the fluctuations in the population of whitefly and jassids, on different transgenic genotypes of cotton, with those of their physico-morphic characters.

Character	Whitefly (a)	Jassid (b)
Trichome density		
Leaf lamina	0.771**	-0.016^{ns}
Leaf midrib	0.716**	-0.005^{ns}
Leaf vein	0.765**	-0.010^{ns}
Gossypol glands		
Leaf lamina	0.819**	-0.014^{ns}
Leaf midrib	0.807**	-0.139^{ns}
Leaf vein	0.070^{ns}	-0.569^{ns}
Length of hair		
Leaf lamina	-0.010^{ns}	-0.393^{ns}
Leaf midrib	0.252^{ns}	-0.122^{ns}
Leaf vein	0.141^{ns}	-0.293^{ns}
Thickness of leaf lamina	0.283^{ns}	-0.776**

*: Significant (P<0.05); **: Highly significant (P<0.01); ns: Non-significant.

which showed a positive correlation with the jassid population. These findings are in agreement with those of Wahla et al. (1996), while not in agrrement with the results of Gogoi et al. (2000), who concluded that the relative humidity favors the jassid population.

Rainfall also showed a non-significant and positive correlation with the jassid population, on almost all genotypes, except on CP-1401 and Bts-496. These results agree with those of Riaz et al. (1987) and Bashir et al. (2001).

Physico-morphic plant character

The results on the above estimates are displayed in Table 3. A perusal of this table shows that all the morphological plant-traits significantly, vary among the plant genotypes.

Correlation of the fluctuation in the population of whitefly, with those of the physico-morphic plant-characters

The above information is contained in Table 3. A perusal of this table revealed that the whitefly population had a positive and significant correlation with the trichome-density and gossypol-glands on the leaf lamina, midrib and vein. The results of Chu (2000) and Chu et al. (2003) are similar to those of our findings. Parveez et al. (1997), who reported that gossypol-glands, showed positive correlation with the whitefly population, is in agreement except, where they reported a positive and non-significant correlation with the thickness of leaf-lamina and length of hair on the midrib and vein, on leaf-lamina that showed a negative and non-significant correlation with the whitefly population. It is similar to the findings that the length of hair is positively correlated with the whitefly (Ali and Ali, 1991). Bashir et al. (2001), who reported a positive correlation with the thickness of leaf-lamina also favors the present study.

Correlation of the fluctuation in the population of jassid, with those of the physico-morphic plant-characters

The information on the above estimates is displayed in Table 3. A perusal of this table shall show a negative and non-significant correlation, not only between the jassid-population and trichome-density, but also the gossypol-glands and length of hair, on the leaf-lamina, midrib and vein. Jassid-population in this case, showed a negative and significant correlation with the thickness of leaf-lamina. Ali et al. (1999), Bashir et al. (2001) and Aheer et al. (1999) reported that the jassid population was negatively correlated with the hair-density, gossypol-glands, and the length of hair and thickness of the leaf-lamina, which is in agreement with the results of our findings.

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