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FULL LENGTH ARTICLE

Effects of plant morphology on the incidence of sucking insect pests complex in few genotypes of cotton

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Abstract The study was conducted to find the role of physico-morphic plant factors viz., number of gossypol glands, hair density, length of hair, plant height and thickness of leaf lamina per plant in fluctuating the population of thrips (*Thrips tabaci* Lind.), jassid (*Amrasca bigutella* Dist.) and whitefly (*Bemisia tabaci* Genn.) on six genotypes of cotton viz., BT-703, CIM-557, CIM-608, CIM-573, BT-3701 and FH-113. All the genotypes showed significant differences against sucking insect pest population. Whitefly adult population exhibited negative response with gossypol glands on leaf lamina, midrib and vein and also with plant height. Whitefly adult and nymphal population correlated positively with hair density on leaf lamina and vein and length of hair on leaf midrib. The nymphal and adult population of jassid showed positive correlation with gossypol glands on leaf lamina, vein and length of hair on leaf lamina, midrib and vein. Adult and nymph population of jassid revealed negative response with hair density on leaf lamina and midrib and also with plant height and leaf lamina thickness. Thrips population showed negative correlation with gossypol glands on leaf midrib, vein, length of hair on leaf lamina and vein. Thrips population correlated positively with hair density on leaf midrib, thickness of leaf lamina and plant height. The genotypes CIM-608 (3.70/leaf), CIM-608 (5.67 /leaf), BT-703(0.86/leaf), BT-703 (1.14/leaf) and FH-113 (0.34/leaf) were found to be susceptible, whereas FH-113 (2.85/leaf), CIM-557 (3.46/leaf), CIM-573 (0.40/

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leaf), CIM-557 (0.48/leaf) and BT-703 (0.08/leaf) were resistant to whitefly adult, whitefly nymph, jassid adult, jassid nymph and thrips population respectively.

1. Introduction

Cotton (*Gossypium hirsutum* L.), that's also named as "white gold" is very imperative non-food economy oriented fiber and cash crop of Pakistan. It occupies a key position as it contributes for 7.1% of value added in agriculture and about 1.5% to the GDP and due to this Pakistan ranked 4th position in the world (GOP, 2015). In Pakistan, both the cotton yield and quality have been reduced by the attack of 145 species of insect pests and a number of diseases are caused by these insects (Bo, 1992). Cotton is handicapped by both, chewing and sucking insect pests. Sucking insect pests reduces the plant vigor by sucking sap from leaves and other tender parts of cotton. In case of serious damage, drooping and wilting of leaves also occur (Abro et al., 2004). Among sucking insect pests i.e. *Bemisia tabaci* (Genn.), *Aphis gossypii* (Glover), *Thrips tabaci* (Lind.) and *Amrasca bigutella* (Dist.) cause significant loss in yield and cause 40–50% damage to the crop (Nizamani et al., 2002; Aslam et al., 2004; Amjad and Aheer, 2007). Farmers mostly rely on chemical insecticides for the control of sucking insects due to their prompt action (Soomro et al., 2000; Razaq et al., 2013). The extensive use of insecticides may result in the health hazard problems, resistance development in insects, resurgence of secondary pest, environmental pollution and interruption of natural balance (Palumbo et al., 2001; Costa et al., 2003). Therefore alternate methods are to be used for the control of sucking insect pests (Soomro et al., 2000).

Host plant resistance plays an important role in compatible with various pest control strategies of IPM (Bughio et al., 1984; Jin et al., 1999; Hua and Hua, 2001 and Khan et al., 2003). It offers an efficient control of insect pests as an environment and economically safe strategy (Pedigo, 1989; Khan and Sexena, 1998). Recent advances such as use of BT cotton varieties improve resistance levels in cotton and became an important tool for integrated pest management (IPM) program. BT can colonize and kill a variety of insect pests (De-Maagd et al., 2001).

Plant traits such as number of gossypol glands, hair density, length of hair, plant height and thickness of leaf lamina play an important role in the sustainable pest management of cotton crop by having positive and negative interactions. Amjad et al. (2009) studied five cotton cultivars viz., FH- 634, FH-643, FH-682, FS-628 and NIAB-78 for their performance against *T. tabaci*, *A. gossypii, A. bigutella* and *B. tabaci*. Cultivar FH-634 showed maximum resistant against the sucking insect pests complex. Naveed et al. (2011) evaluated the hair length and density of three cotton varieties Cyto-46, Cyto-55 and Cyto-12/91 for tolerance to *B. tabaci*, *A. bigutella* and *T. tabaci* and survival of predators and parasitoids. The total numbers of predators were significantly higher on Cyto-12/91 and Cyto-55 having > 600 trichomes per cm^2 whereas the level of parasitism remained the same on all the strains. This study revealed that the early season sucking insect pests can be managed by choosing the variety having moderate leaf hair density.

Keeping in view the work of above scientists, the present study was conducted on six (3 BT and 3 non BT) genotypes of cotton to determine the role of physico-morphic plant factors and to determine the comparative resistance and susceptibility of different cotton cultivars in fluctuating the population of *T. tabaci*, *A. bigutella* and *B. tabaci*. Although a lot of work has been done on physico-morphic interactions with insect pests little work (Khan et al., 2010 and Zia et al., 2011) is done on these cotton varieties.

2. Materials and methods

The experiment was conducted following Randomized Complete Block Design (RCBD), with plot size of 2023.43 m^2 (0.5 acre) in the research area of University College of Agriculture, University of Sargodha. Six genotypes of cotton viz., three BT (BT-703, BT-3701, FH-113) and three non-BT varieties (CIM-557, CIM-608, CIM-573) were the treatments and sown following bed sowing method keeping row to row and plant to plant distance 75 cm and 22–30 cm respectively. Three replicates, each of 6 treatments, produced a total of 18 plots. Each plot consisted of 3 rows of 10 cotton plants, for a total of 30 plants per plot.

Population of adult and nymphs per leaf of cotton whitefly, jassid and thrips were recorded early in the morning at weekly intervals. Three plants were selected randomly from each replication of each treatment and the population of jassid, thrips and whitefly were counted from upper, middle and lower portion of each plant (Arif et al., 2004). Nine plants were selected from one treatment and fifty-four plants from six treatments. Hand magnifying glass was used to count the population of sucking insect pests. A total of twenty observations regarding the population of sucking insect pests were taken for about five months during the course of the study.

For measuring plant characters three plants were chosen at random from each plot and one leaf from upper, middle and lower portion of each selected plant was cut and brought to laboratory (Sohail et al., 2003; Amjad and Aheer, 2007). The number of gossypol glands, hair density and length of hair on leaf lamina, midrib and veins was examined from lower side of the leaves under a CARL ZEISS binocular microscope MCX 100 (Austria) from three different portions of each leaf. For this purpose an iron made dye of 1 cm^2 was used (Arif et al., 2004). The area was one cm in length from midrib and veins, whereas for lamina, it was one cm^2 for determination of number of gossypol glands, hair density and length of hairs. A cross section of leaves was cut with the help of a fine razor and thickness of leaf lamina was determined in mm from three different places of each leaf by using an ocular micrometer under a binocular microscope. For plant height three plants were selected at random from each plot and their height in cm was determined with the help of meter rod.

The data were analyzed on an IBM-PC computer using Micro Stat Package. Means were separated by Honestly Significant Difference (HSD) test at 5% level of probability. Simple correlation was worked out between population density of sucking insect pests and physico-morphological characters of the plant.

3. Results

3.1. Populations of sucking insect pests on different genotypes of cotton

The numbers of sucking insects per leaf showed highly significant differences among varieties (Table 1). The highest numbers (adults and nymphs) of *B. tabaci* were observed on CIM-608 whereas lower populations were noted on FH-113 and CIM-557 respectively. The maximum number of jassid adults and nymphs was found on BT-703 while CIM-573 and CIM-557 have minimum populations. The thrips population was higher on FH-113 variety whereas it was lower on BT-703.

3.2. Physic-morphic plant characters on different genotypes of cotton

Numbers of gossypol glands on leaf lamina/cm^2, midrib and vein/cm, hair density on leaf lamina/cm^2, midrib and vein/cm, length of hair (mm) on leaf lamina, midrib and vein and also thickness of leaf lamina (mm) showed highly significant differences among different cotton genotypes except plant height which did not differ significantly (Table 2). Highest number of gossypol glands on leaf lamina was observed on BT-3701 while minimum gossypol glands were observed on FH-113. BT-703 holds maximum gossypol glands on leaf midrib while lowest number of gossypol glands was recorded on CIM-557. BT-3701 had highest number of gossypol glands on leaf vein whereas minimum number of gossypols was recorded on CIM-557. CIM-557 contained highest number of hairs on lamina while BT-3701 had minimum hair density on lamina. Maximum hair density on midrib was observed on CIM-573 whereas lowest hair density was recorded on BT-703. Genotype CIM-557 had highest hair density on vein while BT-703 had lowest number of hairs. The maximum hair length on lamina was observed in FH-113 while the genotype CIM-608 had minimum hair length. CIM-573 contained highest length of hair on leaf midrib whereas FH-113 had lowest hair length on midrib. Genotype FH-113 enjoys maximum hair length on vein however CIM-557 had minimum hair length. CIM-573 had maximum thickness of leaf lamina while FH-113 genotype had minimum leaf lamina thickness. FH-113 had highest plant height while lowest plant height was observed in BT-703.

3.3. Correlation between sucking insect pests population and physico-morphic plant characters in different cotton genotypes

As correlation (Table 3) of whitefly adults with plants morphological factors is concern it had negative relation with gossypol glands on leaf lamina, midrib and vein and plant height whereas it correlated positively with hair density on leaf lamina and vein and length of hair on leaf midrib. As correlation of whitefly nymph with plant morphological factors is concern it depicted positive response with gossypol glands on leaf lamina and vein, hair density on midrib and vein and length of hair on midrib while it had negative correlation with gossypol glands on leaf midrib, hair density on leaf lamina, length of hair on leaf lamina and vein and also with plant height (Table 3). As correlation of jassid adult with plant morphological factors is concern it showed positive correlation with gossypol glands on leaf lamina and vein, length of hair on leaf lamina, midrib and vein, however it revealed negative response with hair density on leaf lamina, thickness of leaf lamina and plant height. With remaining all other plant characters, it showed nonsignificant response (Table 3). As correlation of jassid nymph with plant morphological factors is concern it exhibited positive response with gossypol glands on leaf lamina and vein, length of hair on leaf lamina, midrib and vein whereas it correlated negatively with hair density on leaf lamina and midrib, thickness of leaf lamina and plant height (Table 3). As correlation of thrips adults with plant morphological factors is concern it depicted negative correlation with gossypol glands on leaf midrib and vein, length of hair on leaf lamina and vein however it correlated positively with hair density on leaf midrib, length of hair on leaf midrib, thickness of leaf lamina and plant height (Table 3).

4. Discussion

Whitefly adult population exhibited negative response with gossypol glands on leaf lamina, midrib and vein. This finding confirmed the results of Bhatnagar and Sharma (1991), Ali et al. (1995b) and Irfan et al. (2008) who suggested gossypol

Table 1 Mean Populations of sucking insect pests on different genotypes of cotton.

Genotypes	Whitefly		Jassid		Thrips
	Adult	Nymph	Adult	Nymph	Adult
BT-703	3.26 ± 0.10**bc**	4.48 ± 0.03**b**	0.86 ± 0.02**a**	1.14 ± 0.03**a**	0.08 ± 0.01**b**
CIM-557	3.61 ± 0.02**ab**	3.46 ± 0.01**c**	0.43 ± 0.01**c**	0.48 ± 0.01**c**	0.27 ± 0.01**a**
CIM-608	3.70 ± 0.27**a**	5.67 ± 0.07**a**	0.62 ± 0.01**b**	0.66 ± 0.01**b**	0.30 ± 0.01**a**
CIM-573	3.25 ± 0.21**bcd**	4.87 ± 0.33**b**	0.40 ± 0.01**c**	0.59 ± 0.01**bc**	0.28 ± 0.01**a**
BT-3701	3.12 ± 0.06**cd**	3.82 ± 0.18**c**	0.57 ± 0.04**b**	0.60 ± 0.01**bc**	0.09 ± 0.00**b**
FH-113	2.85 ± 0.03**d**	3.68 ± 0.12**c**	0.53 ± 0.01**bc**	0.56 ± 0.01**bc**	0.34 ± 0.01**a**

Means sharing similar letters in rows are not significantly different by HSD test at $P = 0.05$.
Note: These are the means of the season in which population of the sucking insect pests were recorded.

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Table 2 Physico-morphic plant characters (leaf gossypol glands, hair density, length of hair, thickness of leaf lamina and plant height) on different genotypes of cotton.

Genotypes	Gossypol glands			Hair density			Length of hair			Thickness of leaf lamina	Plant height
	lamina/cm^2	midrib/cm	vein/cm	lamina/cm^2	midrib/cm	vein/cm	lamina/mm	midrib/mm	vein/mm	mm	cm
BT-703	87.70**a**	39.63**a**	8.81**ab**	275.59**c**	277.70**c**	80.96**c**	2.71**a**	4.21**ab**	4.27**b**	0.75**c**	106.67**a**
CIM-557	50.00**b**	27.89**d**	5.89**c**	388.71**a**	348.85**ab**	178.45**a**	2.43**b**	4.17**ab**	3.33**d**	1.16**b**	119.78**a**
CIM-608	47.82**bc**	35.67**abc**	7.56**bc**	375.18**ab**	334.11**b**	173.08**a**	2.30**c**	4.20**ab**	3.45**c**	1.82**a**	120.33**a**
CIM-573	51.11**b**	31.04**cd**	9.44**a**	366.52**ab**	360.92**a**	158.56**ab**	2.33**c**	4.24**a**	3.37**cd**	1.87**a**	109.67**a**
BT-3701	95.97**a**	34.33**bc**	9.59**a**	243.74**d**	292.36**c**	94.18**c**	2.68**a**	4.11**ab**	4.38**b**	0.84**c**	121.56**a**
FH-113	35.41**c**	36.26**ab**	7.67**b**	345.85**b**	288.23**c**	136.22**b**	2.73**a**	4.09**b**	4.66**a**	0.62**d**	129.78**a**

Means sharing similar letters in rows are not significantly different by HSD test at $P = 0.05$.

Table 3 Correlation coefficient values among sucking insect pests population and physico-morphic plant characters in different cotton genotypes.

Characters	Whitefly (A)	Whitefly (N)	Jassid (A)	Jassid (N)	Thrips
Gossypol glands					
Leaf lamina	−0.185*	0.138*	0.459*	0.523**	−0.942ns
Leaf midrib	−0.254*	−0.075*	0.647ns	0.622ns	−0.291*
Leaf vein	−0.091*	0.592**	0.253*	0.251*	−0.416*
Hair density					
Leaf lamina	0.465*	−0.042*	−0.488**	−0.478**	0.861 ns
Leaf midrib	0.704 ns	0.398*	−0.676 ns	−0.528**	0.531**
Leaf vein	0.591**	0.053*	−0.615 ns	−0.638 ns	0.786 ns
Length of hair					
Leaf lamina	−0.842 ns	−0.475**	0.473**	0.373*	−0.499**
Leaf midrib	0.429*	0.355*	0.092*	0.180*	0.040*
Leaf vein	−0.741ns	−0.354*	0.417*	0.302*	−0.375*
Thickness of leaf lamina	0.829 ns	0.660 ns	−0.373*	−0.261*	0.417*
Plant height	−0.086*	−0.144*	−0.407*	−0.207*	0.279*

ns = Nonsignificant.
** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.

glands as a mean for resistance against whitefly. However, Parvez et al. (1997), Raza et al. (2000), Khan et al. (2010) and Zia et al. (2011) reported that higher gossypol contents supported maximum population of whitefly. Similarly plant height had negative correlation with whitefly adult and nymph population which is contradictory to Raza et al. (2000) who advocated that plant height did not affect whitefly. In the same way, whitefly adult population correlated positively with hair density on leaf lamina and vein whereas whitefly nymphal population also showed positive response with hair density on leaf midrib and vein. Javed et al. (1992), Aheer (1999), Chang et al. (2001), Bashir et al. (2001), Chu et al. (2003), Irfan et al. (2008), Ashfaq et al. (2010) and Zia et al. (2011) reported that *B. tabaci* population positively correlated with hair density. Length of hair on leaf midrib exhibited positive response with whitefly adult and nymphal population and this result is confirmatory with Bashir et al. (2001) and Irfan et al. (2008) while contradictory to Khan et al. (2010) and Zia et al. (2011) who suggested that hair length correlated negatively with whitefly population.

The adult and nymphal population of *A. bigutella* presented positive correlation with gossypol glands on leaf lamina, vein and length of hair on leaf lamina, midrib and vein. These results can be compared with Irfan et al. (2008) who advocated gossypol glands and length of hair for increasing jassid population, while these are not in agreement with Bhatnagar and Sharma (1991), Javed et al. (1992) and Ali et al. (1995a) who considered that gossypol glands and hair length play a significant and negative role toward resistance against jassid. Similarly, jassid adult and nymph population revealed negative response with hair density on leaf lamina and midrib. This finding is confirmatory to Ali and Ali (1991), Javed et al. (1992), Ali et al. (1995a), Raza et al. (2000), Ashfaq et al. (2010) and Naveed et al. (2011) because they all had the opinion that number of hairs correlated negatively with jassid adult and nymph population however it is contradictory to Irfan et al. (2008) who reported that hair density had positive response with jassid population. Thickness of leaf lamina also showed negative correlation with jassid adult and nymph population. These findings confirmed the results of Ali et al.

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(1995a) and Ashfaq et al. (2010) who concluded that jassid population negatively correlated with thickness of leaf lamina. Similarly, plant height correlated negatively with jassid adult and nymph population. This finding is in agreement with Raza et al. (2000) who determined that as the plant height increased, the population of jassid will be decreased. That's why jassid prefer to stay on the middle leaves of the cotton plant at full plant maturity.

T. tabaci population depicted negative correlation with gossypol glands on leaf midrib, vein, length of hair on leaf lamina and vein. These results can be compared with Arif et al. (2004), Arif et al. (2006) and Irfan et al. (2008) who suggested that resistant varieties to thrips population contained maximum gossypol contents and also had greater hair length, while these are contradictory to Ali et al. (1995a) and Raza et al. (2000) who were in opinion that gossypol glands and hair length showed positive response with thrips population. Hair density on leaf midrib correlated positively with thrips population and this result is confirmatory with Arif et al. (2004) whereas it is contradictory to Ali et al. (1995a), Raza et al. (2000), Arif et al. (2006), Irfan et al. (2008) and Naveed et al. (2011) who considered hair density as a tool for resistance against thrips. Thickness of leaf lamina exhibited positive correlation with the population of thrips. This finding is not confirmatory with Raza et al. (2000) who advocated that thickness of leaf lamina correlated negatively with thrips population. Thrips population showed positive response with plant height and this finding is in line with Raza et al. (2000) who reported that as the plant height increased, thrips population will also be increased.

5. Conclusion

Gossypol glands have negative effect on population of whitefly adults and thrips adults while it has positive effect on jassid adults and nymph's population. Hairiness has positive effect on whitefly adults, whitefly nymphs and thrips adult's population while it has negative effect on jassid adults and nymph's population. Hair length has positive effect on the population of whitefly adults, jassid adults and jassid nymphs while it has negative effect on population of whitefly nymphs and thrips adults. Effect of thickness of leaf lamina is positive on thrips adult's population while it has negative effect on jassid adults and jassid nymph's population. Plant height has negative effect on the population of whitefly adults, whitefly nymphs, jassid adults and jassid nymphs while it has positive effect on thrips adult's population.

Therefore, it is concluded that the population of sucking insect pests viz., *B. tabaci*, *A. bigutella* and *T. tabaci* might be influenced by numerous factors such as physico-morphological, positively or negatively. This study would help in pest management of cotton by growing those cotton varieties showing minimum numbers of these pests.

Conflict of interest

All authors declare no conflict of interest.

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