PHYSICO-CHEMICAL BASIS OF RESISTANCE IN COTTON WITH SPECIAL REFERENCE TO SUCKING INSECT PESTS

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ABSTRACT

Cotton, known as 'white gold' plays a prominent role in Indian economy. One of the major constraints in production of quantity and quality of cotton is pest complex attacking at various stages of cotton. Out of 47 arthropods pests, 14 key insect pests reduced the yield from 15-70 per cent in various states of India. Bollworms are now suppressed by introduction of Bt transgenic cotton, however, there is no such control measure developed till date for sucking pests. Transgenic Bt cotton does not afford any protection to sucking pests of cotton and their relative tolerance or resistance is mainly dependent on the morphological or genetic base. Various physico-chemical plant characters are responsible for imparting resistance in cotton crop against sucking insect pests. Plant characters viz., hairs or trichomes, thickness, toughness, leaf length/ width, no. of leaves/ plant, plant height etc. and biochemical contents viz., phenol, tannin, gossypol are contributing a major role in conferring the mechanism of resistance to insect pests.

INTRODUCTION

Cotton, known as 'white gold' plays a prominent role in Indian economy. Total cultivated area under cotton cultivation in India was 10.72 M ha with production and productivity of 32.55 M bales and 516 kg / ha, respectively in 2010-11, which decreased to the tune of 25.50 M bales and 475 kg / ha, respectively in 2012-13, though the area under cultivation was 11.70 M ha (Anonymous, 2013). One of the major constraints in production of quantity and quality of cotton is pest complex attacking at various stages of cotton. Out of 47 arthropods pests, 14 key insect pests reduced the yield from 15-70 per cent in various states of India (Singh, 1984). Bollworms are now suppressed by introduction of *Bt* transgenic cotton, however, there is no such control measure developed till date for sucking pests (Ghule *et al.*, 2011). Transgenic *Bt* cotton does not afford any protection to sucking pests of cotton and their relative tolerance or resistance is mainly dependent on the morphological or genetic base (Reed *et al.*, 2000). The incidence of sucking pests was more or less similar in both *Bt* and non *Bt* hybrids (Bambawale *et al.*, 2004). There was no significant difference in all the four sucking pest (leaf hopper, whitefly, aphid and thrips) population observed among *Bt* and non-Bt cotton varieties (Vanitha and Banu, 2011). Moreover, with the development of insect resistance to insecticides, adverse effects of insecticides on natural enemies and public awareness of environment conservation, there has been a renewed interest in the development of crop cultivars with various basis of resistance to insect pests (Hua and Hua, 2001; Khan *et al.*, 2003).

Basis of resistance

Painter (1951) described plant resistance as "the relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insect. In practical agriculture, it represents the ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population. Kogan (1994) resistance to insects is the "inheritable property that enables a plant to inhibit the growth of insect populations or to recover from injury caused by populations that were not inhibited to grow. Inhibition of population growth generally derives from the biochemical and morphological characteristics of a plant which affect the behaviour or the metabolism of insects so as to reduce the relative degree of damage these insects can potentially cause". There are three mechanisms of resistance *viz*., antibiosis, non-preference or antixenosis and tolerance (Painter, 1951). Population of pest varies from plant to plant and may be due to external or internal physiology of the plant. This is because plants have the ability to alter the behaviour of feeding insect (Karban and Baldwin, 1997) through accumulation and excretion of toxic exudates or host plants which create hindrance against insect pest due to morphological traits (Stadler, 2000; Hirota and Kato, 2001; Goncalves-Alvim et al., 2004), because thick waxy cuticular layer works as a defense against herbivory insect pests (Taiz and zeiger, 1998). These features impair the normal feeding or oviposition of insect pests (Morris and Dwyer, 1997; Underwood, 1999).

Various morphological traits *viz.*, hairiness, colour, thickness, toughness of tissue etc., physiological (osmotic concentration of cell sap) and biochemical traits *viz*., gossypol content, nectar gland, tannin content, phenol compound etc. of host plant are known to confer mechanism of insect resistance in crop plants (Painter, 1951).

Leaf hopper, *Amrasca biguttula biguttula* Ishida

Parnell *et al.* (1949) considered the relationship of hairiness and jassid resistance to be one of the direct causes and effect, and not due to any genetic linkage between hairiness and some other factor conferring resistance. They concluded that lengthy hairs with increased density were associated with jassid resistance. Akram (1984) reported that greater the number of hairs per cm of leaf, greater the amount of resistance against jassid. Bashir *et al.* (2001) observed that jassid population on cotton leaves had negative correlation with hair density on cotton leaf midrib. Leaf injury index due to leaf hopper, *Amrasca biguttula biguttula* Ishida was lower (1.00) in cotton genotype KC 2 due to its thicker leaves (0.08 mm) and higher trichome density (26.02/ leaf microscopic field) than that of the other genotypes, MCU 5 and MCU 12 (kannan *et al*., 2006). A highly significant negative correlation of phenols, tannins and gossypol with leaf hopper incidence was observed (Balakrishnan, 2006). According to Vanitha *et al.* (2007), least per cent survival of leaf hoppers was on *Gossypium raimondii* (6.7%) followed by *G. triphyllum* indicating their strong antixenosis (may be due to higher trichome density and gossypol glands) for settling. Cotton varieties/ genotypes having short to medium staple fibers were reported to be resistant or immune to leaf hopper attack (Bhaskaran and Ravikesavan, 2008). Cotton line Ca 324 X SRT 1 # 147-149 had lower population of leaf hopper throughout the growing season and showed a significant negative relationship with leaf hair density (Sangkhae *et al*., 2008). Leaf hopper had negative correlation with hair density and length of hair on leaf lamina, midrib and vein (Amjad *et al*., 2009). The effect of physic-morphic characteristics of transgenic and non-transgenic varieties possessed similar kind of varied relationship with jassids. The trichome-density on the leaf-lamina, midrib and veins had negative and non-significant correlation with the jassids population. The varieties having thick leaf lamina showed significant positive correlation with the jassids (Ashfaq *et al.*, 2010). CCHO5–2, RAH 100, J. TAPLI (*G. arborium*) and VIKRAM were found resistant due to the presence of morpho- physical characters like hair density and length of hair on midrib and lamina, and recorded lowest injury index value (1.00) with least damage to leaves (Neelima *et al*., 2010). Highly significant negative correlation of plant characters *viz*., plant height, leaf length, leaf lamina thickness and hair density was observed with the incidence of leaf hopper population (Patel, 2010; Patel, 2012). According to Prasad Rao *et al.* (2011), minimum number of leaf hopper (1.42/ plant) and lower leaf injury grade (1.00) in cotton entries H 1316 was due to lower phenol I content (0.9%). Indrayani and Sumartini (2012) reported that cotton leaf with very low hair density harbors leaf hopper population and *vice versa*. BH-172 exhibited maximum average population of Jassid (10.9 and 3.04/leaf), while minimum (1.54/leaf) on FH-941 and PB-900 during 2012 respectively and (1.47/leaf) during 2013. Against jassid attack, all cultivars showed susceptible behavior during 2012 and 2013 (Yousaf *et al.* 2015).

Aphid, *Aphis gossypii* Glover

Khan and Agarwal (1990) studied different anatomical characters of cotton and reported non-preference type mechanism of resistance due to anatomical characters *viz*., less distance among hair basis, less thickness of parenchyma and more distance of palisade tissue from lower leaf epidermis. Dhaliwal and Arora (1998) worked on tolerant and susceptible cultivars of cotton to *A. gossypii* and found that aphid was unable to pierce the stylet in tolerant cultivars due to stem hardness compared to susceptible cultivars. Abundant population of aphid and higher leaf and stem damage was observed with more honeydew secretion on more glabrous types of cotton (Fitt *et al*., 2002). Hairiness had a significant negative effect on resistance to aphids (Nibouche *et al*., 2008). Plant characters *viz*., number of leaves per plant and leaf area contributed a major role in mechanism of resistance to aphid (Patel, 2010).

Whitefly, *Bemisia tabaci* (Gennadius)

Aheer (1999) reported that hair density on vein showed positive and significant correlation with whitefly population. Bashir *et al.* (2001) reported that white fly on cotton leaves had positive correlation with hair density on cotton leaf midrib. Lower number of whitefly adults (9.7/ leaf) was observed in okra leaf-type cotton strains with lower (52.5 cm^2) leaf area and higher (67.8 cm^2) leaf perimeter (Chu *et al*., 2002). Chu *et al.* (2003)

reported that the density of stellate trichomes on under leaf surfaces was the basic factor influencing the varietal susceptibility to adult *B. tabaci*. Acharya and Singh (2008) reported that least number of adults (16.78/ 3 leaves) as well as nymphs (17.04/ 3 leaves) was recorded on cotton genotype RS-875 (less hairy) compared to genotype BBR-358 (with dense hair). The effect of physic-morphic characteristics of transgenic and non-transgenic varieties possessed similar kind of varied relationship with whitefly. The trichome-density on the leaf-lamina, midrib and veins had positive and significant correlation with the whitefly. The varieties having thick leaf lamina showed non-significant negative response for the whiteflies population (Ashfaq *et al.*, 2010). Leaf length, leaf lamina thickness, hair density, plant height and leaf width are the important characters for imparting resistant to whitefly (Patel, 2010). According to Khan *et al.* (2010), gossypol glands (0.67* and 0.78**), hair density (0.61 and 0.50) and lamina thickness (0.66* and 0.46) had positive correlation, whereas hair length (-0.57 and -0.65*) had negative correlation with the population of *B. tabaci* during 2008 and 2009, respectively. Population of *B. tabaci* was minimum on the strain Cyto-12/91 having dense trichome density (1011 ± 21.0/ cm^2) and hair length of 644 ± 27.3 µ (Naveed *et al.*, 2011). Morphological traits *viz*., hair density and gossypol glands on midrib (0.613** and 0.660**), vein (0.428* and 0.716**) and lamina (0.256* and 0.486*) of cotton leaves had significant positive association with whitefly population, however, hair length (-0.658**) and thickness of leaf lamina (-0.446*) had significant negative correlation (Zia *et al*., 2011). Javaid *et al*. (2012) reported that NIAB-814 noted maximum susceptibility against whitefly with population (1.95/leaf) that was at par with MNH-768 bearing population 1.93/leaf. The minimum whitefly population recorded on MNH-700 was (0.99/leaf) and was statistically at par with NIAB-111 and Super-98 with population of whitefly i.e., 1.09 and 1.23/leaf, respectively. Maximum average population of whitefly (4.75/leaf) and (6.00/leaf) was observed on FH-4243, while minimum (3.26/leaf) and (3.49/leaf) on MNH-2007 during the year 2012 and 2013, respectively. Against white-fly all other genotypes showed partial resistance during the year 2012 (Yousaf *et al.*, 2015).

Thrips, *Thrips tabaci* Lindeman

Quisenberry and Rummel (1979) observed cotton resistance against thrips on the basis of leaf area. He reported that more the leaf area more the infestation of thrips. Akram (1984) reported that lesser the number of hairs in leaves lesser the number of thrips on the leaves. Riaz *et al.* (1987) reported that hair density on leaf vein positively and significantly correlated with thrips population. Bashir *et al.* (2001) reported that thrips on cotton leaves had positive correlation with hair density on cotton leaf midrib. Ali *et al.* (1995) reported that less number of hair on leaf midrib and leaf lamina were found to play a part in contributing resistance to thrips. Raza *et al.* (1999) reported that varieties possessing higher gossypol glands showed susceptibility to thrips. Raza and Afzal (2000) reported negative correlation between hair density on leaf lamina and thrips population but positive correlation between gossypol glands and thrips population. Arif *et al.* (2004) reported that various morphological plant traits *viz.*, hair density, length of hair and number of gossypol glands on midrib, veins and leaf lamina and thickness of leaf lamina differed highly significantly among various genotypes of cotton. As far as correlation between thrips population and morphological plant traits is concerned, correlation coefficient values (R-values) revealed that hair density on midrib (0.496) showed positive and highly significant correlation and length of hair on veins and gossypol glands on veins and midrib showed negative but significant correlation while all other morphological traits expressed non-significant correlation towards resistance against thrips population. Arif *et al*. (2005 & 2006) reported that hair density on midrib and vein of upper leaves showed of significant and negatively correlated with thrips. Length of hair on midrib of upper leaves and midrib and lamina of middle leaves and midrib vein and lamina of lower leaves showed negative correlation. Number of gossypol glands on upper, middle and lower leaves proved to be negatively correlated with thrips population. Brown and Simmonds (2006) reported that leaf morphology of host and non-hosts of thrips. This study showing that plant invaded by thrips possessed glandular trichones and coriaceous leaf surface while vice versa in case on non-host plant species. Plant characters *viz*., plant height, leaf length, leaf lamina thickness and hair density showed negative correlation with thrips population (Patel, 2010). The population remained significantly lower on the cotton strain Cyto- 12/91 having high trichome density of 1011 ± 21.0/ cm^2 and hair length of 644 ± 27.3 µ throughout the season (Naveed *et al*., 2011). Genotype AA-802 was found resistant with higher hair density on leaf midrib, whereas gossypol gland on leaf lamina was negatively correlated (Saleem *et al*., 2013). Further, they also reported moisture contents; total minerals, protein, lipids, reducing sugar, calcium, magnesium and zinc were major contributing factors in mechanism of resistance. Tahir (2013) showed confirmatory results of the all the parameters. He reported that gossypol gland on lamina showed negative correlation with thrips population. Hair length on lamina, hair density on vein and hair density on lamina showed positive correlation with thrips population which is the conformation of the morphological parameters. Gossypol glands on leaf lamina and phosphorus contents of leaves showed negative and highly significant correlation -0.447 and -0.490, respectively with the trips population, while hair density on veins and lamina and hair length on lamina showed positive and significant correlation 0.806, 0.574 and 0.45, respectively with the trips population (Khan *et al.*, 2014). Maximum average population of thrips (10.44 & 11.60/leaf) was observed on MNH-814, while minimum (6.46 & 5.87/leaf) on VH-280 during 2012 and 2013 respectively. Thrips attack all cultivars showed susceptible behavior during 2012 and 2013 (Yousaf *et al.*, 2015)..

Mealy bug, *Phenacoccus solenopsis* Tinsley

Johnson-Cicalese *et al.* (1998) found that mealy bug damage ratings were positively correlated with pubescence level because hairs may provide foothold for early instar mealy bugs, whereas leaf thickness, leaf size and leaf width responded negatively with mealy bug population. Tolerant cotton variety PKV Rajat showed highest superoxide dismutase activity (2.84/ mg) whereas, polyphenol oxidase and polyphenol peroxidase activity was higher in susceptible cotton variety CAHH-231 (Ghule *et al*., 2011). Leaf area and leaf thickness exerted negative correlation with cotton mealy bug populations, showing r-values of -0.172 and -0.285 respectively. Trichome density per leaf and length of hair showed significant correlation with the pest population and there was positive response on the population of *P. solenopsis*, showing r-values of 0.357* and 0.190, respectively. Leaf thickness and area of leaf was negatively associated with population of mealy bug, while the reverse was true in the case of hair density and hair length. (Shahid *et al*., 2012).

CONCLUSION

Various physico-chemical plant characters are responsible for imparting resistance in cotton crop against sucking insect pests. Plant characters *viz*., hairs or trichomes, thickness, toughness, leaf length/ width, no. of leaves/ plant, plant height etc. and biochemical contents *viz*., phenol, tannin, gossypol are contributing a major role in conferring the mechanism of resistance to insect pests. *Bt* cotton genotypes could provide resistance to sucking insect pests, if their physico-chemical characters/ contents are improved through various breeding process.

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