HOST RESISTANCE TO THE LEAFHOPPER, *AMRASCA DEVASTANS* (DISTANT) IN COTTON, *GOSSYPIUM* SPP.

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Abstract

The cotton leafhopper, *Amrasca (Empoasca) devastans* (Distant) is a key pest on Upland cotton in India and an upsurge of the pest has been noticed in recent years. The nymphs and adults desap the leaves resulting in hopperburn, drying and shedding of leaves, reduction in plant stand and loss in yield. The management of this pest is made difficult by the development of resistance to insecticides and resurgence caused by indiscriminate applications of synthetic insecticides. Among cultivated cottons, *Gossypium arboreum* and *G. herbaceum* are resistant to the leafhopper. Resistance from these species were transferred to *G. hirsutum* cottons. Among wild cottons, *G. tomentosum*, *G. armourianum* and *G. raimondii* are resistant to the leafhopper.

Morphology of cotton plays an important role in imparting resistance to leafhopper. Hairiness of leaf, toughness of leaf veins, thickness of leaf lamina, length and angle of insertion of leaf hair are associated with resistance. Non-preference for oviposition is because of high concentrations of allomones like tannins and free gossypol. Non-reducing sugars, tannins, free gossypol and silica are key factors that influence the antixenosis mechanism. Anti-nutritional factors like total phenols and epicuticular waxes exert significant adverse effects on leafhopper survival and oviposition. In *G. hirsutum*, *G. tomentosum* and *G. arboreum* varieties, hairiness and leafhopper resistance are governed by a dominant gene. The available resistance needs to be exploited both by conventional methods and new innovative techniques. Cumulative resistance derived from diverse gene pools will be more lasting and there is need to identify new genes that govern the resistance.

Introduction

Cotton is a warm weather plant and its production is limited to tropics and temperate zones. Of the many pests that infest cotton, the leafhopper, *Amrasca (Empoasca) devastans* (Distant) (Cicadellidae: Homoptera) is an important pest. The nymphs and adults suck the sap from leaves and cause phytotoxic symptoms known as hopperburn which results in complete desiccation of plants. Severe infestation leads to poor crop stand and stunted growth (Narayanan and Phundan Singh, 1994). The leaf hopper is essentially an early phase pest of cotton. However, in recent years, the insect occurs all through the cotton season and has become one of the limiting factors in economic productivity of the crop. The yield reduction is estimated to be 40% in some agro climatic zones of this country if the pest is not checked in time. Among 24 species of *Empoasca* complex known in India, the jassid, *Amrasca devastans* is the most serious pest. *Amrasca bigutulla bigutulla* Ishida and *Sundapteryx bigutulla bigutulla* Ishida are considered synonyms of *Amrasca devastans.* Three other species, *Empoasca kerri* var. *motti* Pruthi, *E. minor* Pruthi and *E. punjabensis* Pruthi also occur on cotton. However, these species do not inflict any appreciable damage on cotton.

Many cotton growers depend on chemical insecticides for controlling the leafhopper. However, the use of pesticides has led to problems such as development of resistance and resurgence of secondary pests. Therefore, there is a need for exploring alternative methods of managing this pest. One of the alternative method is the use of resistant varieties. This method has shown great potential in that it is environmentally safe and resistant genotypes exhibit stability of heritable characters. The development of cotton cultivars resistant to *E. fascialis* in

South Africa, during the first quarter of this century, has been the most successful and outstanding achievement in managing this pest (Parnell *et al.,* 1949). Growing resistant varieties has essentially eliminated the cotton leafhopper as a major pest in tropical Africa. In Sudan, varieties of *Gossypium barbadense* resistant to *E. lybica* (de Berg evin and Lanon) are grown. Leafhopper resistant cotton cultivars are also grown in India. This paper reviews the state of art on leafhopper resistance in *Gossypium* spp. in India.

Methods

Genetic resources

Gossypium is a rich and economically important genus comprising 43 diverse species of which four are cultivable for cotton lint and seed (Percival and Kohel, 1990). Among the linted species, two are Old World (Asiatic) diploid (2n=26) cottons *(Gossypium arboreum* and *G. herbaceum)* and the other two are New World allotetraploid (2n=52) cottons *(Gossypium hirsutum* and *G. barbadense).* The latter two are also known as upland and sea-island cottons, respectively. India is the home of Asiatic cottons particularly the races *Bengalense, Indicum* and *Cernum* of *G. arboreum* and the race *Wightianum* of *G. herbaceum.* The National Gene Bank of Cotton (NGBC) in India located at the Central Institute for Cotton Research, Nagpur holds accessions collected from around the world comprising of 4005 of *G. hirsutum*, 390 of *G. barbadense,* 1701 of *G. arboreum,* 400 of *G. herbaaeum,* 24 wild species and about 400 perennials as race stocks, sterile hybrids of various species, polyploids and their derivatives, totalling around 7000. Of the cultivated cottons, G. *arboreum* and G. *herbaceum* are resistant to the leafhopper. Among wild cottons. G. *tomentosum, G. armourianum* and *G. raimondii* are resistant to the leafhopper (Narayanan and Phundah Singh, 1994). The pubescence in *G. raimondii* and *G. tomentosum* is attributed for the resistance (Santhanam, 1958).

Screening techniques

Screening and evaluation for leafhopper resistance are done in the field under unsprayed conditions taking advantage of the natural infestation. Cotton entries are sown in unreplicated plots each consisting of a single row 6 m in length, with a spacing of 75 x 30 cm between rows and plants respectively. Okra, *Abelmoschus esculentus* (L.) Moench is sown as host source crop at the rate of one row for every four rows of cotton entries (Uthamasamy, 1993).

Counts on population of nymphs and adults are recorded from three leaves per plant one from the top, the middle and the bottom portions of the canopies of the selected plants. Ten plants per plot are selected at random and the population assessment is made in the early in the morning when the leafhoppers are generally inactive and easier to count. Counts are done on the 30th, 45th and 60th days after sowing.

Entries are short listed based on their resistance to the leafhopper. The population of leafhopper during each count and the injury index (hopperburn grade) are the criteria for short listing the entries. The short listed entries from field screening are further evaluated to test the permanence of resistance. This is done by caging five pairs of leafhopper on the entries. The leafhoppers from a stock culture maintained at the insectary are released into individual cages containing a single plant of the genotype. The release of leafhopper is made on 25 day old plants and counts made on the increase in population and hopperburn injury up to 60 days of age. This technique enables the identification of genotypes which are consistently resistant and avoids the inclusion of 'escapes' from field screening. In addition, the role of pubescence in imparting resistance is also estimated. For this purpose, the number of trichomes on the adaxial surface of third, fifth and seventh leaves from the terminal end of the main stem is assessed (Maiti *et al.,* 1980). This is done by counting the number of trichomes in one cm^2 area on the 30th day after sowing.

Entries which are consistent in exhibiting resistance are then tested in multilocation experiments. These experiments are conducted in hot spot areas of different ecological niches such as rain grown cotton, irrigated cotton as well as winter and summer cotton zones of the country. The cotton entomologists of the All India Co-ordinated Cotton Improvement Project (AICCIP) collaborate in this study. In all these experiments, a standard cultivar (popular with cotton growers of the respective zone) is raised for comparison. Performance of the entry, in terms of resistance, kapas yield, fibre qualities and reaction to other pests are considered before approval as a variety.

Assessment of hopperburn damage

Hopperburn injury is assessed as per the Indian Central Cotton Committee (ICCC, 1960) methods and based on resultant symptoms of infestation. Visual rating of hopper injury (hopperburn) on each entry is recorded on the 45th and 60th day after sowing and the mean injury index (grade index) is calculated. The hopperburn grades consist of:

Grade 1: Leaves free from crinkling or with no yellowing, bronzing and drying (undamaged leaves);
Grade 2: Few leaves on lower portions of the plant curling, crinkling and slight yellowing;
Grade 3: Crinkling and curling all over, yellowing, bronzing and browning in the middle and-lower portion, plant growth hampered; and
Grade 4: Extreme curling, yellowing, bronzing and browning, drying of leaves and defoliation, stunted growth.

A jassid resistance index (also known as hopperburn index, grade index, injury index) is calculated as proposed by Nageswara Rao (1973) which is:

$$\frac{G_1xP_1+G_2xP_2+G_3xP_3+G_4xP_4}{P_1+P_2+P_3+P_4}$$

Where "G" represents the number of the grade of ICCC and "P" the number of plants under that grade for each entry. Grouping of injury index into categories of resistance is as follows:

Grade index	Category
0.1 - 1.0	Resistant
1.1 - 2.0	Moderately resistant
2.1 - 3.0	Susceptible
3.1 - 4.0	Highly susceptible

Results and Discussion

Mechanisms of resistance

Both morphological and biochemical mechanisms operate in *Gossypium* spp. against the leafhopper. Morphological characters such as the hairiness of leaves, toughness of leaf veins, thickness of leaf lamina, length of hair, angle of insertion are reported to be associated with resistance (Uthamasamy, 1985). Non-nutritional and anti-nutritional leaf factors play a significant role in conferring resistance.

Morphological

The *Gossypium* spp. have acquired defence mechanisms in the course of their evolution against insect pests. These include leaf shape, thickness of leaves, hairiness on leaves, stem, petiole, bract etc.

Pubescence

Leaf hairiness is associated with the resistance of cotton varieties, hybrids and germplam accessions particularly in *G. hirsutum* and *G. barbadense*. The role of pubescence in imparting resistance to leafhopper in cotton and the breeding of very hairy cottons, in Africa and Asia, to combat jassids is well established and documented (Thomson, 1987). Leaf hairiness has been reported to be the only recognisable morphological attribute which is closely linked with resistance to the leafhopper (Agarwal *et al.,* 1978). Bhat *et al.* (1982) was of the view that the hairiness of the lower surface of the leaf imparts a high degree of resistance but not complete resistance. Nevertheless, breeding hairy-leafed cultivars to manage jassids has been the approach in India. Parnell *et al.* (1949) considered the relationship of hairiness and leafhopper resistance as one of direct cause and effect, and not due to any genetic linkage between hairiness and some other factors conferring resistance. These authors also concluded that hair length is most important and if length is maintained, increased hair density increases resistance. Thus, it appears that hairiness on the undersurface of leaves is the most important morphological character positively related with leafhopper resistance (Jagathesan *et al.,* 1963; Singh *et al.,* 1972; Uthamasamy, 1985). Presence of hairs does not always confer resistance and some glabrous genotypes also show resistance.

Chemical

The biochemical and physiological resistance is imparted by non-nutritional and anti-nutritional components. The cotton genotype HB 69 was reported to be resistant to the leafhopper (Balasubramaniam *et al.,* 1978). The fecundity of the insect was less, nymphal duration was longer, and survival of nymphs was reduced compared to the susceptible variety PRS 72. The lifespan of females was longer on PRS 72 than on HB 69. This was because of increased amounts of total sugars and reducing sugars in the resistant variety compared with the susceptible one. Sugars in low concentrations may act as phagostimulants but are toxic at higher concentrations (Uthamasamy, 1979). Hence, the suitability of the susceptible variety with low sugars for leafhopper growth and development. Four organic acids (oxalic, fumaric, malic and citric) were observed in PRS 72 but not in HB 69 and this variety also had higher total nitrogen. The free amino acid concentration was lower in resistant varieties and higher in susceptible varieties. In the resistant HB 69, the total and orthodihydroxy phenols were in high concentration than the susceptible PRS 72.

XG-15, was moderately resistant to the leafhopper (Singh, 1987). High concentrations of allomones like tannins and free gossypol were responsible for the non-preference for oviposition in this genotype. Gossypol, was also implicated as a factor conferring resistance to leafhopper in cotton (Narayanan and Phundan Singh, 1994). Non-reducing sugars, tannins, free gossypol and silica were key factors that influenced the antixenois mechanism of the leafhopper (Singh and Agarwal, 1988). Anti-nutritional factors (total phenols and epicuticular waxes) showed significant adverse effects on leafhopper survival and oviposition and these compounds were in high concentrations in resistant plants. The leafhopper females were able to discriminate between nutritionally superior and inferior plants for oviposition and survival (Singh and Agarwal, 1988; Singh and Taneja, 1989).

Considering the present status of the understanding on this aspect of host-plant resistance, it is viewed that non-preference for feeding and oviposition operate in this crop. These are governed by biophysical factors like dense, long and erect hairs which provide viable and heritable resistance against the cotton leafhopper. It also confirms that all resistant varieties are hairy but not all hairy varieties are resistant. Antibiosis mechanism indicated that the resistant varieties are not suitable hosts in terms of growth and development of the leafhopper.

Genetics of resistance

A knowledge of plant genetics relative to insect resistance is essential to understand the basic aspects of resistance. In cotton, the main source of resistance to the leafhopper has been the *G. hirsutum* (Cambodia) cottons in India, which have hairy leaves and stems. Pubescence is usually associated with leafhopper resistance. In *G. hirsutum, G. tomentosum* and G. *arboreum* varieties, hairiness and jassid resistance are controlled by a dominant gene. Resistance in G. *barbadense* was due to a partially dominant gene H-l, together with several modifier genes (Knight, 1952). The gene controlling hairiness in upland variety pubescent T 661 was identical with G. *tomentosum* gene H-2. Besides H-2, *G. herbaceum* carries minor H genes and modifying genes that affect hair length (Knight, 1954). According to Muttuthamby *et al.* (l969), two complementary genes H-l and H-2 controlled hairiness; one gene was present in Pak 51L and 11 and the other in Empire Red Leaf and Acala. The variety Hirsu-anom (H 59), resistant to leafhopper, was a cross between *G. hirsutum* and *G. anomalum* (Khush and Brar, 1991). The genetics of resistance reveals the complexity of combining conflicting characters to evolve a resistant cultivar.

Exploitation of resistant sources

Insect resistant varieties should form the basis of Integrated Pest Management (IPM) on which other tactics are superimposed. During the past three decades through intensive research, screening techniques for evaluating insect resistance have been developed and sources of resistance identified. Network research programmes for evaluation of genetic materials and development of insect resistant varieties are in progress in State Agricultural Universities (SAUs) and Crop Research Centres of the Indian Council of Agricultural Research (ICAR) in this country. Many varieties resistant to leafhopper in cotton (Table 1) have been released for cultivation (Sundaramurthy and Chitra, 1992). Continuous evaluation of germplasm and breeders' lines indicates the vast potentiality of resistant sources (Uthamasamy *et al.*, l991; Uthamasamy and Sivasubramaniam, 1989, 1990, l991a, b). There must be frequent exchange of germplasm entries among the research centres. A strong team work is essential to exploit the resistant sources and to develop insect resistant cotton varieties. Resistance breeding both by conventional methods and new innovative techniques are gaining momentum and crop varieties with built-in resistance are likely to be developed in the coming years.

Conclusions

For cotton farmers, use of leafhopper resistant varieties is economically cheap and reduces the need to use high cost inputs like insecticides. Given the problems associated with reliance on pesticides, the selection of insect resistant varieties is more pressing than ever before. Even partial resistance may be useful as it may enhance the effect of natural enemies and possibly reduce the need for other control tactics. Concerted efforts are essential to breed newer varieties as the present day cultivars are of narrow genetic base which would make them vulnerable to other pests and development of biotypes of leafhopper. Cumulative resistance, derived from diverse gene pools will be more lasting and research attempts should be directed in this line. For continued success of host resistance, research programmes should be directed to identify new gene(s) that impart resistance. Chemical ecology which encompasses the role of varieties that influence the host plant-insect interactions should be directed to identify the role of phytochemicals *vis-a-vis* host selection by leafhopper. Biotechnology, through the use of genetically engineered transgenic plants offers greatest scope and is one of the virgin areas of research with a lot of potential.

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Table 1. Leafhopper resistant cotton genotypes in India.

Species of cotton	Entries/Varieties
Gossypium hirsutum	1412, SRT 1, BN, Khandwa 2, G. cot 12, Badnawar 1, DHY 286, B 1007, J64-51, MCU5, BJ 592, Mahalaximi, Krishna, PK 688, TH 144, D 551, D5-57, J 34, EL 0162, Co 2, K 3400, GS 23, LH 299, CNH 36 Laxmi, B52-2-51.
B. barbadense	Sujatha
G. arboreum	Maljari, K7, K8
G. herbaceum	Jayadhar, Vijay, Sujay