Breeding for Insect Resistance in Cotton Utilizing Morphological Traits at the Cotton Research Institute, Sakrand, Sindh, Pakistan

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ABSTRACT

Resistance to insect pests is of importance in cotton production. Losses due to insect pests increase production costs by reducing yield, lint and seed quality. Early maturing, insect resistant cultivars provide an economic and effective control measure. At Central Cotton Research Institute, Sakrand, earliness and some morphological traits offering resistance against various insects have been utilized in developing new varieties. Early maturing strain CRIS-335 opens 70% of the bolls by 110 days after planting compared to 9% for NIAB-78 and 3% for CRIS-9 both commercial varieties of Sindh. Two other strains, CRIS-342 and CRIS-355, also earlier than the commercial checks have been developed. These strains escape late season whitefly and bollworms attacks. The hairy variety CRIS-7A is resistant to jassids and agronomically, compares favourably with check varieties NIAB-78 and CRIS-9. Okra leaf shape has been utilized in nine strains. Strain CRIS-310 yielded 35% and 27% more seedcotton than commercial varieties NIAB-78 and CRIS-9, respectively, in unsprayed blocks. The strains are early maturing, offer tolerance to pink bollworm and whitefly and resistance to boll rot. Eight glabrous, high yielding, early maturing strains yielded 17% to 28% more than NIAB-78 and 9% to 21% more than CRIS-9 with two pesticide applications in trials over three years from 1994 to 1996. Other morphological traits, include nectariless, red plant colour and frego bracts, have been introduced into high yielding, environmentally adapted varieties to develop insect resistant strains. This material is in the F_6 generation.

Introduction

Cotton is the most important cash crop of Pakistan. The national record yield of 769 kg/ha in 1991-92 is low compared to advanced cotton producing countries like Australia, USA and China. One of the major causes of low yield is insect pest damage that takes a heavy toll of the crop at various stages of its development. The damage varies from year to year depending on weather conditions and the intensity of insect pest attack. About 145 species of insect pests are recorded on cotton in Pakistan. However, only about a dozen of these are major pests and cause economic losses (Shafi, 1993); six being the key insect pests: cotton jassid (*Amrasca devastans*), cotton whitefly (*Bemisia tabaci*), cotton thrip (*Thrips tabaci*), American bollworm (*Helicoverpa armigera*), spotted bollworm (*Earias sp.*) and pink bollworm (*Pectinophora gossypiella*).

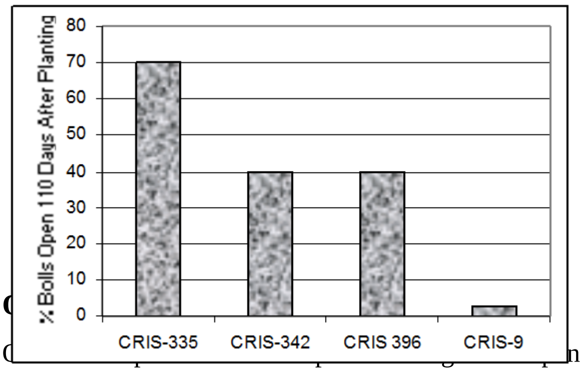
Currently, researchers and growers depend heavily on pesticides to get acceptable seedcotton yield and lint quality. The tremendous, often indiscriminate, increase in pesticide use in Pakistan has created many problems of resistance, resurgence, emergence of new pests and environmental contamination.

Resistance to insect pests is important in cotton production. Early maturing, insect resistant cultivars provide an effective cotton insect control approach that is inexpensive compared to alternative measures. They can either be used as the principal control measure or combined with other measures to develop appropriate pest management systems, depending on the level of resistance.

Earliness means shortening the time between planting and harvesting. One of the main goals in introducing early maturing cotton varieties is to minimize losses from diseases and insects by escaping late season infestation, especially of bollworms, whitefly and aphids. Early, rapid fruiting cottons can be utilized in managing boll weevil and bollworm infestations (Walker and Niles, 1971). Early maturing cottons escape insect damage by setting the major part of the boll load before pest populations increase to damaging levels (Wilson *et al.*, 1981). Earliness has the advantages of reducing the number of insecticide applications; increasing time for land preparation for the following crop; and overall reducing production costs. Currently, two commercial cultivars NIAB-78 and CRIS-9 account for 85% and 10% of the cotton area of Sindh, respectively. The maturity period of both varieties ranges from 160-170 days. A number of strains have been developed that are earlier than these varieties. Figure 1 shows that CRIS-335 is the earliest variety, followed by CRIS-342 and CRIS-355. After 110 days, CRIS-335 opens 70% of the bolls compared to NIAB-78 and CRIS-9 that open only 9% and 3% respectively, while CRIS-342 and CRIS-355 open

40% of the bolls. CRIS-335 matures in 120-130 days and. CRIS-342 and CRIS-355 in 135-145 days.

Figure 1. Earliness comparison of new strains and commercial varieties NIAB-78 and CRIS-9.



plant canopy, having about 40% less foliage than normal varieties at maturity and permitting 70% more sun light to penetrate the canopy (Jones, 1972). It confers resistance to banded-wing whitefly (Jones, *et al.* 1975) and has considerable value against pink bollworms (Wilson and George, 1982). Okra leaf breeding stocks in certain backgrounds have a modest level of resistance to pink bollworm and yield as much or more lint than do normal leaf cultivars (Wilson, 1986). In trials of 15 cotton strains in Israel, the lowest whitefly infestation was on okra leaf varieties (Butler *et al.* 1988). Okra leaf shape is associated with significantly higher flowering rate during the first six weeks of fruiting, is ready for harvest about one to two weeks earlier than normal varieties, giving higher yields and less boll rot. Gains in earliness are accompanied by a favourable impact on some insect pests, a safety margin against inadequate light within the canopy, permit reasonable weed control without excessive use of herbicides and produce yields as good as or better than normal varieties with increased earliness, boll size and micronaire value (Jones and Andries, 1967; Andries *et al.* 1969; 1972; Jones, 1982). There is little effect on fiber length but super okra caused a slight reduction in yield

The Institute has developed a number of okra leaf strains. Table 1 summarizes their yield performance against normal leaf standards (NIAB-78 and CRIS-9), showing that almost all the okra leaf strains were better yielders than NIAB-78. Of nine okra leaf strains, three exceeded, two equalled and four were inferior to CRIS-9 in yield. CRIS-310 gave the top yield of 1985 kg/ha that was 27% higher than CRIS-9 and 35% higher than NIAB-78. The trial in 1997-98 was a randomized complete block with four replications using recommended agronomic practices and no insecticide. The incidence of boll rot on okra leaf strains was 4% less than on non-okra types. Table 2 shows that okra leaf varieties except CRIS-312, were 2 to 11% earlier than normal leaf standards NIAB-78 and CRIS-9. CRIS-312 was about 3% later at 150 days after planting, confirming the results of earlier studies on the impact of okra leaf on boll rot and earliness.

Okra leaf strains were tested for resistance to the sucking complex (thrip, jassid and whitefly) infestation during 1997-98 in untreated plots. Table 3 shows that that all the okra leaf strains had lower thrip infestation than the normal leaf checks, results with jassid were mixed while whitefly populations were lower on okra leaf strains than on normal varieties NIAB-78 and CRIS-9.

Hairiness

Leaf hair density and distribution are considered important components of jassid resistance in cotton. Some research has shown that hairiness is negatively correlated with jassid population but has no relationship with whitefly (Ali and Ahmad, 1982) but other studies found that it contributes to jassid resistance but susceptibility to whitefly (Ahmed, 1980). Greater hair density on the mid rib and leaf lamina was found to be associated with resistance to jassid (Singh *et al.* 1972; Javed, 1974, Smith *et al.* 1975; Hussain, 1984; and Agarwal *et al.* 1987). When associated with a greater number of gossypol glands on mid rib, it contributes to whitefly and thrip resistance (Ahmed *et al.* 1987). All the varieties showing resistance were hairy.

High plant hair density is a promising mechanism for resistance to pink bollworm in cotton (Wilson *et al.* 1980). Moths are attracted to vegetative parts with heavy pubescence for oviposition. This extends the exposures of first instar larvae to predators, parasites and high temperature as they journey through dense hairs on leaves and petioles to squares or bolls, thus reducing the survival rate (Smith *et al.* 1975; and Wilson and Wilson, 1977).

A profusely hairy variety CRIS-7A, developed by the Institute, offers substantial tolerance to jassid, the major pest of Sindh, which remains active throughout the season, especially on cloudy days. Heavy infestation causes premature shedding of leaves, flower buds and bolls. CRIS-7A is being tested in National Co-ordinated Varietal Trials, the final stage of variety tests. Table 4 summarized the performance of CRIS-7A in trials under two spray regimes. Being profusely hairy, it had a lower jassid infestation than NIAB-78 and CRIS-9. Its average seedcotton yield over two years was 2,442 kg/ha followed by CRIS-9 (2,427 kg/ha) and NIAB-78 (2,292 kg/ha).

Glabrous character

Glabrous cottons were found to have at least 50% less oviposition and correspondingly smaller larval populations of bollworm (*Helicoverpa zea*) and tobacco budworm (*Heliothis virescens*) than normal cottons, leading to an ultimate reduction in damage by about 50% (Lukefahr *et al.* 1971; Benkwith, 1971 and Lukefahr *et al.* 1965). The glabrous and nectariless traits are known to have cumulative effects on the *Heliothis* sp. The glabrous trait is also known to suppress cotton fleahopper (Cowan and Lukefahr, 1970) but its value in controlling this pest is questionable since certain glabrous stocks have low tolerance to this pest.

A number of glabrous strains developed at the Institute were tested over three years (Table 5). The glabrous varieties surpassed the checks NIAB-78 and CRIS-9 significantly by 17%, 28% and 9% - 21%, respectively. The experiments received two insecticide applications in 1994 and 1995 and three in 1996 against the sucking pest complex. They were also tested in demonstration plots that received two spray applications against the sucking pest complex in 1997-98 (Table-6). The bollworm damage percent was less in glabrous strains than in the commercial checks and the percentage of live larvae was also less except and in CRIS-107 (1.23) and CRIS-105 (1.09). Seedcotton yields of almost all the glabrous strains exceeded the commercial checks. The top yielding strain CRIS-19 exceeded NIAB-78 by 44.2% and CRIS-9 by 42.0%.

Nectariless trait

The presence of two recessive genes ne_1 and ne_2, results in the absence of extra-floral nectaries on leaf mid rib, bracts and calyx. Many adult insects prefer to feed and lay eggs on cotton that has extra-floral nectaries (Adjei-Maafo and Wilson, 1983; Henneberry *et al.*, 1977; Lukefahr and Rhyne, 1960; Schuster *et al.*, 1976). Laster and Meredith (1974) reported low plant bug populations, earlier maturity, and higher yield of nectariless cotton than their nectaried isolines. Meredith *et al.* (1973) and Schuster and Maxwell (1974), confirmed by Schuster *et al.* (1976) for fleahoppers, found that nectariless strains reduced populations of plant bug by about 60%. The exact mechanism is probably related to the absence of sugars that are essential for plant bug development (Butler *et al.* 1972). Schuster and Frazier (1976) suggested that nectariless confers resistance through non-preference and in the absence of nectar, antibiosis resulting from nutritional deficiency. Nectariless plants experience lower infestation of the bollworm complex with reduced oviposition on glabrous, nectariless cotton (Lukefahr and Houghteling, 1969; Lukefahr *et al.* 1971). In trials nectariless gave 40% reduction in pink bollworm infestation (Wilson and Wilson, 1976).

Nectariless material developed by the Institute, comprising ten promising single plant progenies from various cross combinations, were isolated in the F_5 generation in 1997-98. They will be sown in the F_6 generation during May 1998 and new strains will be bulked according to their homogeneity and performance, for comparison in variety tests against commercial varieties.

Frego bract character

Frego bract trait has also been utilized in the breeding program at the Institute. Since this trait is well documented for suppression of boll weevil, it is unlikely to be of value for resistance against the insect pest complex in Pakistan. However, frego bract lines have completed their fifth generation and will be bulked for variety tests during 1998-99 season, based on their performance of yield and quality. One thing of importance is that frego bract progenies produce quality lint with less trash. However extensive studies regarding this gain are in progress.

Red plant colour

This morphological trait induces non-preference in boll weevil but is unlikely to be of value in Pakistan. However, light greenish red plants has offered a fair degree of non-preference against whitefly (*Bemisia tabaci*) but this requires further study. It has been incorporated in hybridization program and red colour progenies will be planted in the F_6 generation in May 1998. Hopefully economically profitable red plant cotton varieties will be developed.

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Table 1. Average performance of newly developed okra leaf strains at Central Cotton Research Institute, Sakrand, Sindh, Pakistan during 1997-98.

Strains	Yield S/C (kg/ha)	Ginning outturn (%)	Staple Length (mm)	Uniformity ratio (%)	Boll rot (%)
CRIS-285	1450 c	34.4	27.2	55.8	1.2
CRIS-289	1374 c	33.6	27.4	55.4	1.8
CRIS-291	1527 c	37.6	28.1	54.8	0.9
CRIS-299	1298 c	35.0	27.5	53.7	1.3
CRIS-306	1450 c	40.6	25.6	52.6	1.1
CRIS-310	1985 a	36.0	26.4	52.7	0.5
CRIS-312	1298 c	40.3	25.6	56.6	2.2
CRIS-381	1374 c	31.5	28.3	59.5	1.8
CRIS-385	1603 b	36.0	28.1	54.3	0.8
NIAB-78	1298 c	35.0	26.5	54.4	6.9
CRIS-9	1450 c	36.0	26.5	52.9	6.0

Table 2. Earliness comparison of okra leaf strains developed at Central Cotton Research Institute, Sakrand, with normal leaf commercial varieties during 1997-98.

Strains	Bolls formed			Bolls opened		% opening
	90 dap	120 dap	150 dap	120 dap	150 dap	150 dap
CRIS-285	15	29	43	21	38	88.4
CRIS-289	12	22	32	15	26	81.2
CRIS-291	18	37	48	25	41	85.4
CRIS-299	13	24	34	16	29	85.3
CRIS-306	14	30	41	19	37	90.2
CRIS-310	22	45	61	31	55	90.2
CRIS-312	11	21	30	13	23	76.7
CRIS-381	13	24	41	16	33	80.5
CRIS-385	17	32	44	22	38	86.4
NIAB-78	12	23	14	27	79	79.4*
CRIS-9	10	21	39	19	31	79.4

Dap = days after planting.

Table 3. Average population (per leaf) of sucking complex on okra leaf strains compared with commercial varieties during 1997-98 at Central Cotton Research Institute, Sakrand.

Strains	Population per leaf		
	Thrips	Jassid	Whitefly
CRIS-285	3.81	0.89	0.87

CRIS-289	4.07	0.36	0.81
CRIS-291	3.64	0.59	0.92
CRIS-299	4.18	1.17	0.73
CRIS-306	3.88	0.95	0.95
CRIS-310	2.32	0.33	0.90
CRIS-312	3.37	1.21	0.82
CRIS-381	3.85	1.01	1.01
CRIS-385	3.89	0.73	0.79
NIAB-78 (Check)	4.83	0.98	1.91
CRIS-9 (Check)	4.53	1.03	1.89

Table 4. Average performance of CRIS-7A at Central Cotton Research Institute, Sakrand.

Strains	Seedcotton yield (kg/ha)			Average jassid per leaf
	1995	1996	Average	
CRIS-7A	2791	2093	2442	0.15
NIAB-78	2551	2033	2292	1.82
CRIS-9	2791	2063	2427	1.91

Table 5. Average seed cotton yield (kg/ha) of glabrous strains tested from 1994 to 1996 at Central Cotton Research Institute, Sakrand.

Strains	Seedcotton yield (kg/ha)			
	1994	1995	1996	Average
CRIS-19	1714	3495	2791	2666
CRIS-52	2184	3157	2671	2671
CRIS-54	2223	3109	2751	2694
CRIS-78	2153	3070	2392	2538
CRIS-107	2309	2791	2392	2538
CRIS-82	2526	3548	1914	2663
CRIS-105	2583	3468	2591	2881
CRIS-85	2377	3269	2711	2786
NIAB-78 (Check)	1607	2551	2033	2064
CRIS-9 (Check)	1950	2791	2063	2268

Table 6. Average seedcotton yield and bollworm damage of glabrous strains in demonstration trial of 1997-98 at Central Cotton Research Institute, Sakrand.

Strains	Bollworm damage (%)	Live larvae (%)	Seedcotton yield (kg/ha)
CRIS-19	3.23	0.35	4101
CRIS-52	4.01	0.54	3218
CRIS-54	4.67	0.87	3036
CRIS-78	5.57	0.95	2697
CRIS-107	5.98	1.23	2130
CRIS-82	4.77	0.86	2833
CRIS-105	5.89	1.09	2470
CRIS-85	4.83	0.91	2923
NIAB-78 (Check)	6.72	1.16	2289
CRIS-9 (Check)	6.67	1.04	2379