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Full Length Research Paper

CRSM-38, a new high yielding coupled with CLCuV tolerance cotton (*Gossypium hirsutum* L.) variety

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CRSM-38 is a high yielding and leaf curl virus tolerant cotton variety, developed in Pakistan. Hybridization and subsequent pedigree method's selection work was carried out under natural field conditions at Cotton Research Station, Multan during the year 2001 and 2002 by using a virus tolerant strain (583-85/99) and a variety (FH-900). The new variety exhibited an average of 77.9% higher degree of tolerance against cotton leaf curl virus (CLCuV) over respective checks, and attained an average of 46.52 % higher seed cotton yield than that of CIM-496 under various climatic conditions revealing its wider adaptability. It possesses harmonious combination of fiber traits, that is, 39.94% ginning out turn (GOT), 29.07 mm fiber staple length, 4.38 µg/inch fiber micronaire and 31.38 g/tex fiber strength. Significant differences among genotypes showed higher degree of genetic variability, heritability (78 to 90%) and genetic advance (38 to 63.90%) in seed cotton yield suggesting that these genetic components were under the control of additive genetic effects, whereas tolerance to CLCuV could be improved through selection for high seed cotton yield. On the basis of the aforementioned features, CRSM-38 was recommended for general cultivation by Punjab Seed Council during the year 2009.

Key words: *Gossypium hirsutum* L., CRSM-38, seed cotton yield, cotton leaf curl virus (CLCuV), heritability, additive genetic effect, genetic advance.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is the main cash crop of Pakistan with its lion's share of 57% in the foreign exchange earnings (Anonymous, 2008). As an industrial crop, it has several sectors in the productive chain that provides occupation from farmer's field to cotton ginning and textile industry.

Cotton leaf curl virus (CLCuV) disease is one of the major reasons limiting productivity of cotton in Punjab province of Pakistan (Briddon et al., 2000). In the past, cotton production in this province increased steadily since the debacle (high rainfall and insect pressure) of 1983 and reached the highest records of 12.2 million bales during 1991 and 1992; but in the following year, it reduced to 8.2 million bales due to severe attack of cotton leaf curl virus disease (Arshad et al., 2002). CLCuV was firstly noted in 1967 at Multan (Punjab) by Hussain and Ali (1975). Unfortunately, it was not given importance in previous years, because of late infestation and low incidence; consequently, it proved disastrous disease for cotton crop in 1992 to 1993 (Hussain and Mahmood, 1988).

To tackle this disease, cotton breeders in Pakistan started a research work on evolving CLCuV tolerant/ resistant varieties in 1993; as a result, a number of CLCuV resistant varieties were developed during 1996 and 2001. Due to the resurgence of new strain of CLCuV

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(B. strain) in 2001, all the varieties as well as available cotton germplasm became susceptible. Therefore, in the absence of immune source, alternative approach is to develop CLCuV tolerant varieties which is need of the day, long-term and viable approach to tackle this problem (Akhtar et al., 2002a) as previously practiced in Sudan (Kirkpatrick, 1931).

To develop CLCuV tolerant, genotype, genetic variability is the prerequisite for effective selection. Genetic variability was explored among varieties by many scientists (Singh et al., 1973; Ahmad et al., 1982; Hanif et al., 2001) who reported significant differences for seed cotton yield. Similarly, Soomoro et al. (1986) and Afzal et al. (2002) reported significant differences among varieties for seed cotton yield, ginning out turn percentage, fiber staple length, boll weight, number of bolls per plant and plant height. Afzal et al. (2001) also reported highly significant variation among genotypes for number of bolls per plant, seed cotton yield and boll weight.

For cultivar selection procedure or variety recommendation [Genetic (G) × Environment (E)], interaction and stability are among major challenges for plant breeders (Suinaga et al., 2006). It is a fact that Pakistan's climatic conditions vary from province to province and within the province as well; consequently, performance of cotton crop vary under varying environments (Khan et al., 2008). Genetically, it happens because different genes regulate the trait differently under different environmental conditions (Sial et al., 1999). McPherson and Gwathmey (1996) and Tuteja et al. (1999) found significant (G × E) interaction for seed cotton yield, general and specific adaptation and high seed cotton yield. Hence, identification of those genotypes with high adaptability, stability, predictable performance and productive potential under specific or general environmental conditions is required for a genotype to be released as commercial cultivar (Cruz and Carneiro, 2006; Maleia et al., 2010).

Therefore, the main objective of our research was to develop a variety of cotton (*G. hirsutum* L.) which can endure high incidence as well as high intensity of cotton leaf curl virus disease and produce better yield under wide range of agro-climatic zones than those of the existing commercial cultivars.

MATERIALS AND METHODS

CRSM-38, the new CLCuV tolerant variety of cotton was developed through hybridization between 583-85/99 (a CLCuV tolerant line with 42% ginning out turn (GOT), 28.5 mm staple length, 5.2 µg/inch micronaire and 100 g/tex strength) and FH-900 (a CLCuV tolerant variety with 37.5% GOT, 28.5 mm staple length, 4.5 µg/inch micronaire and 94.0 g/tex strength) during 2001 and 2002 at Cotton Research Station, Multan. A pedigree method of plant breeding and selection was employed to advance the segregating population. Following this method, only CLCuV free/highly tolerant and high yielding plants were selected and their seeds were bulked till F_5 generation. In F_5 generation, the superior progenies were tested in a series of replicated trials before putting it into a national testing system which is mandatory for the release of a variety in Pakistan. Therefore, CRSM-38 was tested for seed cotton yield and virus tolerance in preliminary yield trials (PYT) during 2006 and 2007 and advance yield trials (AYT) during 2007 to 2008 and 2008 to 2009 at Cotton Research Station, Multan against CIM-496, the only commercial variety relatively tolerant against CLCuV and widely cultivated through out the Punjab. The new variety was compared with a commercial variety CIM-496 as well as different other candidate varieties as checks under national coordinated varietal trials (NCVT) throughout Pakistan and provincial coordinated cotton trials (PCCT) throughout the Punjab during 2007 to 2008 and 2008 to 2009, because two years studies are compulsory for the approval of any variety. It was also tested in exhibition block at Punjab Seed Corporation Khanewal and different private farms in Punjab. Data regarding earliness, GOT (%), fiber staple length, fiber micronaire, fiber strength, insect pest attack, different doses of fertilizers, different plant spacing and sowing dates were recorded at Cotton Research Station, Multan. Data of seed cotton yield in NCVT and PCCT for the year 2007 to 2008 and 2008 to 2009 were subjected to statistical analysis of variance using the procedure given by Steel and Torrie (1981). Heritability was estimated in the broad-sense for seed cotton yield as described by Lush (1940).

$$h^2BS = \sigma^2g / \sigma^2p \times 100$$

where σ^2g is genetic variance and σ^2p is phenotypic variance.
Genetic advance (GA) and genetic gain (GG) values were calculated as suggested by Johnson et al. (1955a).

$$GA = Kh^2\sigma p$$

where K = 2.06 (selection differential at 5%); σp = phenotypic standard deviation. GG was calculated from GA expressed as a percentage of the population mean.
Other fiber traits including staple length, micronaire and strength were determined by high volume instrument (HVI), Spectrum 1, Uster (American company). Ginning out turn was calculated using the following formula:

GOT (%) = weight of lint in sample / weight of seed cotton in sample × 100

Virus percentage was calculated by the following formula:

Virus (%) = number of virus affected plants / total number of plants × 100.

RESULTS

The analysis of variance revealed that genotypes differed significantly at $P \leq 0.05$ probability level for seed cotton yield in NCVT and PCCT (Table 2), indicating the existence of sufficient degree of genetic variability.

The results exhibit that average yield of CRSM-38 in PYT during 2006 and 2007 was 3074 kg/ha and in AYT during 2007 to 2008 and 2008 to 2009 was 2800.33 kg/ha indicating an increase of 14.2 and 14.20% over 2690 and 2103.83 (kg/ha) of check variety CIM-496, respectively (Table 1). CRSM-38 was tested in NCVT during 2007 to 2008 and 2008 to 2009 with an approved variety CIM-496 as well as different candidate varieties

Table 1. Yield performance and CLCuV (%) of CRSM-38 in Preliminary Yield Trial (PYT) during 2006 and 2007 and Advance Yield Trial (AYT) 2007 and 2008 and 2008 and 2009 at Cotton Research Station Multan, Pakistan.

Year	Name of trial	Yield (kg/ha)		± Over CIM-496 (%)	CLCuV (%)		± Over check (%)	LSD (0.05)
		CRSM-38	Check (CIM-496)		CRSM-38	Checks		
2006 - 2007	PYT - 3, 4	3074	2690	14.2	12.0	77.5 (CIM-499)	-84.5	160.9,
2007 - 2008	AYT - 3	2995	1911	56.7	7.6	30.7 (CIM-496)	-75.2	233.19
2007 - 2008	AYT - 5	3369	2963	13.7	11.2	32.1 (MNH-496)	-65.1	160.17
2007 - 2008	AYT - 7	2472	2312	6.9	5.7	15.7 (CIM-499)	-63.7	132.13
2008 - 2009	AYT - 3	2819	2176	29.5	11.9	82.2 (CIM-496)	-85.5	239
2008 - 2009	AYT - 4	2560	1649	55.2	13.6	64.4 (CIM-496)	-78.9	140
2008 - 2009	AYT - 5	2587	1612	60.5	9.7	43.9 (CIM-496)	-77.9	149
Average of AYT		2800.33	2103.83	14.20	9.9	44.8	-77.9	

CLCuV, Cotton leaf curl virus; ±, increase or decrease; LSD, least significant difference.

exhibiting that the new variety obtained higher yield than all other varieties (Table 3). CRSM-38 recorded highest yields than that of all other varieties in PCCT conducted by Director Cotton Research Institute, Faisalabad during same years (Table 3). In NCVT, under various climatic conditions of six main cotton growing districts of Pakistan, CRSM-38 produced higher average yield 1350 and 3124.71 (kg/ha) with an increase of 1.00 and 19.00% over 1337 and 2623.46 (kg/ha) of check variety CIM-496, respectively during 2007 to 2008 and 2008 to 2009 (Table 4). Similarly, in PCCT, it produced higher average yields 2982.78 and 2547.29 (kg/ha) that was 29.00 and 20.00% increase over 2317.50 and 2118.67 (kg/ha) of CIM-496, respectively (Table 5) during both years, indicating its wider adaptability and tolerance against CLCuV.

The response of the variety to CLCuV was studied at Cotton Research Station, Multan (Table 1). The comparison of CRSM-38 with check varieties showed a 77.9% reduction of CLCuV incidence than check varieties. CRSM-38 also showed earliness in maturity which was determined in terms of (%) age of cotton picked on different picking dates starting from 15th September to 15th December. The results reveal that new variety showed 95.2% boll opening on 15th October and 100% on 1st November when compared with CIM-496 which showed 75.3% of boll opening on same date at Cotton Research Station, Multan. At Punjab Seed Corporation, Khanewal Farm, 77.1% was picked after 139 days of sowing, although sowing was late than routine/ normal sowing (Table 6). Results show that it possessed harmonious combination of fiber quality characters, that was, (39.942%) ginning out turn, (29.07 mm) staple length, (4.385 µg/inch) micronaire and (31.38 g/tex) strength higher than CIM-499, CIM-496 and MNH-786 (Table 7). Entomological studies on CRSM-38 were conducted to assess its tolerance level against insects (jassid, whitefly, thrips and bollworms) damage in terms of the number of insects per plant (Table 8). The data of pest population indicates that the new variety had greater level of tolerance, that was, 0.75 and 2.35 jassids and whiteflies, but almost equal level of thrips 1.45 when compared with check variety (CIM-496) which showed 0.80, 2.75 and 1.00 for jassids, whiteflies and thrips per plant, respectively. Percentage of bollworms attack was also almost equal 3.5% than that of 3.4% in CIM-496. The response of CRSM-38 to increased fertilizer application was positive which is evident from the results (Table 9). The new variety CRSM-38 produced highest yields 4202.46 and 3349.625 kg/ha at highest dose of nitrogen, phosphorus and potassium (168, 112 and 60) during the years under study (2007 to 2008 and 2008 to 2009). In spacing trials, the results reveal that at 30 cm plant to plant spacing, the maximum yield of 4202.46 and 3349.625 (kg/ha) was recorded followed by 15 cm, under which it obtained 3337 and 3377 (kg/ha) during 2007 to2008 and 2008 to 2009 (Table 10). On the basis of mean yield of two years, CRSM-38 recorded higher yield of 3771.04 kg/ha on 1st May sowing followed by 3001 kg/ha on 15th May sowing. The data

Table 2. Mean squares for analysis of variance of seed cotton yield in *G. hirsutum* L. genotypes under NCVT and PCCT during 2007and 2008, and 2008 and 2009.

SOV	*df*	NCVT	NCVT	*df*	PCCT	*df*	PCCT
		2007 - 2008	2008 - 2009		2007 - 2008		2008 - 2009
Reps	3	66753.767^{NS}	92309.546^{NS}	2	156587.931^{NS}	2	19489.244^{NS}
Var	19	1394757.621**	2284712.323**	23	1249020.512**	25	1463625.609**
Error	57	91076.065	56941.660	46	75704.452	50	66849.270

*Significant (P ≤ 0.05); **highly significant (P ≤ 0.01); NS, non-significant; SOV, source of variability; *df*, degree of freedom; Reps, replications; Var, varieties; NCVT, National Coordinated Varietal Trial; PCCT, Provincial Coordinated Cotton Trial.

indicate higher yield of CRSM-38 than that of CIM-496 across all sowing dates (Table 11).

Heritability, genetic advance and genetic advance as percentage of population mean were estimated (Table 12). In our studies, the magnitude of heritability was high (78 to 90%) coupled with high genetic advance (38 to 63.90 %) for seed cotton yield.

DISCUSSION

Chemical control of CLCuV is difficult and less economical. Weiss (2000) reported that agricultural practices would be of no value unless these are accompanied by research into method of disease tolerance/resistance. Disease tolerance/resistance has one major importance in cotton breeding and a lot of work has been done already. In our studies highly significant results of NCVT and PCCT revealed the existence of sufficient degree of genetic variability within species. Similar reports were described by Brugnoli and Lauteri (1991), Muneir et al. (1995) and Ray et al. (1987) that variation exists within species. The average yield of CRSM-38 in PYT and AYT were higher than that of check variety (CIM-496). Similar kind of results were reported by Afzal et al. (2002) and Hussain et al. (2010a, b). CRSM-38 also obtained higher yields than that of check variety CIM-496 and other candidate varieties over different locations in NCVT and PCCT. This indicated the better adaptability of new variety over wide range of agro-climatic zones of Punjab and Pakistan. These findings are supported by the studies of earlier scientists, such as Tariq et al. (2003) who found higher yield in new variety of cotton than that of check.

Fiber quality traits of CRSM-38 were better than that of check varieties. These traits are combination of different characteristics including staple length, fibre strength, fiber fineness, fiber maturity and fiber elongation. These traits are becoming an increasingly critical issue in modern textile industry (Ali et al., 2008) and have their individual importance in spinning, weaving and dying units (Munro, 1987). CRSM-38 also found greater level of tolerance against insect pests than commercial variety (CIM-496). Hussain et al. (2010a, b) also reported similar conclusion. Yield was increased with increased level of nitrogen, phosphorus and potassium (168, 112 and 60, respectively), proving the fact that among the nutrients, phosphorus is necessary for cell division that stimulates number of flower buds and bolls per plant (Russell, 1973). It enhances growth of cotton crop economically, increases seed cotton yield and improves fiber quality traits (Gill et al., 2000; Sawan et al., 2008; Sharma et al., 1991). Nitrogen is an essential nutrient in composing fatty acids of oil and in building the protein structure of cotton plant (Frink et al., 1999). Potassium (K) increases the photosynthetic rates of crop leaves (Sangakkara et al., 2000) and helps in metabolism of nucleic acids, proteins, vitamins and growth substances (Bisson et al., 1994; Bednarz et al., 1999) resulting in enhancing seed weight and quality. Plant spacing is one of the significant factors affecting yield of cotton crop, and suitable spacing is critical to exploit yield potential of newly developed variety of G. *hirsutum* (Bhalerao et al., 2010). In our studies, the highest yield of CRSM-38 was recorded at 30 cm plant to plant spacing followed by 15 cm. Hussain et al. (2000) recorded similar findings that 30 cm plant to plant spacing enhanced plant height, number of bolls per plant and boll weight comparing 10 and 20 cm. The sowing date is the most critical management factors in cotton crop. Suitable planting dates enhance seed cotton yield and lint quality. In our experiment, on the basis of mean yield of two years, CRSM-38 recorded higher yield on 1st May followed by 15th May. Delaney et al. (1999) reported similar results that seed cotton yield has been reduced significantly when cotton sown later than 30th May in Alabama, USA.

Similarly, seed cotton yield has been maximized in early planted cotton crop as compared to late planting in which number of bolls per plant and boll weight reduced (Anonymous, 2008a, b, 2009a, b). Different cotton research organizations of Pakistan also found the same result, that cotton sown later than 15th June is not economical (Anonymous, 2007a, 2008a).

Hence, CRSM-38 appeared early in maturity. The present investigation revealed that May sowing with close plant spacing (30 cm) could be applied to enhance

Table 3. Average yield performance of different candidate's varieties and an approved variety CIM-496 in NCVT and PCCT at Cotton Research Station, Multan during 2007 and 2008 and 2008 and 2009.

S/N	Variety	SCY (kg/ha) in NCVT 2007- 2008	Variety	SCY (kg/ha) in NCVT 2008 - 2009	Variety	SCY (kg/ha) in PCCT 2007- 2008	Variety	SCY (kg/ha) in PCCT 2008 - 2009
1	SLH-284	3201.25	TH-06/02	1918.50	FH-113	2856.00	FH-942	3694.67
2	CRSM-38	4040.25	CIM-496	1695.75	BH-167	3217.33	RH-260	1905.33
3	GS-1	2453.00	NH-3	2294.25	NIAB-777	2551.00	VH-255	2340.67
4	ARS-1	3329.75	CRSM-38	4157.25	CRSM-38	4364.67	CRS-2007	2495.33
5	CRIS-342	2700.25	CRIS-129	1542.25	SLH-284	2577.67	MG-6	2396.00
6	NIBGE-115	3409.25	NIAB-852	1020.50	ASR-1	2451.67	CIM-557	1582.67
7	RH-610	2401.50	GS-1	1968.25	RH-610	2432.33	GS-1	1466.33
8	CIM-541	2042.75	FH-941	2696.00	CIM-554	2749.00	VH-278	1325.00
9	TH-198/94	1722.75	BH-172	3662.50	MG-1	926.00	N-852	2372.67
10	NIAB-777	2591.25	VH-278	1820.75	NIAB-852	3083.33	CRSM-38	2542.00
11	GH-102	2675.50	PB-900	2446.25	CRSM-70	3664.33	FH-207	1838.67
12	CRIS-129	2496.25	CIM-554	1638.25	GS-1	2002.33	SLH-317	2128.00
13	V-259	3091.50	NIAB-78	2211.75	BH-168	3309.67	CIM-496	612.67
14	BH-167	2491.00	CRSM-2007	1841.75	MG-3	2757.33	GS-14	1049.33
15	CIM-496	3164.75	GS-14	1842.50	CIM-541	2498.00	CIM-554	2135.00
16	CRSM-70	2944.50	GH-102	2264.75	NIAB-846	2525.67	PB-900	1028.00
17	CIM-554	2575.00	FH-942	3264.25	MG-2	1759.67	N-777	2162.00
18	FH-113	2251.00	SLH-317	2441.75	RH-541	2684.00	Sitara-008	1248.00
19	NIAB-846	3160.75	CIM-557	2866.25	VH-255	3048.67	A-1	1638.00
20	TH86/02	1608.75	NIAB-777	1870.75	NIBGE-115	2417.00	FH-941	2964.00
21	-	-	-	-	FH-942	2868.67	BH-172	2474.00
22	-	-	-	-	VH-260	2484.33	FH-2015	1661.33
23	-	-	-	-	CIM-496	2604.00	NIAB-2008	1362.67
24	-	-	-	-	FH-941	2816.67	FH-113	2963.00
25	-	-	-	-	-	-	NH-3	1850.00
26	-	-	-	-	-	-	Alseemi-160	2521.00
CV (%)	-	11.11	-	10.50	-	10.21	-	12.99

NCVT, National Coordinated Varietal Trial; PCCT, Provincial Coordinated Cotton Trial; SCY, seed cotton yield.

Table 4. Comparative yield of CRSM-38 with check variety in NCVT during 2007 to 2008 and 2008 to 2009 under different agro-climatic zones.

S/N	Location	Yield (kg/ha) 2007 - 2008		± Over CIM-496 (%)	Yield (kg/ha) 2008 - 2009		± Over CIM-496 (%)
		CRSM-38	CIM-496		CRSM-38	CIM-496	
1	CRS, MUL	4040.25	3164.75	27.66	4157.25	1695.75	145.16
2	CCRI, MUL	3628	3660	-0.9	2772	2138	29.7
3	CRS, VHR	1167	395	195.4	2624	2456	6.8
4	PSC, KWL	2724	2610	4.36	3046	3578	-14.9
5	RARI, BWP	1026	736	039.4	3075	3135	-1.9
6	CRS, SWL	3993	2815	41.8	3074	2738	12.3
7	CRS, BWP	1343	1330	0.98	-	-	-
Average	-	1350	1337	1.00	3124.71	2623.46	19.00

NCVT, National Coordinated Varietal Trial.

Table 5. Comparative yield of CRSM-38 with check variety in PCCT during 2007 to 2008 and 2008 to 2009 under different agro-climatic zones.

S/N	Location	Yield (kg/ha) 2007 - 2008		± Over CIM-496 (%)	Yield (kg/ha) 2008 - 2009		± Over CIM-496 (%)
		CRSM-38	CIM-496		CRSM-38	CIM-496	
1	CRS, MUL	4364.67	2604.00	67.61	2542.00	612.67	314.91
2	CCRI, MUL	2995	2510	19.3	2242	1350	66.1
3	CRS, VEH	1453	700	107.6	2368	1991	18.9
4	PSC, KWL	3265	2796	16.8	3354	3265	2.7
5	ARS, BWP	2712	2698	0.52	2823	2946	-4.2
6	CRS, SWL	3107	2597	19.6	2350	2173	8.15
7	CRS, BWP	-	-	-	2152	2493	-13.7
Average	-	2982.78	2317.50	29.00	2547.29	2118.67	20.00

PCCT, Provincial Coordinated Cotton Trial.

Table 6. Comparison of percent cotton picked in CRSM-38 during 2008 and 2009 at CRS Multan.

Testing center	Variety	Sowing date	Picking date						
			15/9	1/10	15/10	1/11	15/11	1/12	15/12
CRS MUL	CRSM-38	15/5	50.3	81.5	92.5	100	-	-	-
CRS MUL	CIM-496	15/5	30.5	50.8	75.3	85.3	95.2	100	-
PSC KWL	CRSM-38	28/6	-	-	58.2	-	77.1 (139 days)	-	100

earliness in CRSM-38. Dowker (1971) supported our results and found out those environments in which the genotypic effects of interaction may be enhanced and was of opinion that it is desirable to capitalize on the G × E interaction in a breeding programme. Palomo et al. (1998) and Carvalho et al. (1999) also made recommendations for favorable and unfavorable environments on the basis of stability parameters in cotton. In certain cases, the environmental factors with adverse effects may be remedied if suitable agronomic or other steps were taken e.g. control of white fly. However, it may often be easier to cure the genotype rather than the environment (Epstein, 1963; Allard and Bradshaw, 1964). Therefore, Bucio-Alanis et al. (1969) and Bains (1976) reported that the mean performance and the ability to perform con-sistently over variable environments can be genetically manipulated.

Our studies show high magnitude of heritability for seed cotton yield. Results are in conformity with those of Hanif et al. (2008) who assessed high estimates in broad sense heritability (0.68 to 0.99) for six plant characters in cotton. High heritability percentage shows high heritable variance which indicates that improvement of a population is possible through selection (Ansari et al.,

Table 7. Comparative GOT (%), staple length, micronaire and strength of CRSM-38 in preliminary yield trial and advance yield trial at CRS, Multan during 2006 to 2007, 2007 to 2008 and 2008 to 2009.

Year	Trial	Variety	GOT (%)	SL (mm)	MIKE (µg/inch)	Strength (g/tex)
2006 - 2007	PYT-6	CRSM-38	39.8	29.3	4.1	33.4
		CIM-499	39.0	27.5	5.2	30.5
2007 - 2008	AYT-3	CRSM-38	40.2	29.8	4.5	32.8
		CIM-499	37.5	28.4	4.2	31.5
	AYT-5	CRSM-38	38.7	29.4	4.2	31.6
		MNH-786	37.6	27.4	5.0	30.3
	AYT-7	CRSM-38	38.8	28.4	4.4	30.7
		CIM-499	38.0	28.9	4.8	29.7
2008 -2009	AYT-3	CRSM-38	41.4	28.2	4.4	29.7
		CIM-496	40.2	27.0	5.2	28.0
	AYT-4	CRSM-38	41.4	29.4	4.6	30.9
		CIM-496	39.7	27.4	5.2	28.6
	AYT-5	CRSM-38	39.3	29.0	4.5	30.6
		CIM-496	38.6	27.7	4.8	28.8
Average of CRSM-38	-	-	39.942	29.07	4.385	31.38

GOT (%), Ginning out turn (%); SL, staple length; MIKE, micronaire (µg/inch).

Table 8. Comparative study of CRSM-38 with CIM-496 for insect attack at CRS Multan during 2007 to 2008 and 2008 to 2009.

Variety	Number of insect per leaf			Bollworm (% damage)
	Jassid	Whitefly	Thrips	
CRSM-38	0.75	2.35	1.45	3.5
CIM-496	0.80	2.75	1.00	3.4

Table 9. Comparative yield of CRSM-38 under different doses of fertilizer at CRS Multan during 2007 to 2008 and 2008 to 2009.

S/N	N-P-K (kg/ha)	Average seed cotton yield (kg/ha)		Average
		2007 - 2008	2008 - 2009	
1	0-0-0	1523	915	1219
2	168-56-0	2522	1766	2144
3	168-112-0	2662	1776	2219
4	168-56-60	2786	1937	2362
5	168-112-60	4202.46	3349.625	3771.085

N, Nitrogen; P, phosphorus; K, potassium.

Table 10. Performance of CRSM-38 in spacing trial at Cotton Research Station Multan during 2007 to 2008 and 2008 to 2009.

S/N	Spacing (cm)	Average seed cotton yield (kg/ha)	
		CRSM-38 (2007 - 2808)	CRSM-38 (2008 - 2009)
1	15	3337	3377
2	30	4202.46	3349.625
3	45	2601	2824

Table 11. Yield performance of CRSM-38 under different sowing dates during 2007 to 2008 and 2008 to 2009 and comparative study of CRSM-38 and CIM-496 at CRS Multan during 2007 to 2008 and 2008 to 2009.

S/N	Sowing date	Seed cotton yield (kg/ha)		Average	Check CIM-496	Increase over CIM-496 (%)
		CRSM-38 (2007 - 2008)	CRSM-38 (2008 - 2009)			
1	01 - 05	4202.46	3349.625	3771.04	2019.285	86.75
2	15 - 05	3487	2514	3001	2012	49.2
3	01 - 06	3091	1686	2389	992	140.8
4	15 - 06	1570	729	1150	307	274.6
5	01 - 07	927	114	521	35	1388.6

Table 12. Components of variance, broad sense heritability and genetic advance and GA as percentage of population mean of CLCuV tolerance in *G. hirsutum* L. genotypes for seed cotton yield in NCVT and PCCT during 2007 to 2008 and 2008 to 2009.

Parameter	Genetic component	NCVT 2007 - 2008	NCVT 2008 - 2009	PCCT 2007 - 2008	PCCT 2008 - 2009
SCY	$\sigma^2 g$	325920.389	556942.665	391105.35	349194.085
SCY	$\sigma^2 p$	416996.454	613884.325	466809.81	416043.355
SCY	h^2 BS	78	90	84	83.9
SCY	GA	1037.59	1452.6238	1182.209	1114.7966
SCY	GA as percentage of mean	38	63.90	43.88	56

h^2 BS, Broad sense heritability; GA, genetic advance; CLCuV, cotton leaf curl virus; SCY, seed cotton yield; NCVT, National Coordinated Varietal Trial; PCCT, Provincial Coordinated Cotton Trial.

2004). While Johnson et al. (1955a) and Eid (2009) emphasized the fact that without genetic advance, the heritability values would not be more reliable in selection based on phenotypic appearance. In our studies, high heritability values coupled with high genetic advance were recorded for seed cotton yield. Soomro et al. (2010) found similar results that seed cotton yield showed 81.14% high heritability in broad sense coupled with high genetic advance of 60.18%. The higher estimates of genetic components, such as heritability and genetic advance as percentage of population mean together confirmed the presence of additive genetic effects which played a greater role to transmit genetic variation from parents to progeny.

This indicates that resistance or tolerance to CLCuV could be improved by selection for seed cotton yield and this trait could easily be fixed in the genotypes through selection in early generations. Larik et al. (1997, 2000) supported our findings, that seed cotton yield is a complex polygenic trait and its inheritance is most fluctuative exhibiting high broad sense heritability and genetic advance, showing that it is controlled by additive type of genes and improvement of these traits has been suggested by simple selection method.

Conclusion

It was concluded that seed cotton yield was under the control of additive genetic effects and selection was effective in the development of CRSM-38. The new variety CRSM-38 performed better than that of the commercial variety CIM-496 and the new strains of different research institutes of Punjab in terms of yield, CLCuV tolerance and fiber quality traits. Therefore, CRSM-38 was recommended for general cultivation in Punjab province of Pakistan by the Punjab Seed Council.

REFERENCES

Afzal M, Arshad M, Khan MI, Jan T, Illahi N, Haider S (2001). Genotype environmental interaction for yield and its components of newly evolved cotton genotypes under Multan conditions. Pak. J. Bio. Sci. 4 (Suppl.5):440-441.

Afzal M, Arshad M, Khan MI, Jan T, Illahi N (2002). Yield response of indigenously evolved upland cotton genotypes for various traits in National Coordinated Varietals Trail (NCVT) under Multan conditions. Asian J. Pl. Sci. 1(2):119-120.

Ahmad M, Memon AH, Baloch AH (1982). Effect of site and season on varietal performance in Desi Cotton. Pakistan Cottons, 26:33-5.

Akhtar KP, Haq MA, Hussain M, Khan AI (2002a). Whitefly transmitted Gemini viruses and associated disorder in cotton, a: review. Pakistan J. Phytopath. 14:140-150.

Ali MA, Khan IA, Awan SI, Ali S, Niaz S (2008). Genetics of fiber quality traits in cotton *Gossypium hirsutum* L. Australian Journal of Crop Science, 2(1):10-17.

Allard RW, Bradshaw AD (1964). Implications of Genotype-Environment interactions in applied plant breeding. Crop Sci. 4:503-508.

Anonymous (2007a). Annul Summary Progress Report. Central Cotton Res. Inst. Multan, Pakistan.

Anonymous (2008). A report published by the Govt. of the Punjab,

Pakistan.
Anonymous (2008a). Annual Summary Progress Report. Central Cotton Res. Inst. Multan, Pakistan.
Anonymous (2008b). Annual Technical Progress Report. Cotton Res. Inst. Faisalabad, Pakistan.
Anonymous (2009a). Annul Summary Progress Report. Central Cotton Res. Inst. (OIC Centre of Excellence in Asia) Multan, Pakistan.
Anonymous (2009b). Annual Technical Progress Report. Cotton Res. Inst. Faisalabad, Pakistan.
Ansari BA, Ansari KA, Khund A (2004). Extent of heterosis and heritability in some quantitative characters of bread wheat. Indus. J. Pl. Sci. 3:189-192.
Arshad M, Hanif M, Ali R, Afzal M, Illahi N (2002). Development of a new virus resistant high yielding cotton variety CIM-473. The Pakistan Cottons, 45(3,4):75-83.
Bains KS (1976). Parent dependent genotype × environment interaction in crosses of spring wheat. Heredity, 36(2):163-171.
Bednarz CW, Oosterhuis DM (1999). Physiological changes associated with potassium deficiency in cotton. J. Plant Nutr. 22:303-313.
Bhalerao PD, Patil BR, Ghatol PU, Gawande PP (2010). Effect of spacing and fertilizer levels on seed cotton yield under rainfed condition. Indian J. Agric. Res. 44 (1):74 - 76.
Bisson P, Cretenet M, Jallas E (1994). Nitrogen, phosphorus and potassium availability in the soil physiology of the assimilation and use of these nutrients by the plant, Challenging the Future: Proceedings of the World Cotton ResearchConference-1 held at Brisbane Australia, February pp. 14-17, Eds., Constable GA, Forrester NW, CSIRO, Melbourne, pp. 115-124.
Briddon RW, Mansoor S, Bedford ID, Pinner MS, Saurdess K, Stanley J, Zafar Y, Malik KA, Markham PG (2000). Clones of cotton leaf curl Gemini virus induce symptoms atypical of cotton leaf curl disease. Virus Genus, 20(1):19-26.
Brugnoli E, Lauteri M (1991). Carbon isotope discrimination and salt tolerant (*Gossypium hirsutum L.* and salt sensitive (*Phaseolus vulgaris L.*) C3 non helophytes. Pl. Phy. 95(2):628-635.
Bucio-Alanis L, Perkins JM, Perkins JL (1969) Environmental and genotype-environmental components of variability. V. Segregating generations. Heredity, 24:115-127.
Carvalho LPDE, Costa JNDA, Freire EC, Farias FJC, Vieira RDEM (1999). Adaptability and stability of cotton lines originating from wild material. In: Anais II Congresso Brasileiro de Algodao: O Algodao no seculo XX, perspectivas para o seculo XXI, Ribeirao Preto, SP, Brasil, pp. 5-10 Setembro 1999. Campina Grande Brazil; Empresa Brasileira de pesquisa Agropecuaia, Embrapa Algodao, 527-529.
Cruz CD, Carneiro PCS (2006). Modelos biométricos aplicados ao melhoramento genético. UFV: Viçosa, p. 585.
Delaney DP, Monks CD, Reeves DW, Bannon JS, Durbin RM (1999). Planting dates and populations for UNR cotton in Central Alabama. Proc. The Beltwide Cotton Conference. 2:1278-1279.
Dowker BD (1971). Variation studies in carrots as an aid to breeding. I. Concepts. J. Hort. Sci. 46:485-497.
Eid MH (2009). Estimation of heritability and genetic advance of yield traits in wheat (*Triticum aestivum* L.) under drought condition. International Journal of Genetics and Molecular Biology, 1(7):115-120.
Epstein E (1963). Selective ion transport in plants and its genetic control. Desalination Research Conference. Nat. Acad. Sci., Nat. Res. Council Publ. 942:284-297.
Frink CR, Waggoner PE, Ausubel JH (1999). Nitrogen fertilizer: retrospect and prospect. Proc. Natl. Acad. Sci. USA, 96:1175-1180.
Gill KH, Sherazi SJA, Iqbal J, Ramzan M, Shaheen MH, Ali ZS (2000). "Soil Fertility Investigations on Farmers Fields in Punjab", Soil Fertility Research Institute, Department of Agriculture, Govt. of Punjab, Lahore, Pakistan, pp 133-135.
Hanif M, Noor E, Murtaza N, Qayyum A, Malik W (2008). Assessment of variability for salt tolerance at seedling stage in *Gossypium hirsutum* L. J. Food, Agriculture & Environment, 6(1):132 - 136.
Hanif M, Arshad M, Afzal M, Khan MI (2001). Yield response and yield parameters of newly developed cotton varieties of *G. hirsutum* L. Baluchistan J. Agric. Sci. 2(1):9-13.
Hussain M, Akhtar LH, Rafiq M, Aslam MZ, Tariq AH, Aslam M, Arshad M, Ahmad S (2010b). Mairaj-08: new wheat (*Triticum aestivum*) variety released for general cultivation under normal and late planting in Punjab province (Pakistan). Int. J. Agri. Biol. 12(3):341-347.
Hussain M, Hussain G, Akhtar LH, Tariq AH, Rafiq M, Aslam MZ, Aslam M, Arshad M, Ahmad S, Sahi ST (2010a). New wheat variety "FAREED-06" for irrigated areas of Punjab, Pakistan. Pak. J. Bot. 42(5):3285-3297.
Hussain S, Farid ZS, Anwar M, Gill MI, Dilbaugh M (2000). Effect of plant density and nitrogen on yield of seed cotton of CIM - 473. Sarhad J. Agric. 16(2).
Hussain T, Mahmood T (1988). A note on leaf curl disease of cotton. The Pakistan Cottons, 32(4):248.
Hussain T, Ali M (1975). A review of cotton disease of Pakistan. The Pakistan cottons, 19(2):71-86.
Johnson HW, Robinson HF, Comstock RE (1955a). Estimation of genetic and environmental variability in soybeans. Agronomy J., 47:314-318.
Khan NG, Naveed M, Khan NI (2008). Assessment of some novel upland cotton genotypes for yield constancy and malleability. Int. J. Agri. Biol. 10(1):109-111.
Kirkpatrick TW (1931). Further studies on leaf curl of cotton in the Sudan. Bull Entomol. Res. XIII (3):323-363.
Larik AS, Ansari SR, Kumbhar MB (1997). Heritability analysis of yield and quality components in *Gossypium hirsutum* L. Pakistan J. Bot. 29(1): 97 - 101.
Larik AS, Malik SI, Kakar AA, Naz MA (2000). Assessment of heritability and genetic advance for yield and yield components in *Gossypium hirsutum* L. Sci. Khyber, 13(1):39 - 44.
Lush JL (1940). Intra-sire correlation and regression of offspring in rams as a method of estimating heritability of characters. Proc. American Soc. Animal product. 33:292-301.
Maleia MP, Filho PSV, Kvitschal MV, Gonçalves-Vidiga MC (2010) Stability and adaptability of commercial cotton cultivars (*Gossypium hirsutum* L. race *latifolium* H.) in Mozambique. Afri. J. Agri. Res. 5(7):539-550.
Mcpherson R, Gwathmey O (1996) Yield and stability of cotton cultivars at three west Tennessee locations. Proceed. Beltwide Cotton Conf. 1:596-598.
Munir A, Abdul R, Mukhdum MI (1995). Study on salt tolerance of cotton 9 (*Gossypium hirsutum* L.). Ind. J. Agric. Res. 29(1/2):64-68.
Munro JM (1987). Cotton: Tropical Agriculture series, 2nd edition. Longman Scientific and technical John Willey Sons Inc, New York, pp. 161.
Palomo GA, Santamaria CJ, Godoy AS (1998). Stability of yield and fibre quality in 12 cotton genotypes. Agricultura Tecnica en Mexico, 24(2):145-153.
Ray M, Jadhav SB, Khaddar VK (1987). Effect of graded salinilty levels on the lint quality of *hirsutum* cotton cultivars. Ind. J. Agric. Res. 21(3):127-132.
Russell EW (1973). Soil condition and plant growth. The English Language Book Society and Longman, London, pp 68.
Saleem MI, Shah SAH, Akhtar LH (2002). "BR-99": A new guar cultivar released for general cultivation in Punjab province. Asian J. Pl. Sci. 1(3):266-268.
Sangakkara UR, Frehner M, Nösberger J (2000). Effect of soil moisture and potassium fertilizeron shoot water potential, photosynthesis andpartitioning of carbon in mungbean and cowpea. J. Agron. Crop Sci. 185:201-207.
Sawan ZM, Mahmoud MH, El-Guibali AH (2008). Influence of potassium fertilization and foliar application of zinc and P on growth, yield and fiber properties of Egyptian cotton (*Gossypium barbadense* L.). J. Plant Ecol. 1:259-270.
Sharma CP, Sharma PN, Chatterjee C (1991). Manganese deficiency in maize affects pollen viability. Plant Soil, 138:139-142.
Sial MA, Jamali KD, Arain MA, Ahmed M (1999). Adaptability of semi-dwarf spring wheat in sindh province. Pakistan J. Sci. Ind. Res. 42:342-344.
Singh HG, Mital RK, Upadhyah RK (1973). Variety improvement and interaction in American Cotton (*G. hirsumtum* L.) in Uttar Pardesh.

India J. agri. Sci. 43(5):463-466.
Soomro BA, Nachnani GH, Memon GM (1986). Performance of seven upland cotton varieties at five locations in Sindh. The Pak. Cottons, 30(1):31-38.
Soomro ZA, Kumbhar MA, Larik AS, Imran M, Brohi SA (2010). Heritability and selection response in segregating generations of uplan cotton. Pakistan J. Agric. Res. 23(1 - 2):25 - 30.
Steel RD, Torrie JH (1981). Principles and Procedures of Statistics. A Biological Approach. 2nd edn, McGraw Hill Inc., New York, Toronto, London.
Suinaga FA, Bastos CS, Rangel LEP (2006). Phenotypic adaptability and stability of cotton cultivars in Mato Grosso State, Brazil. Pesq. Agropec. Bras. 36:145-150.
Tariq MA, Rana SA, Shah RA, Shah SM, Ali S, Zafar M, Akhtar LH (2003). BH-118" A new cotton variety released for general cultivation in southern Punjab. Sci. Tech. Develop., 22(2):15-19.
Tuteja OP, Singh DP, Chhabra BS (1999). Genotypic × Environment interaction on yield and quality traits of asiatic cotton. Indian J. Agric. Sci. 69:220-3.
Weiss EA (2000). Oilseed crops. Second edition. Blackwell Sci. Ltd. London.