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COMPOSITE-CROSSING METHODOLOGY PAYS RICH DIVIDEND IN COTTON BREEDING—A RESUME

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ABSTRACT

The paper summarises results of two decades (1969–1988) of successful cotton breeding (*Gossypium hirsutum* L. and *G. barbadense* L.) done by the author, using the composite breeding methodology. The elements of technology include: identifying high general combining lines for yield, bolls/plant, boll weight, lint out-turn, superior fibre quality from top-cross testing, using a double cross varietal hybrid as the pollen source, crossing the selected lines in numerous combination, composite-crossing between the resultant hybrids by mixing pollen from all the hybrids, raising extensive progenies (20,000 plants) from such composite crosses, selecting superior recombinant segregates and mating them again through composite-crossing over 3–4 cycles, followed by 2 to 7 cycles of inter se mating within the family. The results were highly gratifying. Numerous high yielding lines were developed and a few released for commercial cultivation (e.g. JK 97, Sharada—multiple pest-resistant rainfed cotton; Abadhita—bollworm, aphid and jassid resistant irrigated cotton JK 119) combining desirable traits. The varieties have given significant jump in yield (70–100% over checks), shortened crop duration (150–155 days, checks 200–210 days), high boll weight (10.6 g, check 3.8 g) high lint per cent (39–42%, check 34.5%) multiple pest-resistance (resistant to jassids, aphids, bollworms, stem weevil, red spider and whitefly) wide adaptability across agroclimatic zones of India. Single stem, short-branch lines maturing in 130–135 days, suitable for high density planting and machine picking giving 106% higher yield and 45–47% lint out-turn are undergoing multilocation testing across the Nation. The *G. barbadense* variety BCS 23-18-7 giving 70–100% higher yield over the check, Suvin, shorter in maturity and having excellent fibre quality, is undergoing final testing before release. Varieties JK-119 and BCS 23-18-7 have produced 15–24% higher yield than DCH-32 hybrid cotton with matching fibre quality.

Key words: Composite-crossing, combining ability, quantum jump, adaptability, multiple pest-resistance.

A working hypothesis was put forth nearly three decades ago that "modern plant breeders may have overextended the logical implications of the pure line theory and become

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enslaved in uniformity and confirmity conventions" [1]. This holds true even today among breeders of autogamous crops including cotton. Advanced breeding methodologies based on concepts accruing from basic researches in biometrical genetics have been utilised by breeders of allogamous crops but not by those of autogamous crops [2]. Recombinant gene assortment and deliberately increasing the chances of recovering new recombinants of agricultural value and prospects of improving the breeding material need not be overemphasised. Harlan and others [3–5] proposed composite breeding in which F_2 seeds of several crosses were mixed and grown for increasing genetic variability and obtained 20–25% increased yield in a period of 20–25 years of continuous selection.

Therefore, a breeding methodology based on high general combining ability in economic characters of cotton (*Gossypium* spp.) was devised and plan of execution was chalked out during 1965–1969. The objectives were to achieve quantum jump in yield and fibre quality characters taking into consideration future needs of the cotton farmers and cotton industry during the next 25–30 years. High general combiners were identified by top cross testing and used for composite-crossing among F_1s, and followed similarly in 3–4 further generations [6]. *G. hirsutum* and *barbadense* cotton varieties, which produced 70–100% higher yield than checks, were evolved including multiple pest resistant varieties and compact cottons maturing in 130–135 days. Four varieties were released for general cultivation in a period of 8–16 years.

MATERIALS AND METHODS

TOP CROSS TESTING

A highly heterozygous pollen source resembling an open pollinated variety of maize was created in 1968 at the Indian Agricultural Research Institute, New Delhi. For this, a double-cross F_1 was made using four cotton genotypes from distant geographical distribution. These were: Acala 5675 (USA), CL-20 (South Africa), K 3814 (USSR), and DC 516 (South India), the last being a derivative of a cross between perennial *barbadense* and annual *hirsutum* [7, 8]. Pollen from the double-cross F_1, (Acala 5675 x CL 20) x (DC 516 x K 3814) was used for dusting on emasculated flowers of selected 480 healthy growing genotypes in 1969 from genetic stocks maintained at Dharwad as female lines. The top-crossed seeds were collected linewise. Seeds were sown female linewise and parental linewise at the Agricultural Research Station, Dharwad Farm, in 1970 in augmented randomized block design in duplicate plots. Observations were recorded on each of the 40 plants per replication in respect of boll number, boll weight, *kapas* (seed cotton) yield, lint out-turn, fibre length and strength.

Those top-crossed F_1s which showed 25% higher yield than the general mean (GM) of all F_1s were marked using the following equation:

$$\frac{\text{Mean yield of } F_1\text{s of a female line}}{\text{General mean yield of all } F_1\text{s}} = X = 25\% \text{ of GM}$$

Among the genotypes investigated, 216 lines showed high general combinity for yield, 62 among them were identified as high general combiners for all the six characters [9].

COMPOSITE-CROSSING

The F_1 hybrids were created in 1972 involving high general combiners chosen in accordance with the specific objectives. The F_1s grown in two rows of 21 plants/row were composite crossed by emasculating flowers in the afternoon and collecting anthers in Petri dishes, and kept overnight. The next morning pollen grains from these anthers were thoroughly mixed and dusted on all the emasculated flowers. The procedure was repeated daily for 3–4 weeks. *Kapas* from such composite-crossed bolls was bulk collected, ginned and the seeds obtained represented composite-crossed S_0 seeds. Five such composite-crossed populations were created with specific objectives. Sixty two high general combiners were used: CC I—for attaining giant boll weight; CC II—for developing high yielding, high lint out-turn extra long and high strength fibre variety; CC III—for developing multiple pest resistant variety; CC IV—producing high yield; and CC V—for evolving compact cotton strains with high lint out-turn of 45% with extra long and strong fibres, and suitable for machine picking.

A few examples of composite-crossed populations are: CC I—JK 97, JK 125-2-50, Stoneville 2B, 101-102 B, Dixieking, MCU 5 and CPD 8-1; CC II—JK 97, JK 79-418, JK 125-2-50, Stoneville 2B, MCU 5, DBS 11-4; CC III—JK 97 as base variety and 36 other genotypes which showed mild degree of tolerance to bollworms and jassids; CC IV—JK 44 as base variety and the same 36 genotypes as in CC III; and CC V—PRS 72, PRS 74, JK 97, JK 125-2-50, JK 79-418, MCU 5, Stoneville 213, D 33 and Laxmi.

The CC seeds were sown to obtain 22,000 plants in each population. Selection of plants were done at peak flowering stage and they were again composite crossed using all the selected plants. The procedure was repeated in 3–4 cycles depending on the objective. Plant progenies were intermated within family for 2 to 7 cycles until the objective was achieved.

RESULTS AND DISCUSSION

Estimates of phenotypic and genotypic variability for nine characters in CC III and CC IV are presented in Tables 1 and 2 (courtesy Sharma, 1979). Tremendous amount of

Table 1. Estimates of phenotypic and genotypic variances, mean, range and coefficients of variability for nine characters in a composite cross of cotton, CC III

Parameter	Yield per plant (g)	No. of bolls per plant	Boll weight (g)	Locules per boll	Seeds per boll	Lint index (g)	Seed index (g)	Ginning %	Fibre length (mm)
Range	0–155.3	0–44.0	0.9–5.5	3.0–4.0	12.0–40.0	2.1–7.4	4.3–13.0	26.3–44.3	17.0–31.0
Mean	17.85	5.33	3.42	3.10	24.44	5.12	9.39	35.21	24.06
Phenotypic variance	316.87	24.13	0.62	0.09	22.63	0.86	1.83	6.30	8.02
Genotypic variance	276.63	21.78	0.48	0.05	20.01	0.72	1.60	4.87	7.41
PCV	99.74	92.14	23.11	9.46	19.46	18.10	14.39	7.13	11.77
GCV	93.20	87.52	20.24	7.41	18.30	16.60	13.48	6.27	11.31

variability for all the characters except locules/boll was recorded in both populations at phenotypic and genotypic levels. Genotypic coefficient of variability was only 3 to 7% lower than the respective phenotypic coefficient of variability, indicating predominance of genetic variation.

Table 2. Estimates of phenotypic and genotypic variances, mean, range and coefficients of variability for nine characters in a composite cross of cotton, CCIV H

Parameter	Yield per plant (g)	No. of bolls	Boll weight (g)	Locules per boll	Seeds per boll	Lint index (g)	Seed index (g)	Ginning %	Fibre length (mm)
Range	1.3–225.3	1.0–61.0	1.3–6.6	3.0–4.7	12.0–46.0	2.8–7.7	6.6–13.3	26.2–44.5	17.0–31.0
Mean	24.16	7.04	3.52	3.14	25.41	5.03	9.30	34.98	25.01
Phenotypic variance	591.65	50.23	0.71	0.10	28.47	0.75	1.46	9.76	4.70
Genotypic variance	551.42	47.87	0.57	0.07	25.85	0.61	1.24	8.34	4.08
PCV	100.00	100.70	23.92	10.08	21.00	17.17	13.01	8.93	8.66
GCV	97.21	98.31	21.34	8.24	20.01	15.50	11.98	8.25	8.08

Kapas yield per plant showed a range of 0–155 g/plant in CC III and 1-255 g/plant in CC IV. Considering 55,500 plants/ha grown under rainfed conditions, the yield of 155 g and 255 g/plant amounts to 75 and 125 q/ha, respectively. From such highly variable population a large number of plants could be selected for further composite crossing in the next generation. Harlan [3] described the variabilit observed by composite mixing of F_2 seeds to be more than what was seen at the Centre of diversity of barley (*Avera sativa* L.) and each plant looked like a mutant plant. Thus, it is evident that composite crossing of F_1s would throw out extremely high variability from which the desired plants could be selected as an outcome of genetic recombination.

The method also eliminates any possible formation of selfed zygotes. For instance, if 5 parental genotypes are involved in the programme, 10 possible F_1s could be created excluding reciprocals. Pollen grains and ovules produced on the F_1s hybrids are the results of new genetic recombination. If 1 selfed gamete is formed in a tetrad, then the chances of this gamete fertilizing another similar gamete in a cotton boll containing 25 seeds would be:

$$\frac{1}{4} \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{25} = \frac{1}{10{,}000}$$

If a given plant produces 25 bolls, the chances of recovering an entirely selfed plant resembling one of the parental genotypes would be 25 in 10,000. Therefore, when such rare and new genetic recombinants are found in a composite-crossed population originating from 5 parental types, the widest scope of selection would be available in the population handled by any breeder when a larger number of genotypes are used in the composite crossing programme.

The cotton varieties grown in South India until 1970s were of 200–210 days duration. Therefore, CPD 8-1 was evolved out of the composite crossing made by using the same genotypes as in the top-cross testing during 1972. The variety was tested in All India Coordinated Cotton Improvement Project and released in 1980 in the name of Sharada. The variety had a total duration of 150–155 days, and within that period produced up to 70% higher yield than cv. Laxmi in Karnataka, with a ginning out-turn of 40–42%. Two years testing in the National Elite Varieties Trial confirmed wide adaptability of Sharada (Table 3). On an average of six locations in North, West, East, Central and South Indian centres, CPD 8-1 produced 25 q/ha, and was the first South Indian variety to flower timely in North India and give high yields. This is also the only variety which recorded 38% lint out-turn at Sirsa, whereas other varieties grown in North India exhibit only 31 to 33% lint out-turn.

Boll number and boll weight are known to be negatively correlated with each other in *Gossypium* spp. [10–12]. Therefore, with a view to improve average boll weight while retaining the number of bolls per plant at the same level, composite crossing (CC I) was resorted to between the F_1s and among selected plants in six future generations. In this exercise, six strains which had shown additive gene action for boll weight were chosen. The detailed tabulated data from Kadapa [13] are reproduced here (Table 4) in abridged form. The data show that by chosing selected genotypes for composite crossing followed by 6–7 cycles of intermating between selected plants, it was possible to increase the average boll weight without decreasing their number per plant. The check varieties Sharada and JK 97 produced 35 and 30 bolls/plant. BAR-JK97GB produced slightly higher number of bolls/plant, with average weight of 10.6 g kapas per boll. This shows that by composite crossing it should be possible to break the established negative linkages between economic yield components like boll number and boll weight, both of which can be improved without affecting each other.

Table 3. Performance of BAR-JK97-GB grown under irrigation with check varieties of cotton

Strain	Bolls per plant	Boll weight (g)	Seed cotton yield (q/ha)	Lint out-turn (%)	Mean fibre length (mm)
BAR-JK97-GB	36	10.6	39.3	39.9	28.8
Sharada	35	3.9	21.2	41.2	24.1
MCU-5	19	4.6	16.2	31.0	32.7
JK-97	30	4.8	20.2	37.4	26.2
Laxmi	24	4.1	19.0	35.2	24.5
Stoneville 13	18	7.3	18.3	37.3	28.7
Auburn M.	14	5.4	14.5	38.8	26.1
CD 5%			5.1		

During 1974, Dr. H. R. Arakeri supported the extraordinary plan of breeding pest resistant varieties, including bollworms resistance in cotton. Therefore, CC III and CC IV, which comprised some of the parents with mild tolerance to bollworms in previous years, were grown under unprotected conditions every year. Both populations were combined to form a single population during 1974–79 by selecting and crossing among them every year. Selection was practiced to identify the single plants which produced 10 g kapas/plant in the second cycle of composite crossing. The norm of selection was raised up to 20, 30 and up to 60 g/plant by the year 1979, and finally 106 single plant progenies became available for large scale testing in replicated trials without any plant protection measures.

Screening of strains under artificially infested conditions with regard to bollworms (*Erias* spp. and *Heliothis armigera* L.) and sucking pests like jassids (*Empoasca bigutella bigutella*) and aphids (*Aphis gossypii*) was undertaken for 3 years, growing the crop every year without any plant protection cover. The plants that bore unaffected bolls on every sympodial branch were intermated and were advanced to the next year. Thus, 12 strains were identified which produced 100–200% higher yield than the check varieties when grown without plant protection. Of these, the top ranking 4 strains in yield as well as fibre quality characters were grown without any plant protection in 6 replications for 3 seasons (Table 5).

Bollworms of cotton are severe pests throughout the world. Normally 80–90% yield reduction is observed when cotton is grown without plant protection [14]. The bollworm resistant cotton strains showed only 49 to 55% shedding of the reproductive parts (JK 276-4-1, JK 260-2 and JK 119-25-54), as compared to the check varieties showing 85–90% shedding. Secondly, due to excessive very few bolls were left on the plant in the check variety. Bolls with one locule affected in the resistant varieties were also recorded as affected bolls. Thus, total bolls affected did not differ significantly from checks. But the number of unattacked bolls/plant in all the 4 resistant varieties was significantly higher, consequently, the yield in JK 276-4-1, JK 260-2 and JK 119-25-54 was 100% more than in Sharada and up to 125% more than Laxmi and LRA 5166. The yields realised were 12.5–14.3 q/ha and 5.2–7.6 q/ha in the resistant and susceptible genotypes, respectively.

Since the new strains were grown without plant protection, it was decided to find out the amount of insecticide spray required to produce normal yields (18–20 q/ha) at Dharwad which are generally obtained under complete protection with 8 sprays (Table 5). So represents no plant protection

Table 4. Squares and boll shedding, No. of bollworm attacked and unattacked bolls/plant, *kapas* yield, lint %, and fibre length in cotton grown without plant protection (rainfed)

Strain or check variety	Shedding due to bollworms (%)				Bollworm attacked bolls/plant				Unattacked fully open bolls/plant				*Kapas* yield (q/ha)				Lint %	2.5% span length (mm)
	1983	1984	1985	mean	1983	1984	1985	mean	1983	1984	1985	mean	1983	1984	1985	mean		
JK 276-4	52	54	53	53.0	3	4	3	3.3	11	14	16	13.3	11.8	11.2	13.3	12.1	37.5	28
JK 26-2	55	52	50	52.3	6	3	3	4.0	10	12	12	11.1	14.0	12.3	11.3	12.5	35.0	26
JK 345-3	46	50	48	48.0	3	3	2	2.6	14	15	17	15.6	13.6	15.6	12.5	12.8	36.0	25
JK 119-25-54	49	53	56	52.3	6	5	5	5.3	12	14	18	14.6	14.3	13.1	15.6	14.3	41.0	34
Sharada	83	85	89	85.6	5	4	4	4.3	3	3	6	4.0	8.3	7.1	4.4	6.6	42.0	26
Laxmi	90	93	89	90.6	5	5	6	5.6	4	3	5	4.0	6.1	6.0	4.2	5.4	35.3	26
LRA5166	96	91	92	93.0	7	9	8	8.0	3	3	2	2.6	—	5.6	5.2	5.2	35.5	28
DCH-32	90	95	93	92.6	12	9	14	11.6	6	4	7	5.6	8.3	8.0	6.8	7.6	33.2	36

Table 5. Seed cotton yield (q/ha) from the bollworm resistant strains and susceptible checks varieties/ hybrids of cotton under different plant protection schedules (rainfed)

Strains or check variety		Pesticide sprays					Mean of two years	Dusting pesticide powder				Mean of two years
		S_0	S_1	S_2	S_3	S_4		D_0	D_1	D_2	D_3	
JK 276-4-1	1984	15.5	19.2	21.8	21.0	21.5	19.04	13.0	13.8	16.9	17.1	17.8
	1985	14.1	16.3	21.1	19.9	19.8		14.4	17.4	19.5	18.7	
JK 260-2	1984	13.6	18.3	20.3	20.7	20.6	18.66	12.4	12.7	13.6	13.0	14.8
	1985	12.9	18.8	20.6	20.0	20.8		13.6	17.4	18.1	17.4	
JK 345-3-3	1984	13.7	19.3	21.0	20.9	21.0	19.18	11.1	11.3	14.7	11.8	14.2
	1985	15.5	18.9	20.6	20.0	20.6		13.1	16.5	18.7	16.6	
JK 119-25-54	1984	13.1	13.9	20.6	23.3	23.4	19.14	13.3	14.1	21.4	20.9	17.8
	1985	14.4	15,6	21.9	24.8	23.6		13.8	14.6	21.8	22.4	
Sharada	1984	8.0	8.4	10.9	14.6	16.7	12.04	9.2	11.6	12.5	14.4	12.8
	1985	7.0	8.3	9.4	16.0	18.1		9.4	14.4	14.6	15.9	
Laxmi	1984	6.3	6.8	7.1	9.2	14.6	8.39	6.3	8.3	9.3	12.3	9.9
	1985	6.0	6.5	7.5	9.0	15.9		6.9	8.3	14.4	13.5	
LRA 5166	1985	5.3	5.6	5.4	8.5	11.3	13.1	5.1	5.6	6.3	8.1	6.3
DCH 31	1984	6.0	6.1	6.6	8.4	14.6	7.45	5.6	6.1	6.9	8.1	6.8
	1985	5.1	5.9	6.3	9.1	13.4		5.4	6.3	6.6	8.6	

and S_4—four sprays. With no spraying at all, JK 276-4-1, JK 260-2 and JK 119-25-54 produced 15.5, 13.6 and 14.4 q/ha seed cotton as compared to 8.0 and 5.3 q/ha in the check varieties. The bollworm resistant varieties given with one spray (S_1) at preflowering stage yielded 75 and 100% more *kapas* than Sharada and Laxmi, respectively. Two insecticidal sprays (S_2) further increased yield of JK 276-4-1, JK 260-2 and JK 119-25-54 by 20–40%, while the yield of Sharada and Laxmi increased by 0–20%, indicating that Laxmi and Sharada require more sprays to produce normal yields. JK 119-25-54 responded well up to 3 sprays (S_3) while JK 276-4-1 responded up to two sprayings only (S_2); thereafter yield remained nearly static with S_3 and S_4 levels of spraying. The highest yield of 21.8 q/ha was obtained in JK 276- 4, which was 50–60% more than that of checks with two sprays.

It was possible to select for resistance against sucking pests also when the bollworm resistant strains were grown without plant protection. The initial level of infestation and reproduction rate thrips (*Thrips tabacii*), jassids and aphids was recorded for 4 weeks (Table 6). Initial infestation of thrips under PP_0 was only 1.6/leaf on JK 276-4, which increased to 2.8/leaf after 4 weeks. But on Sharada and Laxmi, it was 3.8–14.8 initially and increased to 3.0–16.3/leaf after 4 weeks. Jassid infestation was the same initially as well as

Table 6. Initial infestation level and rate of multiplication during 4 weeks of sucking

Strain or variety	No. of nymphs/adults per cm[2] leaf area of 0.4 cm stem tip (aphids) with PP_0											
	thrips				jassids				aphids			
	1	2	3	4	1	2	3	4	1	2	3	4
JK 276-4	1.6	1.9	2.1	2.8	1.0	1.3	1.6	2.0	0.3	0.8	0.8	0.6
JK 260	1.3	1.6	2.0	2.5	2.9	2.1	2.7	3.4	0.2	0.6	0.9	0.7
JK 344	2.1	2.6	3.4	4.2	1.3	1.9	2.1	2.0	0.8	0.9	1.2	1.1
JK 345	2.5	3.1	3.6	3.9	0.8	1.1	1.6	1.5	1.0	1.6	1.8	1.8
Sharada	3.8	6.8	10.6	14.8	1.2	1.5	1.7	1.4	2.3	4.6	6.5	10.6
Laxmi	3.0	5.6	11.8	16.3	0.8	1.1	1.3	1.1	2.4	3.9	7.6	9.8

PP_0—no plant protection; PP_1—one spray of rogor 20–25 days after sowing.

Initial observation periods: thrips 15th day, jassids 50th day, and aphids 90th day.

4 weeks later. The aphid attack was practically nil on JK 276-4 and JK 260 while on Sharada and Laxmi it increased from 2.4 and 2.3 to 10.6 and 9.8 in the same period. This showed that JK 276-4 and JK-260 were practically free from incidence of thrips and aphids and moderately free from jassids. Considering the superior fibre quality characters, JK 276-4-1 was released as Abadhita-1 for general cultivation. Further selections like JK 276-4-1-10-3, JK 345-3-3 and JK 260-2-1-5 have shown multiple pest tolerance and are undergoing further trials.

The composite cross CC II was meant to replace the variety MCU-5, an irrigated cotton variety of India, which is the only cotton variety producing fibres capable of spinning 60 counts. Since MCU-5 was relatively low yielding, CC II was intensively followed for 5 cycles of composite crossing between the selected plants until JK 119-25-54 strain was evolved. This strain was tested for 5–7 years in the All-India Coordinated Cotton Project in South India along with MCU-5 as common check and other strains and varieties as trial entries. JK 119-25-54 (JK 119) was released as AICCIP as well as Karnataka State.

JK 119-25-54 produced top ranking yields and the highest average yield of 36–37 q/ha was produced in the 7-year trials at Siruguppa and Raichur, while MCU-5 gave the highest average yield of 26.8 q/ha. Thus, the *kapas* yield of JK 119 was 37% higher than that of MCU-5. However, lint yield of JK 119 was 55% higher than in MCU-5. As compared to other varieties also, JK 119 produced 50–75% higher yield of lint because lint out-turn was 40% in JK 119 as against 31.0–34.5% in other strains. It has also shown resistance against jassids, *Erias* and *Heliothis* bollworms.

The CC V population was developed with a view to increase yield of *kapas* and lint by increasing plant population to a density of 333,000/ha [15, 16]. The JK 400 series of cotton

pests on cotton strains grown without or with minimum plant protection

No. of nymphs/adults per cm^2 leaf are of 0.4 cm stem tip (aphids) with PP_1											
thrips				jassids				aphids			
1	2	3	4	1	2	3	4	1	2	3	4
1.5	1.0	1.3	1.6	1.1	1.2	1.0	1.5	0.5	0.6	0.7	0.9
1.4	1.5	1.8	1.5	1.4	1.7	1.6	1.8	1.0	0.8	1.1	1.3
1.8	1.8	1.6	1.3	0.9	1.1	0.8	1.4	0.4	1.0	0.8	0.9
2.0	2.1	2.0	1.8	1.4	0.6	1.0	0.8	1.1	1.4	1.3	1.6
3.1	4.6	5.6	9.3	0.8	1.2	1.4	1.3	2.8	5.2	9.8	20.4
3.6	4.3	8.2	11.3	1.0	1.0	0.8	0.6	3.1	4.6	9.8	17.3

strains are undergoing multilocation tests in Southern, Central and Northern cotton zones of India. CC V resulted in the development of compact cotton strains which produced 100% higher yield of *kapas* during 1988–89, 45–47% lint out-turn and 2.5% span lux length of 28 to 33 mm. The crop duration has been reduced to 130–135 days from seed to seed. The data available from locations in South, Central and Northern Research Stations revealed that the strains produced 76–110% higher yield than the local checks (Table 7). The new compact cotton strains as well as check varieties were grown at the population density of 225,000–333,000 plants/ha at different locations. At each location at least one JK strain produced 100% higher yield of seed cotton than the respective check varieties. JK 410-6 at Sirsa, JK 400-6-1, JK 441-3 and JK 410-6 at Srivilliputtur, JK 400-6-1, JK 441-3 and JK 410-6 at Dharwad and JK 417-12 and JK 416-8 at Aduthurai produced 100% higher yield of *kapas* within 135 days, whereas the local checks took 160–185 days to produce the recorded yield.

Lint out-turn values of JK 400 series ranged between 42.3–47.1%, thus registering 10–15% more lint out-turn at Sirsa. All the compact JK 400 series strains

Table 7. Performance of compact cotton strains at different locations, 1988

Strain or variety	Seed cotton yield (q/ha)				Lint out-turn
	Sirsa	Shrivilli-puttur	Dhar-wad	Aduth-urai	
JK 400-6-1	16.3	29.6	36.5	10.6	42.3
JK 441-3	17.5	31.2	39.1	9.8	46.3
JK 410-6	19.1	32.5	34.5	8.7	47.0
JK 417-12	13.7	25.6	31.2	12.5	45.1
JK 416-8	13.4	25.4	29.8	13.1	43.4
JK 406-5	15.4	28.8	30.5	11.1	45.5
H-777	9.59	—	—	—	31.2
MCU-5	—	14.8	—	—	34.6
Sharada	—	—	18.2	—	39.8
MCU-7	—	—	—	5.9	36.2

flowered in time at Sirsa to produce high yields. Similar response to photoperiod was shown by the variety CP 8-1. The strains of JK-400 series are expected to produce more than 50 q/ha *kapas* if adequate fertilizer doses are given under increased plant density. One such trial was conducted in summer 1988 at Siruguppa. The strains JK 410-10, JK 441-2-7, and JK 406-5 produced 59–73 q/ha *kapas* when plant population was 333,000/ha and fertilizer applied at the rate of 150:75:75 kg NPK/ha.

Similarly, one composite-cross populations was created in *G. barbadense* using 13 genotypes. The strains BCS 23-18-7 and BCS 9-55 were tested for 5 years under irrigated condition at five research centres. On an average, BCS 23-18-7 produced 70% higher yield of *kapas* and 100% higher yield of lint as compared to cv. Suvin. Fibre maturity up to 93% has been shown by these two *barbadense* strains which produce soft, silky extra long fibres showing 3 mm guaze fibre strength of 29.3 g/tex., thus nearly matching Suvin in fibre quality also (except in fibre length).

From the foregoing discussions it can be concluded that the composite-crossing method is a sure method of breeding autogamous crops for achieving quantum jump in yield. The requirements of the method are: utilization of high general combiners in the crossing programme, growing sufficiently large number of F_1 hybrids. Composite crossing of all the hybrids, growing large population (more than 20,000 plants in crops like cotton), intensive selection of plants showing the required characters as per the defined objective, composite crossing between the selected plants for 3–5 cycles, and intermating among plant progenies for the required number of cycles. The method would produce pure strains within a period of 8–14 years. High adaptability of the developed strains is also assured. Better fibre quality can also be attained if selection is appropriately exercised. This method may also be put into practice by breeders of all autogamous crops.

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