TAKING PIGEONPEA HYBRIDS TO THE DOOR STEPS OF FARMERS

Project Report
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Contents

Progress Report

1. Introduction

Pigeonpea [*Cajanus cajan* L. Millsp.] occupies an important place in Indian agriculture. Globally, it is cultivated on 4.92 m ha **(Table 1)** and 72.7% (3.58 m ha) of it is confined to India alone. Pigeonpea is credited to be the most suitable crop for subsistence agriculture because it is drought tolerant, needs minimum inputs, and can produce reasonable quantities of food even under unfavorable production conditions. New pigeonpea cultivars released in India have attracted many rainfed farmers and for this reason, the cropped area has witnessed an increase from 2.3 m ha in 1950 to 3.58 m ha in 2006. Unfortunately, so far no increase has been witnessed in its productivity (yield kg ha^{-1}) which has remained consistently low at around 700 kg ha^{-1}. The issue of productivity plateau has been a subject of concern over decades and it still remains a challenge.

The quantum jumps in yields as recorded in various cereal, vegetable, and fruit crops is partly attributed to the breeding of high yielding hybrids. To achieve any breakthrough in pulses, the deployment of a similar hybrid breeding approach is warranted but it could not be achieved in this group of crops due to their high self - pollinating nature. In pigeonpea, however, ICRISAT initiated a concept of breeding hybrid cultivars using its partial (25-30%) natural out - crossing. At present an efficient CMS system is available which provides ample opportunities to develop commercial hybrids in and the results have offered optimism for a breakthrough in this direction. In past few years a significant progress has been made to breed and take the hybrid technology to the farmers and its brief account is presented here.

Table 1: Global Pigeonpea Production Trends

Country	Area (ha)	Production (t)	Yield (kg ha^{-1})
Bangladesh	4000	2000	500
Burundi	2000	1800	900
China	150000	NA	NA
Comoros	440	320	727
Congo	8000	5700	713
Dominican Republic	17000	16065	945
Grenada	520	500	962
Haiti	6000	2400	400
India	3580000	2740000	765
Jamaica	1100	1300	1182
Kenya	196261	110662	5634
Malawi	123000	79000	642
Mozambique	85000	NA	NA
Myanmar	560000	530000	946
Nepal	20703	19085	922
Panama	4800	1949	406
Philippines	813	1258	1547
Puerto Rico	272	218	802
Tanzania	68000	50000	735
Trinidad and Tobago	400	953	2381
Uganda	86000	88000	1023
Venezuela	3344	3015	903
Total / Mean	**4917653**	**3654225**	**898**

2. Maintenance of Male –sterile Lines

During 2008-09, a total of 15 A / B lines **(Table 2)** were maintained at Marathwada Agricultural University, Parbhani, Sardar Krushinagar Dantiwada Agricultural University, SK Nagar; Agricultural Research Station (ARS), Gulbarga; Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola; and International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru . The results are briefly described below:

Parbhani: Under this activity six male-sterile lines including three from ICRISAT (ICPA 2043, ICPA 2047, and ICPA 2092) and three others (BSMR 736, BSMR 2004-4, and GT-288A) from ARS, Badnapur, were maintained by backcrossing for use in breeding programme. Also during this process, roguing of the off-type plants was undertaken to purify the genetic stocks.

SK Nagar: Two locally developed male-sterile lines (GT 603 and GT 601) were sown in isolations at the university farm for maintenance and their large-scale seed production.

Gulbarga: A total of five CMS lines, including four (ICPA 2101, ICPA 2161, ICPA 2078, and ICPA 2043) from ICRISAT and one (GT-288A) from SK Nagar were maintained under an insect proof cage at Gulbarga. Of these ICPA 2078, ICPA 2043, and GT 288A were found to be 100% male-sterile and these were used for crossing with local germplasm and established 10 R-lines. A total of 42 experimental hybrids were produced for evaluation in the next season.

ICRISAT: Two male-sterile lines (ICPA 2039 and ICPA 2043) were maintained in isolation. To study the stability of male-sterility across the environments, a short-duration male-sterile line ICPA 2039 was evaluated at several locations in India (8 locations), China (3 locations), and Myanmar (1 location). At all the locations it expressed very high (98 -100%) level of male-sterility.

Table 2: CMS 'A' and restorers 'R' lines maintained at different centres, 2008

NFSM Centres	CMS 'A'	Restorers 'R'
ICRISAT, Patancheru	2	38
PDKV, Akola	-	-
MAV, Parbhani	6	10
ARS, Gulbarga	5	10
SKDAU, SK Nagar	2	13
Total	**15**	**71**

3. Development of New CMS lines

The main objective of this activity was to breed new CMS lines with good agronomic base and genetic diversity. The reports received from various participating centres are summarized below:

Parbhani: A programme to develop new CMS lines was started during 2008-2009. In this programme four BC_1F_1 and five BC_2F_1 plants were crossed with their recurrent parents. These (partially converted) progenies will be tested for the expression of male-sterility and important agronomic traits during the next season.

SK Nagar: This station has converted all the important genetic stocks in heterosis breeding programme to breed new CMS lines. At present the station has 98 new CMS lines **(Table 3)**. These lines have been characterized for various morphological traits such as maturity, growth habit, seed size, and seed colour. Eighteen lines representing different maturity groups in BC_5F_1generation were advanced in the conversion programme. Further, from a study conducted with Indo-African derivatives, it was found that African male-lines and Indian female-lines complemented each other as far as their expression of heterosis is concerned. Hence, 64 individual plants were isolated from F_6 populations of crosses involving six African and four Indian pigeonpea lines. These lines were crossed with three A- lines (GT 288A, GT 311A, and GT 501A) for ascertaining their fertility restoration.

Table 3: List of diverse CMS lines developed at SK Nagar, Gujarat

S. No.	CMS line	Source line	Sr. No.	CMS line	Source line
1	GT 288A	MS 288F	29	GT 601A	AGS 132
2	GT 33A	PUSA 33	30	GT 602A	AGS 130
3	GT 87A	ICPL 87	31	GT 603A	AGS 123
4	GT 100A	GT 100	32	GT -604A	AGS 102
5	GT 289A	SKNP 289	33	GT 605A	AGS 101
6	GT 290A	SKNP 290	34	GT 606A	AGS 100
7	GT 301A	BDN 2	35	GT 607A	AGS 99
8	GT 302A	SKNP 88-3	36	GT 608A	AGS 98
9	GT 303A	SKNP 9523	37	GT 609A	AGS 96
10	GT 304A	T-15-15	38	GT 610A	AGS 95
11	GT 305A	T-21	39	GT 611A	AGS 94
12	GT 306A	ICPL 84060	40	GT 612A	AGS 93
13	GT 307A	BSMR 736	41	GT 613A	AGS 91
14	GT 308A	ICPL 87051	42	GT 614A	AGS 84
15	GT 309A	B 12	43	GT 615A	AGS 76
16	GT 310A	BDN 31	44	GT 616A	AGS 58
17	GT 31 IA	PUSA 33-1	45	GT 617A	AGS 57
18	GT 40 IA	ICP 5507	46	GT 618A	AGS 53
19	GT 402A	ICP 7078	47	GT 619A	AGS 52
20	GT 403A	AGS 5	48	GT 620A	A GS 50
21	GT 404A	AGS 28	49	GT 621A	AGS 49
22	GT 405A	AGS 30	50	GT 622A	AGS 45
23	GT 406A	BSMR 736	51	GT 623A	AGS 44
24	GT 501A	ICP 7622	52	GT 624A	AGS 9
25	GT 502A	AGS 89	53	GT 625A	GAUT 97111
26	GT 503A	AGS 65	54	GT 701A	ICP 12009
27	GT 504A	AGS 46	55	GT 702A	ICP 8503
28	GT 505A	AGS 55	56	GT 703A	ICP 13175
57	GT 704A	ICP 14388	78	GT 725A	ICP 352
58	GT 705A	ICP 15352	79	GT 726A	ICP 450
59	GT 706A	GAUT 97-74	80	GT 727A	ICP 4295
60	GT 707A	AGS 4	81	GT 728A	ICP 5433
61	GT 708A	AGS 55	82	GT 729A	ICP 7620
62	GT 709A	AGS 68	83	GT 730A	ICP 8976
63	GT 710A	AGS 85	84	GT 731A	ICP 9123
64	GT 711A	AGS 112	85	GT 732A	ICP 9260
65	GT 712A	AGS 113	86	GT 733A	ICP 10948
66	GT 713A	AGS 115	87	GT 734A	ICP 12180

67	GT 714A	AGS 116	88	GT 735A	ICP 14390
68	GT 715A	AGS 125	89	GT 736A	ICP 15367
69	GT 716A	AGS 127	90	GT 737A	GAUT 9539
70	GT 717A	AGS 134	91	GT 738A	GAUT 97104
71	GT 718A	AGS 136	92	GT 739A	GAUT 97107
72	GT 719A	BSMR 198	93	GT 740A	AGS 41
73	GT 720A	ICP 8504	94	GT 741A	AGS 47
74	GT 721A	ICP 11720	95	GT 742A	AGS 64
75	GT 722A	ICP 14410	96	GT 743A	AGS 78
76	GT 723A	ICP 14421	97	GT 744A	AGS 103
77	GT 724A	ICP 14760	98	GT 745A	AGS 107

Gulbarga: This centre is mainly targeting the development of hybrids of 140-150 day maturity duration. As majority of the pigeonpea growing area in the district is under rainfed conditions and to escape terminal drought the farmers demand hybrid varieties of this duration. Therefore, to breed CMS lines of this maturity duration with good agronomic base and genetic diversity, a total of 28 crosses were made **(Table 4)**.

Table 4: Crosses made for the development of stable CMS lines at Gulbarga

S. No.	Name of the cross	No. of pods set
1	ICPA1 -2101 X ICPB1-2101	90
2	ICPA2 -2101 X ICPB2-2101	56
3	ICPA3 -2101 X ICPB3-2101	71
4	ICPA4 -2101 X ICPB4-2101	44
5	ICPA6 -2101 X ICPB6-2101	40
6	ICPA7 -2101 X ICPB7-2101	42
7	ICPA9 -2101 X ICPB9-2101	26
8	ICPA10 -2101 X ICPB10-2101	24
9	ICPA11 -2101 X ICPB11-2101	13
10	ICPA12 -2101 X ICPB12-2101	31
11	ICPA13 -2101 X ICPB13-2101	25
12	ICPA14 -2101 X ICPB14-2101	63
13	ICPA15 -2101 X ICPB15-2101	33
14	ICPA16 -2101 X ICPB16-2101	19
15	ICPA3 -2161 X ICPB3-2161	28
16	ICPA4 -2161 X ICPB4-2161	45
17	ICPA5 -2161 X ICPB5-2161	36
18	ICPA6 -2161 X ICPB6-2161	26
19	ICPA7 -2161 X ICPB7-2161	49
20	ICPA8 -2161 X ICPB8-2161	28
21	ICPA9 -2161 X ICPB9-2161	24
22	ICPA10 -2161 X ICPB10-2161	27
23	ICPA11 -2161 X ICPB11-2161	09
24	ICPA12 -2161 X ICPB12-2161	22
25	ICPA13 -2161 X ICPB13-2161	20
26	ICPA15 -2161 X ICPB15-2161	43
27	ICPA16 -2161 X ICPB16-2161	32
28	ICPA17 -2161 X ICPB17-2161	03

ICRISAT: To breed new maintainer (B) lines, a total of 68 F_1s were grown at ICRISAT during 2008 rainy season. These hybrid combinations were generated by crossing the known diverse B-lines belonging to early (DT x DT=10 F_1s; NDT x DT 30= F_1s) and medium (NDT x NDT= 28 lines) maturity groups. The F_1s were planted along with their parents in a wilt free plot. Plants in each hybrid were selfed to obtain seeds of the next filial generation. In F_2 populations of these crosses, phenotypic selection will be exercised for important agronomic characters such as number of pods, number of primary branches, and seed yield during 2009 rainy season.

4. Breeding New Fertility Restorers

In a dynamic hybrid breeding programme it is essential to identify diverse maintainers and fertility restorers. For this purpose new test crosses were made and evaluated to identify new fertility restorers. The progress from various centres is summarized below:

ICRISAT: Data of short-duration hybrids were received from five locations and on an average the fertility restoration of the hybrids ranged from 87 – 99%. In general, the extent of fertility estimates were low (40 – 95%) at Jalna. At present the reasons for this variation are not known. It was also observed that, in general, the fertility restoration in medium-duration hybrids were higher than those of early types. However, ICPH 3494, 3758, and 4019 were the exceptions. All the medium-duration hybrids were found to be resistant to wilt and sterility mosaic diseases at Patancheru. At ICRISAT, 37 known restorers of different maturity were maintained by selfing and roguing. Some of these lines were used for making experimental hybrids. The parents of known hybrids were multiplied in isolation and used in producing large quantities of hybrid seed. In order to breed new breeding populations of fertility restorers 101 R x R crosses were attempted. Promising crosses will be identified for advancing the generation.

SK Nagar: Thirty four restorers were identified for crossing with two A-lines (GT 288A and GT 505A). Of these, fertility of 29 hybrids was re-confirmed under insect proof net. In the another set of 302 crosses, 122 crosses restored the fertility of female parent. The restoration of the all these lines will be re-confirmed during 2009 season. A wilt sick nursery was artificially created by collecting the soil from different agro-climatic zones of Gujarat where the wilt is a serious disease and 81 R-lines were sown for their assessment of disease reaction. The characteristic of these lines listed in **(Table 5)**.

Table 5: Characterization of established restorer R-lines developed at Sardarkrushinagar.

Sr. No.	Restorer	Characters										
		DF	DM	PH	BP	PP	SP	PL	TW	PT	FC	SC
1	GTR 1	99	142	155	10.2	195	4.1	4.2	10.0	NDT	Y	Orange
2	GTR 2	118	172	137	6.3	176	4.2	4.6	9.5	NDT	RSY	Brown
3	GTR 3	102	138	146	5.6	165	4.3	4.3	10.2	NDT	Y	White
4	GTR 4	100	138	143	6.5	153	5.1	5.2	10.5	NDT	Y	Red
5	GTR 5	113	170	146	6.5	176	4.2	4.3	10.3	NDT	Y	Red
6	GTR 6	111	155	172	9.1	188	4.3	4.2	8.5	NDT	Y	White
7	GTR 7	130	210	185	8.4	136	3.5	4.0	9.4	NDT	Y	White
8	GTR 8	97	145	127	10.3	143	3.4	4.1	9.2	NDT	Y	White
9	GTR 9	92	137	139	9.2	162	4.2	4.2	9.5	NDT	Y	White
10	GTR 10	103	148	153	13.1	207	3.7	4.0	10.1	NDT	Y	Orange
11	GTR 11	95	145	90	4.2	130	3.9	4.1	10.1	DT	Y	White
12	GTR 12	110	165	100	4.3	122	3.5	4.2	9.7	NDT	Y	Orange
13	GTR 13	88	142	110	3.4	140	3.6	3.9	9.7	NDT	Y	Orange
14	GTR 14	89	146	125	5.3	123	3.3	4.3	10.1	NDT	Y	Orange
15	GTR 15	105	159	125	4.2	130	3.6	4.2	10.2	NDT	Y	Orange
16	GTR 16	100	156	110	6.4	160	3.8	4.1	9.9	NDT	Y	Orange
17	GTR 17	115	167	165	4.3	180	3.5	3.6	9.8	NDT	RSY	Orange
18	GTR 18	100	158	150	6.1	155	3.9	4.0	10.2	NDT	Y	White
19	GTR 19	109	158	136	7.0	112	4.3	4.5	9.1	NDT	Y	Orange
20	GTR 20	101	148	122	8.0	84	3.3	3.4	9.0	NDT	Y	Orange
21	GTR 21	118	168	14	6.0	96	4.0	4.3	8.9	NDT	Y	Orange
22	GTR 22	110	162	154	8.0	107	3.0	4.1	9.5	NDT	Y	White
23	GTR 23	94	136	128	12.0	142	3.0	3.8	9.0	NDT	Y	Orange
24	GTR 24	117	161	186	9.0	162	4.0	4.3	9.6	NDT	Y	White
25	GTR 25	124	172	127	6.0	55	3.0	3.2	9.2	NDT	Y	Orange
26	GTR 26	104	152	165	12.0	65	3.4	4.2	9.82	NDT	Y	R
27	GTR 27	106	154	165	8.0	115	4.0	4.5	10.03	NDT	Y	W
28	GTR 28	97	140	112	7.0	135	4.0	4.3	10.12	NDT	Y	R
29	GTR 29	100	144	105	8.0	110	4.0	4.5	9.92	NDT	Y	R
30	GTR 30	101	146	95	5.0	60	3.0	3.5	9.10	NDT	Y	R
31	GTR 31	110	161	190	8.0	140	4.0	4.2	10.35	NDT	Y	W
32	GTR 32	104	152	165	12.0	124	3.7	4.1	10.32	NDT	Y	W
33	GTR 33	102	153	168	11.0	121	3.6	3.9	10.12	NDT	YWR	R
34	GTR 34	93	136	144	5.0	62	3.7	4.1	9.98	NDT	Y	W
35	GTR 35	98	142	84	5.0	95	4.0	5.2	9.02	DT	Y	R
36	GTR 36	102	154	160	8.0	72	4.0	3.2	8.23	NDT	Y	R
37	GTR 37	100	146	148	7.0	108	3.0	3.3	8.26	NDT	Y	W
38	GTR 38	110	164	155	7.0	122	4.0	4.1	7.56	NDT	Y	W
39	GTR 39	113	172	165	8.0	203	4.0	3.8	9.21	NDT	Y	W
40	GTR 40	115	168	161	10.0	258	4.0	3.2	8.24	NDT	Y	W
41	GTR 41	112	162	170	10.0	66	4.0	4.5	7.26	NDT	Y	W
42	GTR 42	102	151	152	7.0	97	4.0	4.1	7.25	NDT	Y	W
43	GTR 43	120	172	164	5.0	125	4.0	4.2	8.25	NDT	Y	R
44	GTR 44	124	173	175	10.0	165	4.0	4.4	9.24	NDT	Y	R
45	GTR 45	98	142	167	6.0	138	4.0	4	7.56	NDT	Y	R
46	GTR 46	97	148	140	6.0	136	4.0	4.2	8.24	NDT	Y	R
47	GTR 47	100	146	126	4.0	148	4.0	4.2	7.54	NDT	Y	R
48	GTR 48	98	140	127	3.0	107	4.0	4.5	8.11	NDT	Y	R
49	GTR 49	96	139	138	5.0	87	4.0	3.8	8.14	NDT	Y	R
50	GTR 50	100	142	142	3.0	76	4.0	4.3	9.21	NDT	Y	W
51	GTR 51	96	142	120	8.0	97	4.0	4.3	8.25	NDT	Y	R
52	GTR 52	90	135	112	6.0	148	4.0	4.2	8.78	NDT	Y	R
53	GTR 53	87	137	127	5.0	211	4.0	4.4	7.89	NDT	Y	W
54	GTR 54	107	154	152	6.0	118	4.0	4.0	8.12	NDT	Y	W
55	GTR 55	98	142	118	7.0	132	4.0	4.2	8.16	NDT	Y	R
56	GTR 56	102	149	127.1	4.0	87.5	4.0	5.0	10.50	NDT	YRS	W
57	GTR 57	118	160	140.4	2.6	65.5	4.0	4.0	9.89	NDT	YRS	W
58	GTR 58	121	155	130.0	4.5	55.6	3.0	4.0	10.76	NDT	YRS	W
59	GTR 59	119	160	90.5	4.0	85.2	4.0	5.0	11.00	NDT	YRS	R
60	GTR 60	126	156	130.1	5.2	110.5	5.0	5.0	11.25	NDT	Y	W
61	GTR 61	109	150	110.2	5.1	60.0	4.0	4.5	10.95	NDT	YRS	R
62	GTR 62	100	148	100.0	2.0	54.0	4.0	4.5	10.40	NDT	Y	R
63	GTR 63	100	149	90.2	4.0	62.0	4.0	4.0	13.76	NDT	Y	W
64	GTR 64	118	156	115.9	5.0	78.0	3.0	3.0	12.65	NDT	YRS	W

65	GTR 65	120	158	115.7	4.8	75.9	3.0	3.4	10.79	DT	Y	W
66	GTR 66	98	146	70.0	3.7	55.7	3.0	5.0	8.90	DT	Y	W
67	GTR 67	100	148	65.1	3.0	60.0	4.0	4.5	7.35	NDT	Y	W
68	GTR 68	98	145	125.1	2.0	61.5	4.0	5.0	10.85	NDT	Y	R
69	GTR 69	103	153	155.6	3.0	65.5	3.0	4.0	14.30	NDT	Y	W
70	GTR 70	101	154	95.0	2.5	65.0	4.0	4.0	11.40	NDT	YRS	W
71	GTR 71	97	143	75.0	3.5	85.0	4.0	4.0	8.58	DT	YRS	R
72	GTR 72	103	148	115.9	6.2	110.0	4.0	4.0	8.95	NDT	YRS	W
73	GTR 73	106	148	130.0	2.0	75.0	4.0	4.5	10.60	NDT	YRS	R
74	GTR 74	97	145	70.0	2.2	57.0	5.0	5.0	7.00	DT	Y	W
75	GTR 75	100	152	115.4	3.5	75.5	3.0	4.0	10.35	NDT	Y	W
76	GTR 76	103	147	140.2	5.0	85.8	4.0	4.5	10.40	NDT	YRS	W
77	GTR 77	105	148	110.5	3.0	75.2	4.0	5.5	10.40	NDT	YRS	R
78	GTR 78	103	148	125.9	4.0	95.3	4.0	4.5	11.25	NDT	YRS	R
79	GTR 79	104	149	115.5	6.0	127.0	5.0	4.5	11.25	NDT	YRS	W
80	GTR 80	103	150	145.0	2.0	135.0	4.0	3.8	10.00	NDT	YRS	W
81	GTR 81	101	149	95.5	2.5	149.0	3.0	2.9	8.35	NDT	YRS	R

DF=Days to flower, DM=Days to maturity, PH=Plant height (d), BP=Branches/plant, PP=Pods/plant, SP=Seeds/pod, PL=Pod length (cm), TW=Test weight (g.), PT=Plant type, FC=Flower color, SC=Seed color

Parbhani: A total of 10 new restorer lines received from ICRISAT were screened against wilt and sterility mosaic diseases in sick nursery at Badnapur. All the lines were found to be highly resistant to wilt; while only six restorers were resistant to sterility mosaic disease. These lines will be used in crossing programme to develop disease resistant hybrids. A total of 38 R-lines were evaluated in eight short-duration and 30 medium-duration hybrid combinations for fertility restoration study in multi-location trials. Forty eight crosses **(Table 6)** were evaluated for identification of restorers. It was observed that the male parent ICP 10934 was perfect restorer and ICPR 3514 was found to be a partial restorer against all the four (ICPA 2043, ICPA 2047, ICPA 2048, and ICPA 2092) CMS lines. In Parbhani, a set of 12 known medium-duration restorers were crossed to ICPB 2043 to develop (B x R) breeding populations. These crosses will be evaluated during next season.

Gulbarga: To conduct restoration studies 42 hybrid combinations have been made during 2009 season **(Table 7)**. The result of the restoration will be known during next generation. The three CMS lines used in developing experimental hybrids were tested for resistance to wilt incidence at Gulbarga. Among these, GT-288A was susceptible, while the other two lines received from ICRISAT, confirmed their resistance to wilt disease. The confirmation for wilt reaction will carried out for another season. In the crossing block no wilt disease was noticed under non-inoculated conditions in ICPA 2078 and ICPA 2043. Three local cultivars and 10 restorers, received from ICRISAT, will be studied further for their stability of disease resistance in the next season.

Table 6: Fertility restoration studies of hybrid combinations at Parbhani, 2008

Male parent	ICPA 2043	ICPA 2047	ICPA 2048	ICPA 2092
ICPR 2671	M	R	PR	R
ICPR 2766	PR	R	R	PR
ICPR 3473	PR	R	PR	R
ICPR 3477	PR	R	PR	PR
ICPR 3513	PR	M	R	R
ICPR 3514	**PR**	**PR**	**PR**	**PR**
ICPL87119	PR	PR	R	PR
ICPL11376	PR	R	PR	R
ICPL13991	R	PR	R	PR
ICPR 10934	**R**	**R**	**R**	**R**
ICPL 10650	R	PR	PR	PR
HPL 2463	PR	PR	PR	R

R= Restorer, PR= Partial Restorer and M = Maintainer

Table 7: List of crosses made for studying fertility restoration at Gulbarga, 2008

S. No.	Cross	S. No.	Cross
1	ICP A-2078 X ICPL 20	22	ICPA-2043 X ICP 7387
2	ICP A-2078 X ICPL 161	23	ICPA-2043 X ICP 7405
3	ICP A-2078 X ICPL 288	24	ICPA-2043 X ICP 6972
4	ICP A-2078 X ICPL 89004	25	ICPA-2043 X Maruti
5	ICP A-2078 X ICPL 93105	26	ICPA-2043 X WRP 1
6	ICP A-2078 X ICPL 98009	27	ICPA-2043 X TS-3®
7	ICP A-2078 X ICP 6974	28	ICPA-2043 X G.RED
8	ICP A-2078 X ICP 7387	29	GT-288-A X ICPL-20
9	ICP A-2078 X ICP 7405	30	GT-288-A X ICPL-161
10	ICP A-2078 X ICP 6972	31	GT-288-A X ICPL-288
11	ICP A-2078 X Maruti	32	GT-288-A X ICPL-89004
12	ICP A-2078 X WRP 1	33	GT-288-A X ICPL-93105
13	ICP A-2078 X TS-3R	34	GT-288-A X ICPL-98009
14	ICP A-2078 X G.RED	35	GT-288-A X ICP-6974
15	ICPA-2043 X ICPL 20	36	GT-288-A X ICP-7387
16	ICPA-2043 X ICPL 161	37	GT-288-A X ICP-7405
17	ICPA-2043 X ICPL 288	38	GT-288-A X ICP-6972
18	ICPA-2043 X ICPL 89004	39	GT-288-A X Maruti
19	ICPA-2043 X ICPL 93105	40	GT-288-A X WRP 1
20	ICPA-2043 X ICPL 98009	41	GT-288-A X TS 3R
21	ICPA-2043 X ICP 6974	42	GT-288-A X G.RED

5. Characterization of Hybrid Parents

A plan was made to characterize elite hybrid parents with respect to various molecular and agronomic traits. The progress made in this direction at two centres is summarized here.

SK Nagar: At this location, 98 CMS lines which were utilized to develop different hybrid combinations were characterized for various agronomic traits **(Table 8)**. The molecular characterization of all the lines is in progress.

Table 8: Characterization of different CMS lines developed at SK Nagar, 2008

S. No.	Recurrent parent	CMS line	Days to flower	Days to maturity	Plant height (cm)	Branches plant	Pods/ plant	Seeds/ pod	Pod length	100-seed weigh (g)	Plant type	Flower colour	Seed colour	Yield $plant^{-1}$ (g)
1	MS 288F	GT 288A	96	140	136	5.5	136	3.7	4.1	9.6	NDT	Y	CW	41
2	Pusa 33	GT 33A	78	136	132	6.3	108	3.8	4.1	8.7	NDT	Y	R	28
3	ICP 87	GT 87A	93	132	76	5.7	96	3.9	4.2	9.1	SDT	Y	R	26
4	GT 100	GT 100A	88	137	107	5.6	135	3.9	4.4	10.2	DT	Y	W	36
5	SKNP 289	GT 289A	95	141	75	4.7	87	4.0	4.7	10.6	DT	R	R	29
6	SKNP 290	GT 290A	83	142	96	4.5	127	3.7	4.7	9.9	DT	Y	R	24
7	BDN 2	GT 301A	122	175	125	7.1	160	3.6	4.2	9.7	NDT	Y	W	48
8	SKNP 88-3	GT 302A	110	153	138	6.8	129	3.7	4.1	10.1	NDT	Y	W	40
9	SKNP 9523	GT 303A	106	148	181	8.5	146	3.5	4.1	9.7	NDT	Y	W	41
10	T 15-15	GT 304A	110	168	162	9.6	153	4.0	4.6	10.3	NDT	Y	W	54
11	T 21	GT 305A	105	148	130	6.1	141	3.7	4.2	9.9	NDT	Y	R	44
12	ICP 84060	GT 306A	108	156	124	11.0	126	3.5	4.1	8.9	NDT	Y	R	36
13	BSMR 736	GT 307A	116	162	112	8.0	112	3.0	3.4	9.7	NDT	Y	R	32
14	ICP 87051	GT 308A	101	148	132	10.0	187	3.8	4.2	9.3	NDT	R	W	44
15	B 12	GT 309A	112	159	129	9.0	143	3.6	4.1	9.6	NDT	Y	R	38
16	BDN 31	GT 310A	96	143	89	14.0	148	3.6	4.6	9.4	NDT	Y	W	34
17	Pusa 33-1	GT 311A	78	136	132	6.3	115	3.8	4.1	8.7	NDT	Y	W	29
18	ICP 5507	GT 401A	119	159	142	4.6	118	3.8	4.1	10.6	NDT	Y	R	27
19	ICP 7078	GT 402A	117	162	146	5.3	142	3.9	4.2	10.2	NDT	Y	W	32
20	AGS 5	GT 403A	126	178	152	6.8	129	4.1	4.3	10.1	NDT	Y	W	32
21	AGS 28	GT 404A	118	173	161	4.3	142	3.7	4.0	9.3	NDT	Y	W	36
22	AGS 30	GT 405A	119	174	139	5.4	118	3.5	3.8	9.4	NDT	Y	W	32
23	BSMR 736	GT 406A	126	181	149	6.2	124	3.4	3.7	9.8	NDT	Y	W	32
24	ICP 7622	GT 501A	108	160	152	6.4	129	3.3	3.5	10.0	NDT	Y	W	35
25	AGS 89	GT-502A	128	180	162	5.4	132	3.6	3.7	9.2	NDT	Y	W	36
26	AGS 65	GT 503A	113	161	158	8.8	149	3.2	3.4	10.2	NDT	Y	R	36
27	AGS 46	GT 504A	124	171	154	6.9	152	4.1	4.3	9.1	NDT	Y	W	31
28	AGS 55	GT 505A	110	157	164	7.4	146	3.8	3.9	9.1	NDT	Y	W	40
29	AGS 132	GT 601A	121	166	145	6	85	5	6.4	10.01	NDT	Y	W	30
30	AGS 130	GT 602A	123	167	160	8	205	5	6.2	9.08	NDT	Y	W	32
31	AGS 123	GT 603A	118	165	185	6	130	5	6.0	8.01	NDT	Y	W	35
32	AGS 102	GT 604A	127	167	145	8	295	5	5.4	7.05	NDT	Y	R	40
33	AGS 101	GT 605A	116	164	190	8	305	4	6.3	8.02	NDT	Y	R	32
34	AGS 100	GT 606A	126	172	170	6	180	5	6.2	9.07	NDT	Y	W	36
35	AGS 99	GT 607A	127	170	180	9	310	4	5.2	9.01	NDT	R	W	35
36	AGS 98	GT 608A	130	175	145	7	230	4	4.5	8.72	NDT	Y	W	26
37	AGS 96	GT 609A	128	174	165	8	230	5	5.5	9.00	NDT	Y	W	38
38	AGS 95	GT 610A	100	145	130	6	140	4	4.6	9.21	NDT	Y	R	39
39	AGS 94	GT 611A	129	169	165	8	305	4	5.0	8.54	NDT	Y	R	42
40	AGS 93	GT 612A	99	143	130	4	120	5	5.3	7.22	NDT	Y	W	45
41	AGS 91	GT 613A	98	140	165	9	305	5	5.7	7.45	NDT	Y	W	41
42	AGS 84	GT 614A	124	159	165	5	120	4	5.2	8.21	NDT	Y	R	23
43	AGS 76	GT 615A	127	170	125	4	120	4	4.7	9.0	NDT	R	R	26
44	AGS 58	GT 616A	122	168	165	5	100	4	5.2	8.23	NDT	Y	W	53
45	AGS 57	GT 617A	97	142	155	8	220	4	5.4	8.54	NDT	Y	W	29

46	AGS 53	GT 618A	100	146	160	5	230	5	5.8	9.02	NDT	Y	W	32
47	AGS 52	GT 619A	103	149	180	9	310	5	5.7	8.14	NDT	Y	R	34
48	AGS 50	GT 620A	119	170	175	7	315	4	5.1	7.88	NDT	Y	W	38
49	AGS 49	GT 621A	98	142	150	5	185	4	5.2	8.21	NDT	Y	W	45
50	AGS 45	GT 622A	124	172	155	5	180	4	5.3	9.12	NDT	Y	W	41
51	AGS 44	GT 623A	136	177	160	9	320	4	5.7	11.00	NDT	Y	W	46
52	AGS 9	GT 624A	126	171	155	8	240	5	5.3	9.24	NDT	Y	W	33
53	GAUT 97111	GT 625A	129	168	150	6	245	6	6.8	11.05	NDT	Y	W	36
54	ICP 12009	GT 701A	99	145	117.7	6.9	111.5	3.8	4.3	8.78	SDT	Y	R	55
55	ICP 8503	GT 702A	101	148	126.7	7.1	119.2	4.0	5.0	11.48	NDT	Y	R	34
56	ICP 13175	GT 703A	104	147	148.8	8.5	162.7	3.5	3.9	11.88	NDT	Y	W	58
57	ICP 14388	GT 704A	100	149	133.0	8.1	141.8	4.3	4.5	14.03	NDT	Y	W	49
58	ICP 15352	GT 705A	102	151	158.2	10.6	141.8	4.1	4.6	11.38	NDT	Y	W	46
59	GAUT 97-74	GT 706A	103	157	121.8	10.2	141.7	3.8	4.3	14.03	NDT	Y	W	38
60	AGS 4	GT 707A	106	158	163.3	8.7	144.3	4.2	5.0	10.50	NDT	Y	R	32
61	AGS 55	GT 708A	103	153	140.7	9.0	180.1	4.1	4.5	9.33	NDT	Y	W	45
62	AGS 68	GT 709A	109	159	146.0	9.2	151.9	4.5	4.9	12.00	NDT	Y	W	33
63	AGS 85	GT 710A	113	160	166.2	9.1	154.1	4.0	4.5	11.15	NDT	Y	W	45
64	AGS 112	GT 711A	105	155	141.7	7.9	112.8	4.6	4.9	13.83	NDT	Y	W	29
65	AGS 113	GT 712A	113	156	142.7	5.6	109.2	4.2	4.5	12.58	NDT	Y	W	38
66	AGS 115	GT 713A	112	157	150.7	7.6	124.3	4.1	4.7	14.85	NDT	Y	W	39
67	AGS 116	GT 714A	106	158	147.4	8.0	95.6	4.9	5.4	11.65	NDT	Y	W	31
68	AGS 125	GT 715A	104	154	154.1	7.1	121.8	3.3	3.8	12.25	NDT	Y	W	33
69	AGS 127	GT 716A	109	156	151.3	6.6	133.1	4.6	5.2	13.70	NDT	Y	R	38
70	AGS 134	GT 717A	103	153	139.3	6.6	135.3	3.9	4.3	12.28	NDT	Y	W	31
71	AGS 136	GT 718A	111	155	163.5	7.7	95.7	3.9	4.7	14.68	NDT	Y	W	32
72	BSMR 198	GT 719A	108	155	146.2	8.1	131.9	4.4	5.1	11.70	NDT	Y	R	35
73	ICP 8504	GT 720A	101	149	142.8	9.1	136.0	4.5	4.8	13.85	NDT	R	R (Black)	51
74	ICP 11720	GT 721A	99	144	104.9	6.6	68.7	3.1	3.7	10.30	SDT	Y	R	30
75	ICP 14410	GT 722A	101	148	142.6	8.1	130.2	3.0	3.8	10.63	NDT	Y	W	34
76	ICP 14421	GT 723A	101	143	147.1	10.0	160.4	3.5	3.9	10.28	NDT	Y	R	33
77	ICP 14760	GT 724A	104	148	141.9	9.1	117.0	3.8	4.0	9.23	NDT	R	R	32
78	ICP 352	GT 725A	99	147	142.2	7.1	110.6	4.0	4.3	8.83	NDT	Y	W	30
79	ICP 450	GT 726A	98	145	119.4	8.0	103.5	4.0	3.9	9.33	NDT	Y	R	31
80	ICP 4295	GT 727A	107	153	136.3	5.5	117.0	3.9	4.7	7.85	NDT	YLRS	R	34
81	ICP 5433	GT 728A	103	147	117.6	7.0	122.0	3.9	3.7	5.60	SDT	Y	R	36
82	ICP 7620	GT 729A	99	145	121.6	8.0	123.1	3.6	3.5	6.80	NDT	Y	R	32
83	ICP 8976	GT 730A	107	146	137.7	5.6	112.7	3.5	4.5	10.30	NDT	YLRS	W	34
84	ICP 9123	GT 731A	98	142	142.5	7.8	117.6	3.5	3.6	10.55	NDT	Y	W	32
85	ICP 9260	GT 732A	102	147	126.8	6.1	103.3	3.9	4.5	8.80	NDT	Y	R	34
86	ICP 10948	GT 733A	102	148	142.2	4.8	80.2	4.0	4.5	13.83	NDT	Y	W	31
87	ICP 12180	GT 734A	103	148	126.2	6.1	93.1	3.7	4.3	11.93	NDT	Y	R	32
88	ICP 14390	GT 735A	102	148	118.6	6.2	116.6	3.8	4.4	10.18	NDT	Y	W	50
89	ICP 15367	GT 736A	103	147	136.3	6.9	105.6	4.4	4.7	11.13	NDT	Y	W	49
90	GAUT 9539	GT 737A	99	146	133.0	7.2	104.2	4.0	4.9	12.03	NDT	YRS	W	32
91	GAUT 97104	GT 738A	99	146	135.2	8.6	118.6	4.5	5.0	12.53	NDT	Y	W	34
92	GAUT 97107	GT 739A	104	149	147.8	6.5	84.2	5.0	5.3	12.53	NDT	Y	W	32
93	AGS 41	GT 740A	109	157	123.8	7.1	112.5	4.0	4.3	9.89	NDT	Y	W	31
94	AGS 47	GT 741A	105	153	120.5	6.2	99.3	4.0	4.0	12.60	SDT	Y	W	31
95	AGS 64	GT 742A	104	153	150.4	5.5	93.7	4.0	4.9	11.98	NDT	Y	R	35
96	AGS 78	GT 743A	110	156	126.0	5.5	88.7	4.5	4.7	11.16	NDT	Y	W	30
97	AGS 103	GT 744A	106	155	142.7	8.1	124.8	4.0	4.1	9.93	NDT	Y	W	32
98	AGS 107	GT 745A	110	155	162.6	6.2	111.8	4.6	4.8	9.90	NDT	R	W	35

ICRISAT: Characterization of hybrid parental lines for important morphological characters was done at ICRISAT. A total of 56 medium-duration 'R' lines were characterized and the data on yield and other traits were recorded **(Table 9 - 11)**. These were also screened in disease nursery and 14 lines were resistant to wilt and 26 lines to sterility mosaic disease. Nine lines had combined resistant to both the diseases. These lines were used in the crossing programme to develop disease resistant hybrid combinations. A total of 18 medium duration A/B lines were also characterized and important traits were recorded **(Table 12 - 13)**.

Table 9: Performance of entries of long duration R-lines at Patancheru, 2008 rainy season

Entry No	Name	Grain yield (kg ha^{-1})	Days to flower	Days to mature	Plant height (cm)	Seeds per pod	100-Seed mass (g)	Plant stand
14	ICP 14085	2299	115	172	160	4.0	9.6	32
12	ICP 13991-2-10	1987	126	180	222	3.8	8.0	36
13	ICP 13991-2-5	1812	129	184	212	3.8	8.0	42
9	ICP 10650-7	1722	117	175	180	3.8	8.5	32
15	ICPL 366(C)	1645	137	189	205	4.0	10.0	34
1	ICPL 366	1599	132	190	210	3.8	9.9	32
8	ICPL 20186	1592	121	178	162	3.9	8.1	39
3	MA 3	1381	137	190	198	3.8	9.2	36
6	ICP 8094	1381	129	189	210	3.8	9.1	40
11	ICP 12320-1-3	1310	129	187	190	3.9	7.5	41
4	MA 6	1141	137	192	188	3.9	10.3	34
2	ICPL 20126	1108	121	180	185	4.0	11.6	30
10	ICP 11376-5	1044	128	184	198	4.1	9.1	36
7	ICP 14282	975	126	186	182	4.0	10.8	37
16	ICP 7035(C)	705	120	182	142	5.0	16.9	28
5	ICP 13092	690	139	193	160	5.3	13.1	37
	SEm±	**147.8**	**1.2**	**2.4**	**7.5**	**0.08**	**0.43**	**3.9**
	Mean	**1399.4**	**127.7**	**184.4**	**187.8**	**4.08**	**9.96**	**35.3**
	CV(%)	**14.9**	**1.4**	**1.8**	**5.7**	**2.84**	**6.05**	**15.4**

Table 10: Performance of medium duration R-lines (Trial – 1) at Patancheru, 2008 rainy season

Entry No	Name	Grain yield (kg ha^{-1})	Days to flower	Days to mature	Plant height (cm)	Seeds per pod	100-Seed mass (g)	Plant stand
22	Asha(C)	2167	118	172	168	4.2	11.2	34
12	ICPL 20099	2087	118	174	165	3.8	11.4	34
1	ICPL 87119	2056	118	173	160	4.0	11.8	30
4	ICPL 96058	2004	120	176	170	4.0	10.6	38
6	ICPL 20058	1997	114	170	175	4.2	8.6	30
17	ICPL 20108	1962	119	177	192	4.0	10.9	32
11	ICPL 20098	1931	122	177	180	4.2	13.0	36
21	ICPL 20113	1906	127	188	182	3.8	9.4	36
2	ICPL 94068	1901	126	187	170	4.0	9.0	42
8	ICPL 20094	1865	121	179	185	4.0	10.9	46
3	ICPL 96053	1855	122	179	155	4.0	11.2	31
5	ICPL 96061	1854	118	172	168	4.0	10.5	34
16	ICPL 20107	1853	119	173	162	4.0	8.6	36
20	ICPL 20112	1831	120	178	188	4.1	8.8	37
13	ICPL 20102	1805	120	175	182	4.2	11.6	34
14	ICPL 20104	1784	120	178	190	4.0	12.9	36
10	ICPL 20096	1692	120	176	155	4.0	10.9	31
18	ICPL 20110	1594	127	185	205	4.0	9.9	32
9	ICPL 20095	1506	117	172	160	4.0	10.4	34
7	ICPL 20093	1426	123	180	190	3.9	12.6	39
15	ICPL 20106	1386	122	179	185	4.2	12.5	33
19	ICPL 20111	1247	122	181	192	3.8	10.4	34
SEm±		**120.8**	**0.8**	**1.5**	**12.1**	**0.08**	**0.43**	**2.8**
Mean		**1804.9**	**120.6**	**177.3**	**176.4**	**4.03**	**10.78**	**35.0**
CV(%)		**9.5**	**0.9**	**1.2**	**9.7**	**2.71**	**5.64**	**11.5**

Table 11: Performance of medium duration R-lines (Trial – 2) at Patancheru, 2008 rainy season

Entry No	Name	Grain yield (kg ha^{-1})	Days to flower	Days to mature	Plant height (cm)	Seeds per pod	100-Seed mass (g)	Plant stand
2	ICPL 20116	2078	116	175	148	3.9	10.8	42
16	ICPL 20177	1940	116	175	135	4.0	11.2	36
3	ICPL 20117	1859	130	191	198	3.9	10.3	43
9	ICPL 20126	1819	119	180	172	4.1	12.2	38
22	Asha(C)	1811	118	177	168	3.9	10.9	36
1	ICPL 20115	1748	127	189	185	3.8	9.4	38
18	ICPL 20202	1742	127	188	210	3.8	10.4	42
21	ICPL 10934	1720	116	173	162	3.9	8.5	38
8	ICPL 20125	1684	120	181	170	4.0	10.4	34
19	ICPL 20205	1652	119	179	162	4.1	8.5	39
15	ICPL 20136	1640	118	177	170	4.0	11.2	41
17	ICPL 20201	1631	131	191	212	3.8	8.2	36
7	ICPL 20123	1555	121	182	170	3.8	11.6	40
12	ICPL 20129	1518	129	192	195	4.2	12.1	35
14	ICPL 20135	1481	121	181	168	4.1	11.0	40
6	ICPL 20122	1446	117	176	160	4.0	10.5	28
10	ICPL 20127	1410	125	184	162	3.9	10.4	37
13	ICPL 20132	1360	120	178	185	4.0	11.0	34
4	ICPL 20118	1358	120	182	165	4.1	10.5	32
5	ICPL 20121	1240	119	177	182	4.0	9.2	36
20	ICP 9939	1162	119	179	152	4.3	12.7	38
11	ICPL 20128	930	122	181	198	4.0	11.3	34
SEm±		**151.9**	**1.3**	**2.4**	**7.2**	**0.09**	**0.36**	**2.1**
Mean		**1581.0**	**121.3**	**181.3**	**174.1**	**4.02**	**10.53**	**37.2**
CV(%)		**13.6**	**1.5**	**1.8**	**5.8**	**3.16**	**4.80**	**8.1**

Table12: Performance of medium duration B-lines (Asha Group) at Patancheru, 2008 rainy season

Entry No	Name	Grain yield (kg ha^{-1})	Days to flower	Days to mature	Plant height (cm)	Seeds per pod	100-Seed mass (g)	Plant stand
8	ICPB 2092	2253	119	171	182	4.0	9.8	32
11	Asha(C)	1965	117	169	150	4.0	11.6	39
9	ICPB 2091	1824	142	203	218	3.9	10.3	38
2	ICPB 2047	1814	119	172	175	4.0	11.2	38
12	C 11(C)	1808	114	168	158	4.0	10.5	32
7	ICPB 2102	1783	112	163	140	4.0	9.5	36
4	ICPB 2049	1729	112	164	145	4.6	11.7	37
1	ICPB 2044	1580	117	169	190	4.2	7.3	30
6	ICPB 2098	1524	115	167	175	4.6	11.2	36
3	ICPB 2048	1506	121	171	190	4.1	11.6	44
10	ICPB 2046	1051	123	178	135	5.2	17.1	45
5	ICPB 2050	875	116	169	150	5.2	12.8	29
SEm		**±285.2**	**2.3**	**2.7**	**10.6**	**0.15**	**0.29**	**4.0**
Mean		**1642.7**	**119.0**	**172.0**	**167.3**	**4.33**	**11.25**	**36.3**
CV(%)		**24.6**	**2.7**	**2.2**	**9.0**	**4.90**	**3.61**	**15.5**

Table 13: Performance of medium duration B-lines (Maruti Group) at Patancheru, 2008 rainy season

Entry No	Name	Grain yield (kg ha^{-1})	Days to flower	Days to mature	Plant height (cm)	Seeds per pod	100-Seed mass (g)	Plant stand
10	BDN 1(C)	2120	115	163	165	4.0	8.0	36
9	Maruti(C)	2081	102	154	140	3.9	9.5	36
6	ICPB 2043	2075	109	159	128	4.0	9.3	31
7	ICPB 2045	1938	118	170	152	4.2	8.3	28
8	ICPB 2051	1456	120	172	175	3.4	10.8	41
1	ICPB 2101	1388	100	152	105	4.9	13.2	34
2	ICPB 2161	1377	96	150	112	4.2	9.8	42
3	ICPB 2078	1182	100	153	100	4.2	13.3	39
4	ICPB 2090	1111	100	152	122	3.8	6.0	34
5	ICPB 2042	619	103	155	120	3.2	7.5	25
SEm±		**89.7**	**1.9**	**1.8**	**4.1**	**0.09**	**0.31**	**2.4**
Mean		**1534.9**	**106.3**	**158.0**	**132.0**	**3.98**	**9.59**	**34.6**
CV(%)		**8.3**	**2.6**	**1.6**	**4.4**	**3.27**	**4.59**	**9.7**

6. Synthesis and Preliminary Evaluation of Hybrid Combinations

The available male-sterile and restorers lines were used to develop new hybrid combinations to assess their yield and adaptation. The progress is summarized here.

Parbhani: A total of 165 hybrids were made. Of these, 102 combinations were constituted at Parbhani **(Table 14 - 15)** and the remaining was made in Badnapur. These will be evaluated in the subsequent season for yield and adaptation. Thirty eight hybrids were evaluated in multi-location trials: Of these, two hybrids ICPH 3477 (2437 kg ha^{-1}) and ICPH 3464 (2481 kg ha^{-1}) found to be superior over control Asha (1893 kg ha^{-1}) by a margin of 29 and 31% respectively.

SK Nagar: Three hybrids SKNPCH 0818, SKNPCH 0808, and SKNPCH 0859 were identified as promising and performed well in multi-locational testing. Large-scale seed of these hybrids will be produced during 2009 for further testing in on farmer trials. Eighty eight different hybrid combinations with the existing male-sterile lines and restorers were evaluated in different trials during 2009. These 81 hybrids were found to be restoring fertility and produced seed under insect proof net house. These were selected for further testing for yield and stability.

Table 14: List of parents used to develop 102 hybrids combinations

CMS lines	Male parents		
1) ICPA 2043	BSMR-198	AKT 9913	ICPL-12749
2) ICPA 2047	BSMR-846	PHULE-T-04-31	ICPR-13991
3) ICPA 2092	BSMR-164	PHULE -T-00-1-25-1	ICPR-10934
	BSMR-20096	AKT9915 (RT)	ICPR-3525
	BSMR-175	PHULE T-00-5-7-4-1	ICPR-10650 (WT)
	BSMR-2	PHULE-T-00-4-11-6-2	ICPR-3374
	BSMR-203	BWR-154	ICPR0-3514
	BSMR-571	BSMR-736	ICPR-3963
	AKT222521	AKT-8811	ICPR-3475
	AKT-00-12-6-	VIPULA-27	ICPR-11376
	TV-1	HPL 24-3(WT)	ICPL-20106
			ICPR-3407(RT)

Table 15: List of parents used to develop 63 hybrids at Badnapur.

BDN – 2004-1	ICG – 19-55	ICPR – 3374
BDN – 2004-2	ICG – 19-57	ICPR – 3405
BDN – 2004-3	ICG –13-37	ICPR – 3406
BDN – 2008	ICG – 62-175	ICPR – 3407
SKNP – 0632	ICG – 62-176	ICPR – 3452
BDN-2	ICG – 15-43	ICPR – 3462
BSMR – 853	ICG – 15-45	ICPR – 3475
BDN – 708	ICG – 62-175	ICPR – 3525
R-284	ICG – 26-76	ICPR – 3963
PUSA-992	ICG – 26-77	ICPR - 3972
BDN – 2004-1	ICG – 19-55	ICPR – 3374
BDN – 2004-2	ICG – 19-57	ICPR – 3405
BDN – 2004-3	ICG –13-37	ICPR – 3406
BDN – 2008	ICG – 62-175	ICPR – 3407
		ICPR – 3452

Akola: A total of 138 hybrids were evaluated in seven replicated trials during 2008 season. These include 79 medium and 59 short duration. Eight hybrids identified in early-maturing group are listed in **(Table 16 - 17).** These will be evaluated again for confirming their performance in Maharashtra.

Short Duration Trials:

Table 16: PYT-I (Early) Kharif 2008-09

Hybrid No.	Days to maturity	Plant height (cm)	No. of branches per plant	No. of pods per plant	Total seeds wt per plant (g)	100 seed wt (g)	Yield (kg ha^{-1})	Per cent heterosis
AKPHE-01-167	151	175	5	97	25	10	1515	23.4
AKPHE-01-128	153	182	7	129	48	9	1362	10.9
AKPHE-01-298	152	171	6	130	35	9	1347	9.7
AKPHE-01-117	155	183	5	101	27	9	1329	8.2
AKT-8811 (Ch)	153	191	8	196	52	8	1228	-
“F” test							**Sig.**	
SE (m) ±							73.32	
CD at 5%							215.63	
CV (%)							9.78	

Table 17: PYT-II (Early) Kharif 2008-09

Hybrid No.	Days to maturity	Plant height (cm)	No. of branches per plant	No. of pods per plant	Total seeds wt per plant (g)	100 seed wt (g)	Yield (kg ha^{-1})	Per cent heterosis
AKPHE-04-295-1	153	198	6	92	44	10	2510	40.4
AKPHE-04-178	154	204	7	51	32	10	2335	30.7
AKPHE-02-244	150	175	6	67	43	8	2083	16.6
AKPHE-02-331-1	151	176	6	61	42	9	2063	15.5
AKT-8811 (Ch)	154	187	6	72	45	8	1787	-
"F" test							**Sig.**	
SE (m) ±							119.95	
CD at 5%							346.95	
CV (%)							9.93	

ICRISAT: The new hybrids generated in 2008 were tested in 2009 rainy season. In 2008, the experimental hybrids were evaluated in 20 replicated trials. Due to poor drainage and heavy rains most fields were water-logged for extended periods and 12 trials were in abandoned. In the remaining trials, based on maturity some promising hybrids were identified in Maruti and Asha maturity groups. In the Maruti maturity group ICPH 3932, ICPH 4187, ICPH 4191, ICPH 4192, and 4226 were found promising with grain yield superiority of 18-28% over best checks. Hybrids ICPH 4208, ICPH 4210, ICPH 4148, ICPH 4145, ICPH 3406, ICPH 4144, ICPH 3816, and ICPH 3813 recorded grain yield superiority ranging from 20-26% over Asha. A total of 199 hybrid combinations were made with the existing male-sterile and restorer. Of these, 20 were of short-duration and 179 belonged to medium-duration maturity group. In the short-duration, about 2500 hand pollinated seeds were obtained from each cross. In medium-duration group, 95 promising hybrids were re-synthesized and 84 were new combinations. The number of crossed seed per cross ranged between 200 -1000. These will be evaluated in 2009-2010.

7. On – Farm Evaluation of Elite Hybrids

Evaluation of ICPH 2671

A total of 38572 kg of hybrid seed was produced by National Seed Corporation (NSC), State Farms Corporation of India (SFCI), Maharashtra State Seeds Corporation Limited (MSSCL), International Crop Research Institute for Semi Arid Tropics (ICRISAT), and some private seed companies in 2008. During this year, NSC distributed 7210 kg seed of ICPH 2671 to Madhya Pradesh (2800 kg), Gujarat (960 kg), Karnataka (1350 kg), Andhra Pradesh (1600 kg), and

Jharkhand (500 kg). In addition ICRISAT also supplied over 2000 kg hybrid seed to Maharashtra for on-farm trials.

A total of 1248 farmers evaluated ICPH 2671 in 403 ha area as on-farm trials during 2008. Overall superiority of hybrid ICPH 2671 was 28.2% over standard check **(Table 18)**. In Maharashtra on-farm trials were conducted as sole crop and as well as inter-crop with maize, soybean, cotton and green gram. The most beneficial cropping pattern was pigeonpea + soybean and superiority recorded was 93% over Maruti. It recorded about 13 % superiority in pigeonpea + cotton cropping system **(Table 19)**. Sixty-nine demonstrations of ICPH 2671 were distributed to farmers of Gulbarga, Bidar, Bellary, and Dharwad districts of Karnataka state. The hybrid was compared with the local varieties. The results were not provided to us.

Table 18: Over all performance of ICPH 2671 in on-farm trials India, 2008

Locations	No. of demos	Area (ha)	Mean yield (kg ha^{-1})		% Superiority
			ICPH 2671	Maruti	
Maharashtra	782	261	969	717	35.0
Andhra Pradesh	172	70	642	441	45.6
Karnataka	14	6	1131	951	19.0
Madhya Pradesh	280	66	1490	1192	25.0
Total/Mean	1248	403	1058	825	28.2

Table 19: Over all performance of ICPH 2671 in on – farm trials at Maharashtra, 2008

System	No. of demos	Area (ha)	Mean yield (kg ha^{-1})		% Superiority
			ICPH 2671	Maruti	
Sole	637	220	1120	913	23
PP + Maize	87	17	829	598	39
PP + Soy	29	12	1250	648	93
PP + Cottn	21	8	730	648	13
PP + Gr'gm	8	3	916	779	18
Total / Mean	782	261	969	717	35

Parbhani: The yields of demonstration plots of hybrid ICPH 2671, grown on 0.2 ha plots by 41 farmers. In Parbhani also on-farm demonstrations were undertaken. Over all, this hybrid has exhibited 35.9% superiority over Maruti cultivar. This hybrid matures in about 165-180 days. ICPH 2671 appears to be a good replacement for the popular cultivar Maruti, which is grown on shallow soils or light vertisols under receding soil moisture conditions, as a pure or an intercrop.

Akola: The Farmer Field Days were organized in five villages of four districts in Vidarbha region. The farmer's participation for all the Field Days was satisfactory. And the events were highlighted by popular local news papers such as ‘Agrowon’, ‘Sakal’, ‘Lokmat’ and ‘Tarun Bharat’. The details of on-farm trials will be prepared separately for circulation to concerned scientists and officials.

Quality Assessment of ICPH 2671:

Its protein percentage, minerals and carbohydrates and other organo-leptic properties are comparable to control Maruti. Limited studies conducted by ICRISAT showed that the milling ability and *dhal* recovery percentage are also similar to the control cultivar Maruti. In Parbhani, a number of crosses using CMS lines were made for evaluation in 2009. The seed color (dark brown) of ICPH 2671 posed some problems in marketing as some farmers got about 5 - 10% less price in the open market. We plan to introduce another brown colored hybrid in 2009 **(Table 20 – 21)**.

Milling data: To asses the ICPH 2671 hybrid seed quality about 1700 kg of seed was used for *dal* processing at Murthzapur, Akola district. The *dal* produced from this was 1177 kg this amounts about 70% recoveries. Of these, 46.47% (790 kg) was 1st quality *dal* while 22.76% (387 kg) was IInd quality *dal*. The *dal* produced from this exercise was distributed to 560 members comprising of farmers, administrators, and field workers in Maharashtra, Karnataka, and Andhra Pradesh. Based on data received, majority liked the *dal* taste and Aroma. Most of them felt keeping quality is same as local *dal*.

Table 20: Milling data of hybrid ICPH 2671

	In kg	**%**
Total seed milled	1700	-
Dal produced	1177	69.23
1st Quality *dal*	790	46.47
2nd Quality *dal*	387	22.76
Husk, broken *dal*	523	30.77

Table 21: *Dal* quality assessment

Item	**Taste**	**Aroma**	**Keeping quality**
Excellent	53 (41.4)	32 (25.2)	20 (22.2)
Good	53 (41.4)	59 (46.5)	25 (27.8)
Same as local *dal*	13 (10.2)	35 (27.5)	44 (48.9)
Not good	09 (7.0)	01 (0.8)	01 (1.1)
Total	**128**	**127**	**90**

Samples distributed : 560
Data received : 139

Evaluation of GTH 1:

SK Nagar: The list of field demonstrations conducted during *kharif* 2007 and *kharif* 2008 is given in **(Table 22)**. The data showed that the hybrid GTH 1 yielded higher than the local cultivar by a margin of 14.3 to 31.7% in 2007 and by 10.4 to 25.6% in 2008.

Table 22: Results of on-farm trials of GTH 1 conducted during in 2007 and 2008

S. No.	Farmers name & address	Demonstration yield (kg ha^{-1})	Local yield (kg ha^{-1})	% Av. yield increase over local
2007				
1.	Bhemiyat Bhola Soma At & Po: Kanabiyavas, Ta: Danta, Dist: Banaskantha	Failed	400	--
2.	Bhemiyat Lalaji Galaba At & Po: Kanabiyavas, Ta: Danta, Dist: Banaskantha	790 (Rainfed)	630	25.4
3.	Bhemiyat Mala Bhojibhai At & Po: Kanabiyavas, Ta: Danta, Dist: Banaskantha	Failed	500	--
4.	Bhatol Girish Ajibhai At & Po: Jalotra, Ta: Vadgam, Dist: Banaskantha	810 (Rainfed)	615	31.7
5.	Khokhariya Kanu Hira At & Po: Laxmipura, Ta: Khedbrahma, Dist: Sabarkabtha	1240	1085	14.3
2008				
1.	Vyas Umiyashankar S. At & Po. Bayaldhakhrol Ta: Modasa, Dist: Sabarkantha	1645	1310	25.6
2.	Patel Romabhai Jethabhai At & Po. Ipaloda, Ta: Meghraj, Dist: Sabarkantha	1470	1205	22.0
3.	Patel Jethabhai Maganbhai At & Po. Matoda Ta: Khedbrahma, Dist: Sabarkantha	1565	1390	12.6
4.	Patel Jasubhai Narsihbhai At & Po. Matoda Ta: Khedbrahma, Dist: Sabarkantha	1455	1285	13.2
5.	Damor Naranbhai Jivaji At & Po. Masota Ta: Vijaynagar, Dist: Sabarkantha	1225	1110	10.4

8. Large – Scale Seed Multiplication of Hybrids and their Parents.

On the basis of results of hybrid performance in different regions, seed of at least six elite hybrid combinations was multiplied for large-scale testing in target agro-ecological regions. The details are given below:

Parbhani: Large-scale seed production of hybrid ICPH 2671 was taken at the university campus in 0.4 ha plot in isolation using 4 female and 1 male row ratio. Some variation for morphological traits was recorded in the parental lines and timely roguing was under taken to purify these lines. From this plot, 389 kg hybrid seed @ 973 kg ha^{-1} was harvested. During the next cropping season large-scale seed multiplication of six more hybrids is planned.

In addition, six specific locations were also used for large-scale seed production of ICPH 2671 during 2008 season. The locations were 1) M.A.U., Parbhani. 2) Agricultural Research Station Badnapur, 3) Soybean Research Scheme, Parbhani, 4) Sorghum Research Station, Parbhani, 5) Breeder Seed Production Unit, Parbhani and 6) Oilseed Research Station, Latur. The results are still awaited.

SK Nagar: The seed production of hybrid GTH 1 was undertaken but this programme failed due to long spells of water-logging conditions. Seed production of hybrid GTH 1 will be undertaken in isolation at different research stations of the university namely, Sorghum Research Station, Deesa, Potato Research Station, Deesa, Agricultural Research Station, Bhiloda and Seed Technology Unit, Sardarkrushinagar. The seed production programme of GTH 1 will also be undertaken in collaboration with National Seed Corporation, Ahmedabad and some private seed companies. In the seed production programme of GTH 1 only 70 kg hybrid seed could be harvested from a two hectare block. This seed will be used in the next season for large-scale evaluation of the hybrid.

Akola: Seed production of 16 promising hybrids, was undertaken in different isolated blocks using a row ratio of 1 male : 3 female. The maximum hybrid seed yield of 823 kg ha^{-1} was harvested from the seed plot of Ms-010 x AKPR-8 **(Table 23)**.

Table 23: Seed production of hybrids and parental lines at Akola, 2008

S. No.	Material	Yield (kg plot)	Yield (kg ha^{-1})
A.	**Hybrid seed of pigeonpea**		
1	MS-06 x AKPR-8	0.30	123.46
2	MS-07 x AKPR-8	0.25	102.88
3	MS-08 x AKPR-8	0.27	111.11
4	MS-09 x AKPR-8	0.48	197.53
5	MS-010 x AKPR-8	4.00	823.05
6	MS-06 x AKPR-197	1.05	432.10
7	MS-07 x AKPR-197	1.34	551.44
8	MS-08 x AKPR-197	1.56	641.98
9	MS-09 x AKPR-197	1.48	609.05
10	MS-010 x AKPR-197	1.18	242.80
11	MS-01 x AKPR-371	0.30	370.37
12	MS-02 x AKPR-371	3.00	617.28
13	MS-04 x AKPR-371	1.40	576.13
14	MS-05 x AKPR-371	1.40	576.13
15	MS-04 x AKPR-402	0.90	185.19
16	MS-05 x AKPR-402	0.65	267.49
B.	**Male-sterile lines (A x B Maintenance)**		
1	MS-07 x AKPR- 647	14.00	960.22
2	MS-08 x AKPR-648	6.00	1058.20
3	MS-010 x AKPR-650	13.50	1515.15

C.	Parent seed (Hy. Male) of pigeonpea		
1	AKPR-8	3.00	336.70
2	AKPR-197	1.86	208.75
3	AKPR-371	6.35	979.94
4	AKPR-402	1.40	192.04
5	AKPR-647	14.00	1571.27
6	AKPR-648	4.00	705.47
7	AKPR-650	17.00	2098.77

Gulbarga: Seed production of ICPH 2671 was taken in one hectare block at Dharwad. The pod set was profuse in the female rows planted adjacent to male rows. It was observed that pod setting in A-lines on either side of the R-line was much better than the middle two rows, which indicates that the row ratio needs to be redefined for this location. Therefore, different row ratios such as 3F: 1M, 2F:1M will be tried in the next season and an economic row ratio will identify.

ICRISAT: Seed production programme was organized at different locations in Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV) and National Seed Corporation (NSC). At JNKVV, Jabalpur large-scale seed multiplication of hybrids and their parents was undertaken. The area of A x R was 33 ha in Jabalpur and Gwalior and A X B was 8 ha in Jabalpur and Indore. This programme is also implemented in Andhra Pradesh by NSC on 28.8 ha. During the seed production programme, it was observed that at some locations seed set was very good **(Table 25)** and at other locations it was poor **(Table 26)** and it was due to availability or non-availability of pollinating vectors.

Hybrid Parents

Parbhani: The seed of four CMS lines and promising restorers was multiplied in isolation at Badnapur and Parbhani.

SK Nagar: Large-scale seed multiplication of GT-288A/B was undertaken during *kharif* 2008 in isolation on three hectare plot at Sorghum Research Station, Deesa, using a row ratio of 4A: 1B. The seed production of GTR 11 was taken in isolation on 0.5 hectare at Potato Research station, Deesa. Despite the terminal drought respectively 500, 150, and 400 kg seed of GT 288A, GT 288B, and GTR 11 was produced. The seed production programme of GT 288A, taken by National Seed Corporation, Ahmedabad, was vitiated at both the two locations due to inordinate weather.

Akola: Seed multiplication of three male-sterile lines and seven restorers was carried out in isolations. The male-sterile lines were MS-07, MS-08, and MS-010. The male-sterile MS-010 produced the best (1515 kg ha^{-1}) seed yield it was followed by MS-08 (1058 kg ha^{-1}), and MS-07 (960 kg ha^{-1}). Among the restorers, the maximum seed was recorded by AKPR-650 (2099 kg ha^{-1}) followed by AKPR-647 (1571 kg ha^{-1}).

ICRISAT: Seed of 43 CMS lines was produced at ICRISAT. Seed production of stable CMS lines ICPA 2039, ICPA 2043, ICPA 2047, ICPA 2048, ICPA 2089, and ICPA 2092 was taken in isolations. Also seed of promising restorer lines (ICPR 2671, ICPR 2740, ICPR 2673, ICPR 2438, and ICPR 2433) was also produced in isolations. The other lines were multiplied on a small scale under a selfing cage.

Off season maintenance and hybrid seed production programme

To overcome the problem of seed deficit due to bad weather conditions, five kilogram of nucleus seed of GTR 11 was sent to Coimbatore for multiplication in the off-season. Two promising hybrids and four male-sterile lines were also multiplied at Vairagadh, Maharashtra in the off season. The sowings were done in the first fortnight of January and a total of 100 kg seed was produced.

9. Estimated Cost of Hybrid Seed Production at Patancheru

The backbone of any hybrid breeding technology lies in its commercial seed production system that will provide quality seeds at economically viable costs. Both the hybrid technology and the crop management practices are important in determining the seed production costs. This study on cost of production was conducted using a CMS-based hybrid ICPH 2671. A total of two row ratios and seven plant populations were studied. The parents of this hybrid were sown in row ratios of 4 female (A-line) and 1 male (R-line) and 3 female and 1 male rows in an isolated block measuring 0.3 ha. The planting distance in both row ratios was 75 cm x 30 cm. The expenses incurred from sowing to threshing and inputs applied were regularly recorded. The data were analyzed using the Statistical Analysis System (SAS).

The planting distances for both the row ratios were significantly different and the yields were higher at closer spacing than wider spacing. The t-test revealed that hybrid seeds recorded in planting distance of 75 cm x 30 cm in both 4:1 and 3:1 row ratios were significantly higher 2,092 kg ha^{-1} (31.4 - 72.2% higher than other treatments) and 1,342 kg ha^{-1} (3.5 - 56.6% higher than the other treatments), respectively.

There were significant differences for productivity of pigeonpea between the two row spacing (75 cm and 150 cm) in 4:1 ratio; but not in 3:1 row ratio. However, for both row ratios combined, the effect of row spacing on the yield differed significantly between rows of 75 cm and 150 cm.

For 150 cm row-to-row spacing, the yields of hybrids were low and comparable in both the row ratios.

Prevailing market prices during the cropping season were used to determine the cost of inputs. The analysis included land, labour and capital utilization costs. The gross expenditure for both 4:1 and 3:1 row ratios for row spacing of 75 cm was Rs 35,512 ha^{-1}; while it was Rs 34,815 ha^{-1} for row spacing of 150 cm. The cost of insecticide was the highest expenditure (Rs 10,000 ha^{-1}) and weeding entails the highest labour demanding operation **(Table 27)**.

Table 27: Gross seed production expenditure of hybrid ICPH 2671 in two row spacing at Patancheru

Particulars	Person days	Row spacing (Rs ha^{-1}) 75cm	150cm
Land rental		7,500	7,500
Field operations		6,250	6,250
Farm inputs			
Fertililizer		1,150	575
Insecticide		10,000	10,000
Irrigation		1,000	1,000
Labor Costs			
Fertilizer application	2.5	250	250
Sowing	12.5	1,250	1,250
Weeding	25	2,500	2,500
Spraying	10	2,500	2,500
Rouging	15	1,500	1,500
Harvesting	15	1,500	1,500
Seed cleaning	11	1,250	1,250
Seed costs			
A-line		(2.5 kg ha^{-1}) 250	(1.25 kg ha^{-1}) 125
R-line		(1.5 kg ha^{-1}) 112	(1.15 kg ha^{-1}) 115
Total Gross Expenditure		**35,512**	**34,815**

Note: Field operations: land preparation, weeding, threshing
Labor cost: Rs100 day^{-1}: Machine rental cost: Rs 350 hr^{-1}
Cost of seeds: A-line @ Rs 100 kg^{-1} and R-line @ Rs 75 kg^{-1}

The wider spacing produced less grain yield at the lowest production cost. The planting distance of 75 cm x 100 cm was expensive both in 4:1 and 3:1 row combinations with Rs 17.88 kg^{-1} and Rs 19.63 kg^{-1}, respectively; while the spacing of 150 cm x 30 cm in 4:1 ratio and 150 cm x 50 cm in 3:1 ratio registered the low cost of hybrid seeds with Rs 3.95 kg^{-1} and Rs 1.04 kg^{-1}, respectively. However, it is to be noted that the low production cost of hybrid seeds is not the only factor that measures its feasibility, and other factors such as net income and cost - benefit ratio are important for determine the viability of any enterprise. Noting that, in the spacing of 75 cm x 30 cm and the row ratio of 4:1, the cost of producing one kilogram of hybrid seed was acceptable [@ Rs 7.37] with substantial amount of yield it produced as against the other treatments **(Fig 1 and Fig 2).**

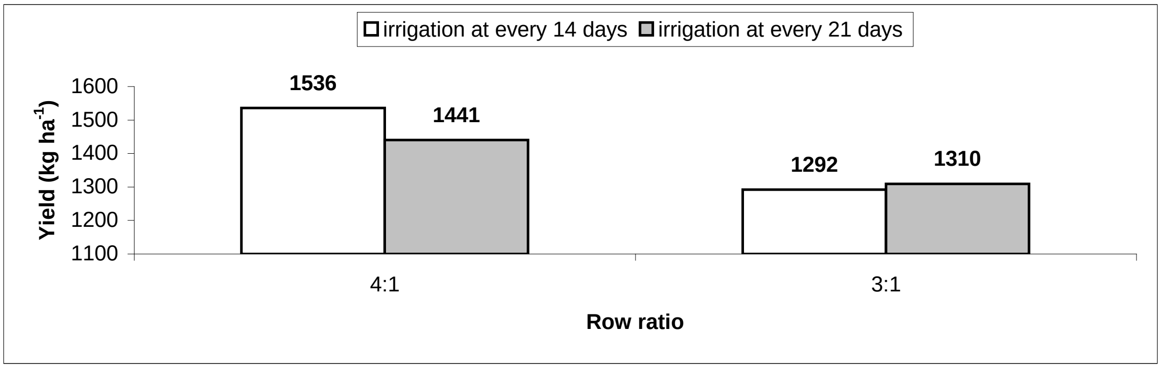

Figure 1: Mean hybrid grain yield (kg ha^{-1}) recurred at two row ratios under different irrigation regimes

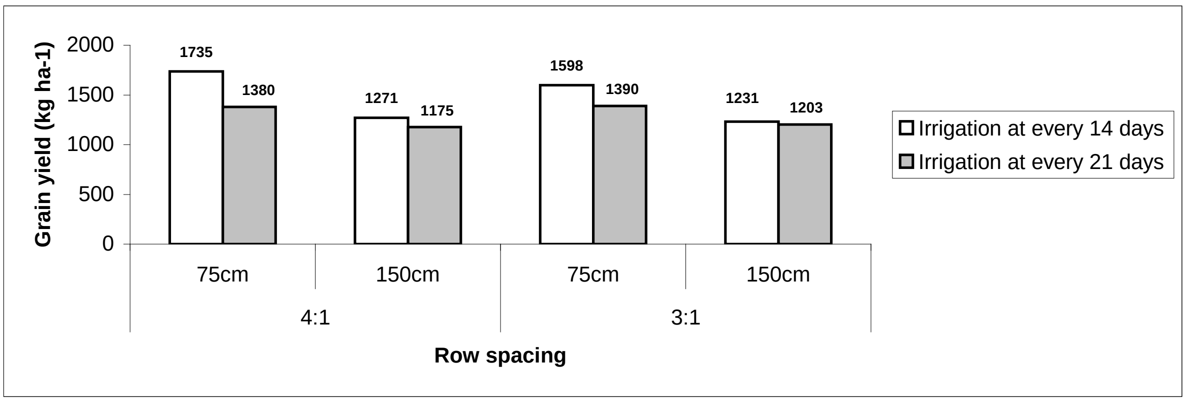

Figure 2: Mean hybrid grain yield (kg ha^{-1}) recurred under two row irrigation regimes at spacing and row ratios.

Net returns were estimated by subtracting the total expenditure from the gross income. For estimating the net return the estimated net yield was used. Gross income was derived using the value of net (hybrid) yield and by - products (R-line, undersized seeds and dry stem). The present investigation showed that a planting distance of 75 cm x 30 cm with 4:1 row ratio gave the highest net income of Rs 224,614 ha^{-1}.

The principle behind in estimating the cost-benefit ratio of seed production for ICPH 2671 is to determine the investment incurred for every rupee invested. Planting distance of 75cm x 30cm in 4:1 and 3:1 row ratios gave the highest cost - benefit ratio of Rs 6.32 and Rs 4.13 respectively **(Fig 3).** Comparing both the ratios, 4:1 gave better cost-benefit ratio due to additional row of female line that provided an increase in hybrid seed yield. The high cost - benefit ratio, in this study showed that producing seeds of hybrid ICPH 2671 at 75 cm x 30 cm spacing in 4:1 ratio was most lucrative.

With respect to economic efficiency, closer spacing at 75 cm x 30 cm in row ratio 4:1 provided the highest net returns with the highest cost-benefit ratio of Rs 6.32. In addition, the cost of producing one kilogram of hybrid seed of ICPH 2671 was estimated at Rs 7.37 kg^{-1}, which is affordable by seed producers. The study also showed that planting at 75 cm x 30 cm with 4:1 row ratio should be recommended for producing hybrid seeds. It is further concluded that increase in yield coupled with acceptable production cost will result in an optimal cost of producing hybrid seeds thus a higher cost-benefit ratio. For this study, it can be deduced that growing hybrid seed production, instead of cultivars, would be more profitable to farmers. The seeds required in growing the hybrid are less @ 5 kg ha^{-1} as compared to 12 -15 kg ha^{-1} in producing cultivars. In the experiments the seed yield advantage from hybrid ICPH 2671 was recorded at 28.5 - 41.6% more than pure line cultivar Maruti. Hence, the increase in yield with an increase in price from Rs 100 kg^{-1} to Rs 150 kg^{-1} will relate to an increase in income to seed producers.

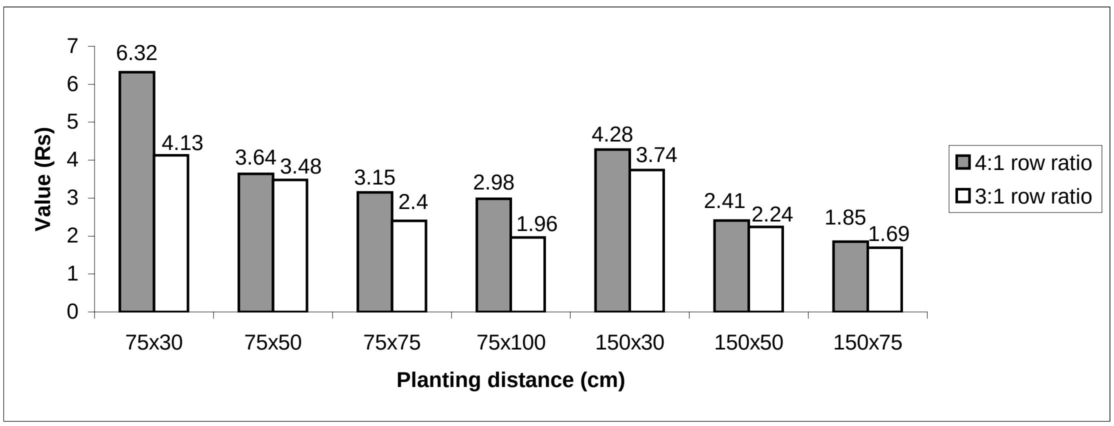

Figure 3: The Cost benefit ratio at different plants spacing and row ratios.

10 Effect of Spacing and Irrigation on Yield of Hybrid seed

The productivity and production issues need to look at the interactions of the genetic materials with bio-physical resources like soil, water and plant density. Planting density and cropping pattern modify crop canopy structure and are important for increasing productivity. Narrow row spacing brings variation in microclimate like light intensity, evaporation and temperature of soil surface. The rate of covering the ground spaces in pigeonpea depends on sowing density and ability of plants to fill such spaces. Crop water requirement generally varies from location to location arising due to variability in agro-climatic and soil related conditions. Some times even in the same location, wide variation in water requirement may exist due to irrigation (method, efficiency, and frequency). Economic benefits from increased water use efficiency under water-limited conditions are usually achieved only if yield is maximized for the available water. This study was conducted for identifying optimal agronomic practices for seed production of a CMS line ICPA 2043. Two row ratios of 4 female: 1 male and 3 female: 1 male, two irrigation frequencies (14 and 21 days interval) and 7 plant spacing constituted the treatments.

(a) Effect of plant spacing and irrigation on yield and yield components

Plant spacing and irrigation in 4:1 row ratio did not significantly affect the grain yield and yield contributing characters of CMS line ICPA 2043. Although there were differences in same agronomic parameters among the treatments, the differences were non-significant except for the biomass and seeds per pod. Plant density either at close or wide spacing did not increase the grain yield. This can be accounted for by more number of pods plant^{-1} in the low plant density. However, spacing at 75cm x 30cm with irrigation at every 14 days gave the highest productivity of 2357 kg ha^{-1} (6% - 61% higher than the other treatments). The increase in yield was due to the increase in plant density per unit area. The spacing of 75cm x 30cm and irrigation at every 14 days gave the highest grain yield of 2699 kg ha^{-1} (28%-76% superior to other treatments). This showed that pigeonpea yield were higher at close spacing. Generally, for both row ratios, spacing of 75cm x 30cm resulted in highest grain yield as compared to other treatments.

(b) Effect of row ratios on yield and yield components

There was a significant difference among the two row ratios on the number of productive branches, number of seeds pod^{-1}, and weight of 100 seed mass while no significant differences were observed for plant height at 50% flowering, diameter of main stem, pods plant^{-1}, and on the grain yield of ICPA 2043. Even though the yield contributing characters of hybrid pigeonpea differed among the two row ratios, the grain yield was not significantly influenced by row ratio. The row ratio of 4:1 gave the highest yield of 1488.40 kg ha^{-1} or 12.58% higher than row ratio 3:1 due to an additional row of ICPA 2043.

(c) Effect of irrigations on yield and yield components

The results showed that the yield components of CMS line ICPA 2043 except for the number of seeds pod^{-1} in row ratio 4:1 and number of productive branches in row ratio 3:1 was not significantly affected by the irrigation treatments. Likewise, there was no significant difference for grain yield amongst the two irrigation frequencies for both the row ratios. The t-test revealed that irrigation at every 14 days (5 irrigations) in row ratio 4:1 yielded highest grain yield of 1536.20 kg ha^{-1} while in 3:1; irrigation of every 21 days (3 irrigations) registered the highest yield at 1309.82 kg ha^{-1} **(Fig 2)**. However, the increase in yield in row ratio 4:1 with irrigation at every 14 days compared with every 21 days was only 6.22% while in 3:1 row ratio, the increase in yield with the 21-day irrigation interval compared with the 14-day irrigation interval was only

1.34%. The correlation between grain yields among the irrigation treatments was low implying that the performance of hybrid pigeonpea under various irrigation treatments is not critical.

(d) Effect of row spacing on yield and yield components

In row ratio 4:1, the various agronomic parameters such as the number of seeds pod^{-1} and yield ha^{-1} differed significantly among the two row spacing (75 cm and 150 cm) with irrigation at every 14 days. In the treatment with irrigation at every 21 days, there was a significant difference on the diameter of main stem, weight of biomass, and number of pods plant^{-1}. In row ratio 3:1, there was a significant difference on biomass production, number of pods plant^{-1}, and yield plant^{-1} with irrigation at every 14 days. A 21-day interval in irrigation resulted in a significant differences in the two row spacing (75 cm and 150 cm) with respect to the diameter of main stem, weight of biomass, yield plant^{-1} and yield ha^{-1}.

This study suggests that the row spacing of 75 cm, irrespective of the frequencies of irrigation, produced the highest grain yield per hectare of CMS line ICPA 2043. Row spacing of 75 cm in row ratio 4:1 in either of the irrigation treatments resulted in the highest increase in grain yield at 26.79% and 22.93% in irrigation at every 14 days and 21 days, respectively as against row spacing of 150 cm. In 3:1 ratio, there was a minimal increase in grain yield for row spacing of 75 cm at 14.83% with irrigation at every 14 days and 13.44% in irrigation at every 21 days as compared to 150 cm row spacing. Overall, there were significant differences on grain yield among various row spacing. The yield tends to be higher at closer spacing between rows where plant density is higher. However, the interaction effects of row spacing did not significantly influence the yield contributing characters of hybrid pigeonpea although, the yield was significantly different among the two row spacing with irrigation of every 14 days in row ratio 4:1 and irrigation at every 21 days in row ratio 3:1. Overall, the spacing of 75 cm x 30 cm with irrigation at every 14 days in row ratio 4:1 and 3:1 gave the highest grain yield of 2357 kg and 2699 kg ha^{-1} respectively.

Other Studies on the Effect of Planting Ratios on Hybrid Yield

Other Seed Production Studies

(a) Parbhani: In order to finalize ratio of male and female in seed production of hybrid pigeonpea, six different ratios were tested. Among these, 3:2 (EW) recorded the highest pod set % and grain yield, followed by 4:1 and 3:2 respectively **(Table 28)**. Similar testing programmes will be formulate the under different environments during next year.

Table 28: Hybrid seed yield harvest with different row ration at Parbhani, 2008

Raw ratio	female : male	Pods per plant	Yield per plant (g)
4:1	ICPA 2043	330.5	79.00
4:2	ICPA 2043	253.7	55.75
3:1	ICPA 2043	276.2	61.00
3:2(EW)	ICPA 2043	201.4	82.30
3:2(SN)	ICPA 2043	290.3	80.00
6:2	ICPA 2043	235.6	68.43
8:1	ICPA 2043	167	42.66

(b) SK Nagar: The seed production protocol for both hybrid seed production and maintenance of A & R lines has been finalized and 4:1 rows ratio of A and B lines or A and R lines were selected for seed maintenance of A-line and hybrid, respectively.

11. Progress in Developing Grow - out Tests

Attempts are being made at ICRISAT to develop suitable molecular and morphological markers to facilitate grow-out testing of pigeonpea hybrids. This will help in controlling seed quality of hybrids and their parents.

(a) Molecular marker

A kit has been developed at ICRISAT for assessing the purity in pigeonpea hybrid seeds. Screening of 148 SSR markers on 159 A-B, and R-lines revealed that 41 markers had polymorphism with 2 to 6 alleles and the polymorphism information content (PIC) for these markers ranged from 0.01 to 0.80 with an average of 0.41 per marker. For purity assessment of hybrid seed and to check the heterogeneity in parental lines of a pigeonpea hybrid ICPH 2438, a set of two markers (CCB4 and CCTTC006) has been identified and utilized in seed lots of the ICPH 2438 **(Fig 4)**.

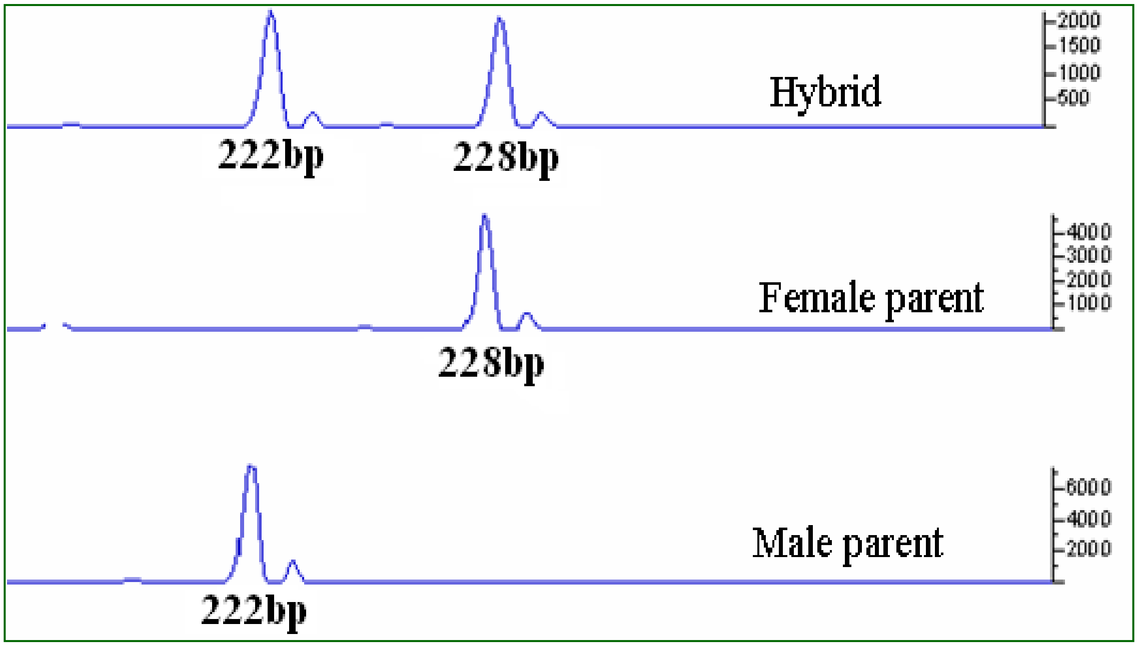

Figure 4: Molecular profiling pattern for CCB4 marker in male, female parent and hybrid ICPH 2438

(b) Morphological (obtuse leaf) marker

A new approach involving a phenotypic marker is being developed at ICRISAT to estimate the proportion of hybrid plants in a given population, with in a short period of 3 - 4 weeks. A technology based on a leaf marker (obtuse) is being developed trait by transferring in to A/B lines. The plants of an F_1 hybrid made by crossing an obtuse leaf female line and normal leaves male line will have normal leaves and the plants showing obtuse leaf will be the result of A x B cross. This trait **(Fig 5)** is governed by a single recessive gene and therefore easy to transfer in different female parents.

Leaf Marker

Normal **Obtuse** **Hybrid**

Figure 5: Testing hybrid seed quality through molecular (obtuse leaf) markers

12. Training Programmes and Field Visits

At Parbhani regular visits to farmers' fields were arranged during hybrid seed production plots to monitor and train the seed producing farmers in hybrid seed production. During the season, 30 scientists, 40 progressive farmers, and over 100 students visited the seed production plot of ICPH 2671 at the university farm. At SK Nagar**,** a hybrid pigeonpea day was organized at the research station on 27th November, 2008, in which more than 40 scientists, 50 progressive farmers, and 20 officials from private companies were exposed to the hybrid research programme in the field. They were also trained on hybrid seed production technology. In addition, 60 officials of the Gujarat State Seed Certification Agencies and Officials from the Department of Agriculture were also trained on November 5-6, 2008.

At Akola, over 50 farmers were trained in the seed production of hybrids and their parents. The Farmer's Field Days were organized in five villages of four districts of Vidarbha region. These Field Days were organized on the pigeonpea plots of the farmers of respective villages to whom the seed of ICPH-2671 were allotted. The farmer's participation for all the Field Days was satisfactory. At ICRISAT a total of 319 persons were trained. This includes 54 scientists, 31 Seed Production Officers, and 234 farmers. ICRISAT organized a training programme on 27th July, 2008 for 23 Seed Production Officers on hybrid seed production programme at ICRISAT campus. Similarly, Dr K B Saxena trained another batch of Seed Production Officers at Jawarharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur. This programme was supported by ICAR. At Gulbarga, one training programme for scientist was organized on the aspect of seed production during the season.

13. Problems Faced and Lessons Learnt

During monitoring of pigeonpea hybrid seed production isolations we noticed some problems and planned for improvement of the same.

Problem 1: Non-availability of pollinating insects:

Solution:

- This situation can be avoided by conducting pilot seed production in these/and any new areas before going for seed production.
- Generally we can expect bees during flowering period hence, the plantings of seed production may be differed by two to three dates of sowings. By which the plot will have continuous pollen availability.

Problem 2: Inadequate roguing:

Solution:

- In spite of advising/guiding the farmers with right plant type still they hesitate to take out off-type plants.

14. Publications

(a) Hybrid seed production manual

The simplified hybrid seed production manual will shortly be published in vernacular language by all the centres. The Technical Bulletins related to hybrid seed production and maintenance in 2004 [Gujarat Tur Hybrid 1 (GTH-1) First Cytoplasmic Genic Male Sterility System Based Pigeonpea Hybrid by Tikka and his coworkers], 2007 [Maintenance Breeding in Context to Protection of Plant Varieties and Farmers' Right Act by Acharya *et al*.], and 2008 *Sui-generis* (Research in Pigeonpea by Acharya and coworkers) have been published by GAU. A seed production manual was published by ICRISAT.

(b) Research articles

Journal Articles (2009)

Published

1. Saxena, R.K., Prathima, C., **Saxena**, **K.B.,** Hoisington, D.A., Singh, N.K. and Varshney, R.K. (2009). Novel SSR markers for polymorphism detection in pigeonpea (*Cajanus* spp.). Plant Breeding. Doi: 10.1111/j.1439-0523.2009.016-0.
2. Saxena, R.K., **Saxena, K.B.,** Kumar, R.V., Hoisington, D.A. and Varshney, R.K. (2009). Simple sequence repeat-based diversity in elite pigeonpea genotypes for developing mapping populations to map resistance to *Fusarium* wilt and sterility mosaic disease. *Plant Breeding. 10.1111/j.1439-0523.2009.0168-0*
3. **Saxena, K.B**. (2009). A hybrid pea for the drylands. Appropriate Technology. 36(2): 38-39.

Accepted

4. **Saxena, K.B**. and Kumar, R.V. (2009). Insect-aided out-crossing in four wild relatives of pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Euphytica. Doi : 10.1007/s 10681-009-0088-0*
5. Dalvi, V.A. and **Saxena, K.B.** (2009). Stigma receptivity in pigeonpea [*Cajanus cajan* (L.) Millsp.]. Indian Journal of Genetics and Plant Breeding. 69(3)
6. **Saxena, K.B.**, Kumar, R.V., Dalvi, V.A., Pandey, L.B., and Guru Prasad, G. (2009). Development of cytoplasmic nuclear male-sterility, its inheritance and potential use in hybrid pigeonpea breeding.

Submitted

7. Mula, M.G., **Saxena, K.B.,** Kumar, R.V., Mula, R.P. and Rathore, A. Seed production cost of a cms-based medium-duration pigeonpea hybrid. Current Science.

Conference Proceedings

8. **Saxena, K.B.** (2009). Increasing production of pulses through breeding with special reference to hybrid pigeonpea. Indian merchant's chamber, economic research and training foundation. Proceedings of high powered seminar on "Achieving Self–sufficiency in Agriculture Production and Nutrition". Publications sponsored by NABARD. 45-55.
9. **Saxena, K.B.** (2009). Evolution of hybrid breeding technology in pigeonpea. Milestone in Food Legume Research. Eds: Masood Ali and Shiv Kumar. Published in IIPR, Kanpur 208 024. Milestones in Food Legume Research Conference 2009. 82-114.
10. **Saxena, K.B.,** Srivastava, R.K., Wanjari, K.B., Gowda, C.L.L., Sarode, S.V., Singh, I.P., Kumar, S., Kumar, R.V. and Ali, M. (2009). Hybrid Pigeonpea- the seeds of excellence. National Symposium on Legumes for Ecological Sustainability: Emerging Challenges and Opportunities, November 3-5, 2007, ISPRD, IIPR, Kanpur 208 024. 392-407.
11. **Saxena, K.B.**, Kumar, R.V., Chopde, V.K., Srivastava, R.K., Gowda, C.L.L., Rao, K.P.C. and Bantilan, C. (2009). ICPH 2671- The world's first commercial grain legume

hybrid. Paper presented at the APB and SABRAO conference at Cairns, Australia. August 2009.

Information Bulletin

Published

12. **Saxena, K.B.** and Kumar, R.V. (2009). Seed production technology of pigeonpea hybrid ICPH 2671. International Crop Research Institute for Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India. January 2009.

Posters presented

13. Saxena, R.K., **Saxena K.B**., Kumar, R.V. and Varshney, R.K. (2009). Genomics tools to combat the constraints in hybrid pigeonpea breeding. International Conference on Current Trends in Biotechnology and its Implications in Agriculture, Meerut 19- 21 Feb.
14. Saxena, R.K., **Saxena, K.B.**, Kumar, R.V., Kavi Kishor, P.B. and Varshney, R.K. (2009). Genomic approaches for enhancing hybrid technology in pigeonpea [*Cajanus cajan* (L.) Millsp.]. Plant and Animal Genome XVII Conference, Sandiago10- 14 Jan.
15. Saxena, R.K., **Saxena, K.B.**, Kumar, R.V. and Varshney, R.K. (2009). Application of genomics in strengthening hybrid technology in pigeonpea. International Conference on Grain Legumes, Kanpur 14- 16 Feb.