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Standard heterosis in pigeonpea and on-farm validation of two A4 CMS-based Hybrid

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Abstract

Study was conducted to estimate the extents of standard heterosis in ten medium maturing A4 CMS-based pigeonpea hybrids for yield and related traits under three diverse environments during 2012-13. Treatment differences and genotype-environment interaction effects, as revealed by pooled analysis, were significant for all the traits. Significant positive heterosis over the pure line control cultivar was recorded for plot yield, yield/plant, pods/plant, seeds/pod, seed size and canopy height. The most promising hybrids identified were ICPH 2671 and ICPH 2740 with, respectively, 55 and 59 % standard heterosis. These hybrids confirmed their high (46- 47%) superiority over the pure line cultivar in 1007 on-farm trials conducted in the states of Andhra Pradesh, Jharkhand and Madhya Pradesh around the India.

Keywords: *Cajanus cajan*, hybrids, standard heterosis, on-farm trials

Introduction

In India, where vegetarian diets are the norms, pigeonpea [*Cajanus cajan* (L.) Millsp.] is a key source of dietary proteins. This pulse is annually grown on 3.88 m ha in the country with a total production of 2.85 m t and productivity of about 700 kg/ha [2]. Intensive pure line breeding efforts spread over the past six decades in different parts of the country did not produce the positive results as far as enhancing its unit productivity was concerned. Therefore, the persistence of the low yield plateau over the half century called for the development of some alternative breeding technology to achieve any breakthrough. In this context, pigeonpea breeders made the first breakthrough by developing a hybrid technology, the first in any food legume [10, 12]. This technology was based on cytoplasmic nuclear male sterility (CMS) and natural cross-pollination systems. To reap the benefits of this innovation on a sustainable basis, it is essential that new high yielding hybrids are bred at regular intervals. Therefore, the present study was conducted to identify new medium maturing high yielding hybrids using three test environments. Also, the productivity performance of two hybrids was validated in 1007 on-farm trials conducted at different locations in three states of central India.

Materials and Methods

The plant materials used in this study consisted of 10 medium maturing hybrids (ICPHs 3933, 2671, 2740, 2751, 3461, 3477, 3491, 3494, 3762, and 4490) and one popular inbred cultivar (Asha) as a control (Table 1). The hybrids were produced by hand pollinating five CMS lines (ICPAs 2043, 2047, 2048, 2078 and 2092) carrying A4 cytoplasm and six known diverse fertility restorers (ICPLs 87119, 20093, 20096, 20098, 20108 and 20120) at ICRISAT, Patancheru, India.

Table 1: Parentage of the hybrids used in the study

Hybrid Name	Female parent	Male parent
ICPH 3933	ICPA 2078	ICPL 87119
ICPH 2671	ICPA 2043	ICPL 87119
ICPH 2740	ICPA 2047	ICPL 87119
ICPH 3477	ICPA 2047	ICPL 20098
ICPH 4490	ICPA 2047	ICPL 20126
ICPH 3494	ICPA 2048	ICPL 20093
ICPH 2751	ICPA 2048	ICPL 87119
ICPH 3491	ICPA 2048	ICPL 20096
ICPH 3762	ICPA 2092	ICPL 20108
ICPH 3461	ICPA 2092	ICPL 87119

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The test locations selected were ICRISAT, Patancheru in Telangana state (17°53' N, 78°27' E, 545.0 m asl), Birsa Agricultural University, Ranchi in Jharkhand state (23°17' N, 85°19' E, 625.0 m asl) and College of Agriculture, Sehore, in Madhya Pradesh (23°12' N, 77°05' E, 498.7 m asl). At each location, the trial was sown at the onset of rainy season in 2012, using randomized complete block design with two replications. Each plot consisted of six rows of 3 m length. Row to row and plant to plant spacing was kept at 75 cm and 50 cm, respectively. A basal fertilizer dose of 20 kg/ha N and 60 kg/ha P was applied and for optimum crop growth, the other cultural practices were carried out as outlined [4]. In each plot observations were recorded on five randomly selected competitive plants on seed yield/plant (g), plant height (cm), 100-seed weight (g), pods/plant and seeds/ pod. The data on bulk seed yield (kg/ha) and days to 50% flowering were recorded on net plot basis. Data obtained from each trial were analyzed first separately and later pooled analysis was also performed. Standard heterosis for different traits was estimated as the percent superiority of a hybrid over the control cultivar. Two high-yielding hybrids were selected for on-farm evaluation and a total of 1007 trials were conducted. Hybrid ICPH 2671 was tested by 399 farmers in Andhra Pradesh, 310 farmers in Madhya Pradesh and 288 farmers in Jharkhand state. The other hybrid ICPH 2740, was tested on a relatively smaller scale in Andhra Pradesh (47 trials) and Madhya Pradesh (13 trials). These trials, coordinated by Pigeonpea Breeding Unit of ICRISAT, were conducted in collaboration with State Departments of Agriculture and State Agricultural Universities in Andhra Pradesh, Madhya Pradesh, and Jharkhand. The seed of the hybrids and control cultivar was provided by ICRISAT. Each farmer conducted the trial under sole cropping in 1-2 acre plot, sharing equal area with hybrid ICPH 2671 or ICPH 2740 and the control. The farmers were allowed to raise the crop using local cultural practices. The field monitoring was undertaken once/twice during podding stage. Yield data were collected and provided to ICRISAT by the collaborating partners.

Results and discussions

G x E Interaction

In each trial, the treatments differences were highly significant for all the traits except days to 50% flower, while the pooled analysis of data revealed significant differences among genotypes for all the traits (ANOVA not reported). Locations effects were significant for all the traits except flowering time and seed size. Since, the productivity of a crop is a complex trait and its expression is influenced by a number of major and minor genes and under such genetic scenario significant effects of environments are often encountered. In the present study also, significant g x e interactions were recorded for all the traits except that of seed size; and this resulted in differential responses of hybrids to the three environments [6, 1]. also reported significant g x e interaction for yield and its related traits in pigeonpea. Such interactions could be attributed to the differences in various soil and climatic parameters.

Per se Performance of Hybrids

Seed yield: Performance data of the test entries are summarized in Table 2. For seed yield/plot, eight hybrids were found superior to the control at Patancheru and of these, ICPH 2740 (1642 kg/ha) and ICPH 2671 (1629 kg/ha) were found promising. At Ranchi, all hybrids were significantly better than the control and ICPH 4490 (2217 kg/ha) and ICPH 2740 (2092 kg/ha) were most outstanding. In Sehore, hybrids ICPHs 3933, 3461, 2671 and 3477 were found promising and ICPH 3933 with 1545 kg/ha yield was the best performer. Over the three locations ICPHs 2740, 2671, 4490, 3933, 3762, 3461 and 3477 were better than the control. Among these, ICPH 2740 (1674 kg/ha) was the best and it was closely followed by ICPH 2671 (1635 kg/ha). On the basis of mean single plant yield over the locations, all the hybrids significantly out-yielded the control. At Ranchi and Sehore, all the 10 hybrids were significantly better than the control, while at Patancheru nine hybrids were found significantly superior to the control.

Table 2: Mean yield of hybrids and control cultivars at different locations

Location	Patancheru		Ranchi		Sehore		Mean	
Entry	Yield/	Yield	Yield/	Yield	Yield/	Yield	Yield/plan	Yield
Name	plant (g)	(kg/ha)	plant (g)	(kg/ha)	plant (g)	(kg/ha)	t (g)	(kg/ha)
ICPH 3933	66.4*	1208	66.6*	1931**	55.3*	1545**	62.8**	1561*
ICPH 2671	72.0**	1629**	76.4**	1813**	70.0**	1463**	72.8**	1635*
ICPH 2740	71.6**	1642**	69.0*	2092*	52.3*	1288*	64.3**	1674*
ICPH 3477	58.2*	1442*	66.2*	1338*	55.5*	1411*	60.0*	1397*
ICPH 4490	59.8*	1383*	78.3**	2217**	58.3*	1288*	65.5**	1629*
ICPH 3494	46.9*	957	54.3*	1440*	46.6*	1250*	49.3*	1216*
ICPH 2751	66.8**	1360*	61.9*	1254*	62.6**	1255*	63.8**	1290*
ICPH 3491	43.6	1263*	52.4*	1598*	46.9*	1125*	47.6*	1329*
ICPH 3762	70.4*	1587*	60.0*	1771**	57.2*	1172*	62.5**	1510*
ICPH 3461	62.7*	1506*	69.2**	1488*	64.1*	1465**	65.3**	1486*
Asha (C)	41.2	1137	40.0	1043	36.0	973	39.1	1051
Mean	58.3	1344.7	61.1	1592.1	53.2	1245.8	57.5	1394
SEm (±)	3.28	107.4	1.92	108.5	3.85	112.5	3.65	114.6
CV (%)	7.98	11.29	8.80	9.60	10.23	12.77	10.23	12.77

*, ** significant at 0.05 & 0.01 respectively

Other traits: At Sehore, the hybrids flowered earlier than rest of the two locations (Table 3). On mean basis, hybrids ICPH 3933 and ICPH 3762 took least (117 days) time to flower, while ICPH 3461 was the latest (124 days). At Ranchi, hybrid ICPH 4490 was the tallest (223 cm), followed by ICPH 2740 (219 cm) and ICPH 3491 (219 cm). The control variety Asha attained the height of 193 cm. On average over three

locations, ICPH 3477 was the tallest (211 cm), followed by ICPH 4490 (206 cm) and ICPH 3461 (202 cm), whereas check Asha was the shortest. At Ranchi, a wide range for number of pods/plant was recorded and it varied from 225 (ICPH 3494) to 496 (ICPH 2671) with a mean of 299. On average over the locations, the highest number of pods/plant was recorded by ICPH 2671 (405) and it was followed by ICPH 2740 (304).

There was a little variation for number of seeds/pod across the location. On average, hybrid ICPH 3491 produced the longest

pod with 3.9 mean seeds/pod. For seed size also the variation among the test entries was narrow.

Table 3: Yield contributing traits of hybrids and control cultivars at different and pooled locations

Entry	Patancheru			Ranchi					Sehore					Pooled						
	Name	PP	DF	PLHT	SP	SW	PP	DF	PLHT	SP	SW	PP	DF	PLHT	SP	SW	PP	DF	PLHT	SP
ICPH 3933	233	121*	189*	3.6	11.6*	295*	117*	210*	3.6	11.6*	237*	112*	178	3.5	11.0*	255*	117*	193*	3.5	11.4*
ICPH 2671	345**	117*	178*	3.3	11.6*	496**	126	206	3.5	10.5	374**	118*	187*	4.1	10.9*	405**	120	191	3.6	11.0*
ICPH 2740	365**	123	188*	3.6	10.5	339*	131	219*	3.4	11.3*	207	113*	172	3.9	9.7	304**	122	193*	3.6	10.5
ICPH 3477	214	120*	205*	3.3	11.5*	264	119*	211*	3.9*	11.6*	297**	116*	217*	4.5*	10.5*	258*	118	211*	3.6	11.2*
ICPH 4490	216	122*	199*	3.4	10.9*	316*	125	223*	3.6	11.6*	262*	121*	196*	3.6	11.6*	265*	123	206*	3.6	11.4*
ICPH 3494	223	123*	206*	3.9*	11.0*	225	125	193	3.6	11.2*	222*	119*	202*	4	11.9*	224*	122	201*	3.8	11.4*
ICPH 2751	286*	123*	192*	3.4	11.0*	277	126	188	3.6	12.1*	280*	110*	198*	3.7	10.5*	281*	120	193	3.5	11.2*
ICPH 3491	213	123*	203*	3.8*	16.0*	234	122	219*	3.9*	11.9*	225*	111*	182*	4.1	11.5*	224	119	201*	3.9	11.7*
ICPH 3762	384**	119*	192*	3.4	9.4	267	124	211*	3.4	10.7	251*	109*	190*	3.7	11.0*	301**	117*	198*	3.5	10.4
ICPH 3461	266*	128	186*	3.2	10	346*	116*	198	3.4	10.6	286*	129	221*	4.1	9.6	299*	124	202*	3.6	10.1
Asha (C)	237	128	170	3.4	9.8	240	122	193	3.7	10.2	196	128	172	3.4	9.1	224	121	178	3.6	9.7
Mean	267	121.8	190	3.5	10.7	299	123.4	207	3.6	11.1	252	115	190	3.8	10.5	272.6	120	196	3.6	10.8
SEm±	20.4	0.6	8.02	0.11	0.39	45.0	2.5	5.8	0.1	0.3	14.4	0.7	5.1	0.1	0.4	12.1	2.1	7.0	0.4	1.0
CV (%)	10.8	2.7	5.9	4.8	5.8	21.3	2.8	4	3.9	4.8	8.1	2.8	3.8	5	5.6	8.1	1.4	3.8	4.9	5.6

Where : PP- Pods/ plant, DF – Days to 50% flower, PLHT – Plant height (cm), SP – Seeds/ pod, SW – 100 seed weight (g)

*, ** significant at 0.05 & 0.01 respectively

Standard Heterosis

Seed yield per plant: The estimates of standard heterosis for both plot and individual plant yield (Table 4) were positive and significant. Based on pooled data for yield/plant, the range of standard heterosis was from 21.74% (ICPH 3491) to 86.19% (ICPH 2740) and eight hybrids ICPH 2671, ICPH 4490, ICPH 3461, ICPH 2740, ICPH 2751, ICPH 3933, ICPH

3762 and ICPH 3477 exhibited highly significant positive values. At Patancheru ICPH 2671 was the best hybrid and the other promising hybrids were ICPH 2740, ICPH 3762, ICPH 2751 and ICPH 3933. At Sehore ICPH 2671 (94.44%) and ICPH 3461 (78.06%) were outstanding. At Ranchi, hybrids ICPH 4490 (95.75%) and ICPH 2671 (91.00%) exhibited highly significant positive standard heterosis.

Table 4: Standard heterosis for yield per plant (g) and Yield (kg/ha) hybrids and control cultivars at different locations

Sehore Ranchi Pooled

Location	Location		Patancheru			Yield (Kg/ha)	Yield/ plant	Entry name
	Yield/ plant (g)	Yield (Kg/ha)	Yield/ plant (g)	Yie (Kld g/ha)	plant (g)			
ICPH 3933	61.17*	6.24	53.61*	58.79*	66.50*	85.14**	60.61*	48.53*
ICPH 2671	74.76**	43.27*	94.44**	50.36*	91.00**	73.83*	86.19**	55.57*
ICPH 2740	73.79**	44.42*	45.28	32.37	72.50**	100.58**	64.45*	59.28*
ICPH 3477	41.26	26.82	54.17*	45.02*	65.50*	28.28	53.45*	32.92
ICPH 4490	45.15	21.64	61.94*	32.37	95.75**	112.56**	67.52*	55.00*
ICPH 3494	13.83	-15.83	29.44	28.47	35.75	38.06	26.09	15.70
ICPH 2751	62.14*	19.61	73.89*	28.98	54.75*	20.23	63.17*	22.74
ICPH 3491	5.83	11.08	30.28	15.62	31.00	53.21*	21.74	26.45
ICPH 3762	70.87**	39.58	58.89*	20.45	50.00*	69.80*	59.85*	43.67*
ICPH 3461	52.18*	32.45	78.06*	50.57*	73.00*	42.67	67.01*	41.39*

*, ** significant at 0.05 & 0.01 respectively

Seed yield per plot: Standard heterosis for plot seed yield (kg/ha) across the three locations varied from 15.70% (ICPH 3494) to 59.28% (ICPH 2740); and six hybrids ICPH 2740 (59.28%), ICPH 2671 (55.57%), ICPH 4490 (55.00%), ICPH 3933 (48.53%), ICPH 3762 (43.67%) and ICPH 3461 (41.39%) exhibited highly significant positive standard heterosis. At Ranchi all the hybrids except ICPH 3491 and ICPH 3494 showed significant standard heterosis. Four hybrids (ICPH 3933, ICPH 3461, ICPH 2671 and ICPH 3477) at Sehore and two hybrids (ICPH 2740 and ICPH 2671) at Patancheru exhibited significant positive standard heterosis for plot seed yield. Other traits: For pods/plant all the hybrids showed positive standard heterosis and remaining two hybrids (ICPH 3494 and ICPH 3491) had negative standard heterosis (Table 5). The four hybrids ICPH 2671 (80.80%), ICPH 2740

(35.71%), ICPH 3762 (34.38%) and ICPH 3461 (33.38%) exhibited highly significantly positive standard heterosis for number of pods/plant. Six hybrids including ICPH 3933, ICPH 2671, ICPH 3477, ICPH 2751, ICPH 3491 and ICPH 3762 showed significant negative standard heterosis for days to 50% flowering. The standard heterosis ranged from 7.30% (ICPH 2671) to 18.54 (ICPH 3477) for plant height; and six hybrids ICPH 3477, ICPH 4490, ICPH 3461, ICPH 3494, ICPH 3491 and ICPH 3762 exhibited significant standard heterosis for plant height. Only two hybrids ICPH 3491 (13.26%) and ICPH 3494 (10.66%) showed significant standard heterosis for seeds/pod. With the exception of ICPH 3762 and ICPH 3461 all the hybrids showed significant standard heterosis for 100-seed weight.

Table 5: Standard heterosis for yield contributing traits of hybrids and control cultivars at across the locations

Entry Name	Days to 50% flowering	Plant Height (cm)	Pods / plant	Seeds/ pod	100 seed weight (g)
ICPH 3933	-3.31**	8.43	13.84	0.86	17.53*
ICPH 2671	-0.83*	7.30	80.80**	4.32	13.40*
ICPH 2740	0.83	8.43	35.71*	4.61	8.25*
ICPH 3477	-2.48**	18.54*	15.18	2.59	15.46*
ICPH 4490	1.65	15.73*	18.30	2.31	17.53*
ICPH 3494	0.83	12.92*	0.00	10.66**	17.53*
ICPH 2751	-0.83*	8.43	25.45	1.73	15.46*
ICPH 3491	-1.65*	12.92*	0.00	13.26**	20.62*
ICPH 3762	-3.31**	11.24*	34.38*	0.86	7.22
ICPH 3461	2.48	13.48**	33.48	3.17	4.12

*, ** significant at 0.05 & 0.01 respectively

On-farm Validation of Productivity of Promising Hybrids

Hybrid ICPH 2671: In Madhya Pradesh a total of 360 on-farm trials of ICPH 2671 were conducted in seven districts. On average, ICPH 2671 produced 1940 kg/ha yield and demonstrated 46% yield advantage (Table 6) over the control cultivar (1526 kg/ha). In Jharkhand 288 trials were conducted and the hybrid (1460 kg/ha) recorded 69% superiority over the control. In Andhra Pradesh (399 trials) also, this hybrid produced 56% more yield than the control (907 kg/ha). Overall, the performance of hybrid ICPH 2671 in 947 on-farm trials was exceptionally good with 46.6% yield advantage over the pure line control cultivar. This is the first medium

maturing A4 CMS-based hybrid that was released for cultivation in the states of India (Madhya Pradesh, Maharashtra, Jharkhand, Gujrat and Andhra Pradesh) [9].

Hybrid ICPH 2740: In Andhra Pradesh a total of 47 trials were conducted (Table 6) and on average, the hybrid (1999 kg/ha) recorded 39% superiority over the control (1439 kg/ha). In Madhya Pradesh, only 13 on-farm trials were undertaken and ICPH 2740 (1874 kg/ha) was found to produce 54% more yield when compared with the control (1217 kg/ha). Based on its high performance, hybrid ICPH 2740 was released for cultivation in the state of Telangana [11].

Table 6: Standard heterosis recorded in the on-farm demonstrations of two CMS based pigeonpea hybrids in different states

Hybrid name State	Farmers (no.)	Mean yield (kg/ ha)		Standard heterosis (%)
		Hybrid	Control	
ICPH 2671				
Andhra Pradesh	399	1,411	907	56
Jharkhand	288	1,460	864	69
Madhya Pradesh	360	1,940	1,326	46
Total/Mean	947	1513.3	1032.3	46.6
ICPH 2740 Telangana				
Madhya Pradesh	13	1,874	1,217	54
Mean/total	60	1936.5	1328.0	45.8

Source: Pigeonpea Breeding Unit, ICRIASAT

Earliness is a desirable trait as it helps in encountering terminal drought. In the present study significant negative heterosis for flowering was recorded and it confirmed the reports of [5, 8, 15]. Standard heterosis for plant height was significant and it ranged from 7.30 to 18.54%, confirming the reports of [13, 15] reported significant positive heterosis for seeds/pod and in the present study also similar results were recorded. The estimates of standard heterosis for seed size in the present as well as those reported earlier by [3] were low to moderate. This could be due to lack of variability and non-additive genetic variation for this trait.

For productivity a wide range of positive heterosis was observed in the present investigation. Further, it was also observed that the heterotic hybrids such as ICPH 2671, ICPH 2740 and ICPH 3762 also expressed significant heterosis for number of pod/plant and seeds/pod and this confirmed the results of [6] and [3]. It is, therefore, concluded that in pigeonpea highly significant hybrid vigour is available for seed yield and it could be exploited to break the decades-old low yield plateau.

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