Research Article

Prospects of Pigeonpea Hybrids in Indian Agriculture

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Abstract

Stagnant production, soaring prices, and enhanced imports of pigeonpea (red gram) have been matter of concern to the prime stakeholders in India. A new hybrid pigeonpea breeding technology, developed jointly by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) and Indian Council of Agriculture Research (ICAR) is capable of substantially increasing the productivity of red gram, and thus offering hope of pulse revolution in the country. The hybrid technology, based on cytoplasmic nuclear male-sterility (CMS) system, has given an opportunity of achieving the long-cherished goal of breaking yield barrier in pigeonpea. In the past two years ICRISAT and ICAR have tested over 1000 experimental hybrids and among these GTH 1 and ICPH 2671 were found the most outstanding. GTH-1 has yielded 32% more yield than best local variety, GT 101. ICPH 2671 is highly resistant to *fusarium* wilt and sterility mosaic diseases and produced 38% more yield over the popular variety Maruti in multi-location trials conducted for over four years. In the on-farm trials conducted in the states of Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, and Jharkhand during 2007, 2008 and 2009 have demonstrated 30% yield advantage over local check varieties. So far the progress in the mission of enhancing the productivity of pigeonpea has been encouraging and the reality of commercial hybrids is just around the corner. The new hybrid pigeonpea will serve as the platform for the tremendous growth of pulse production in India.

Key words:
Pigeonpea, hybrid, heterosis

Introduction

Pulses occupy an important place in Indian agriculture. Within this protein-rich group of crops, red gram or pigeonpea [*Cajanus* cajan (L.) Millsp.] occupies an important place among rainfed resource poor farmers because it provides quality food, fuel wood, and fodder. Its soil rejuvenation qualities such as release of soil-bound phosphorous, fixation of atmospheric nitrogen, recycling of soil nutrients, and addition of organic matter and other nutrients make pigeonpea an ideal crop of sustainable agriculture in the tropical and sub-tropical regions of India. Although pigeonpea is globally grown on 5.2 m ha land in about 50 countries, its 77% area is in India (FAO, 2008). In recent years pigeonpea has been successfully introduced in Myanmar (555,000 ha) for export of its grains and in China (150,000 ha) for conservation of soil in hilly areas. In sub-Sahara Africa (Kenya, Malawi, Tanzania, Uganda, and Mozambique) long duration pigeonpea constitute an important component of rainfed agriculture. In India, pigeonpea is important in the states of Maharashtra (1.1 m ha), Karnataka (0.58 m ha), Andhra Pradesh (0.51 m ha), Uttar Pradesh (0.41 m ha), Madhya Pradesh (0.32 m ha), and Gujarat (0.35 m ha). These six states account for over 70% of the total pigeonpea area in India. As a result of the availability of disease resistant varieties and greater profitability, the cropped area and production of pigeonpea have recorded a steady positive growth in the past 50 years, but the mean national productivity has remained unchanged at around 700 kg ha^{-1} (Fig.1). This is a matter of concern since the domestic demand of pigeonpea is rapidly increasing and the Indian Government has resorted to import about 0.5 to 0.6 million tons of pigeonpea mainly from Myanmar and southern and eastern Africa.

The per capita availability of protein in the country is already one-third of its requirement and if production of this major pulse is not increased significantly, the

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problem of malnutrition among the poor will further aggravate. This could be alleviated either by increasing area or productivity of the crop. Since the opportunities of horizontal increase in the cultivated area are limited, it is important to enhance its productivity by a significant margin. This paper discusses the progress and prospects of genetic enhancement of yield through hybrid breeding to achieve the long cherished goal of breaking yield plateau in pigeonpea.

Advent of Hybrid Pigeonpea Technology

The concept of developing commercial hybrids in pigeonpea was developed at ICRISAT in 1974, when a source of genetic male-sterility (GMS) was identified. Since then huge resources have been invested in the research and development by ICRISAT and ICAR. As a consequence, a genetic male-sterility based pigeonpea hybrid ICPH 8 was released in 1991 in India (Saxena et al., 1992). It is considered a milestone in the history of crop breeding as ICPH 8 is the first ever commercial hybrid released in any food legume in the world. This hybrid could not be commercialized due to its high cost and difficulties in maintaining its seed quality. This development, however, gave two important information: first the presence of exploitable hybrid vigour in pigeonpea and the second- the quantum of pod setting with available partial (25%) natural out-crossing.

To overcome the production constraints, an improved hybrid seed production technology based on more efficient cytoplasmic - nuclear male-sterility (CMS) system was planned. This breakthrough was achieved by integrating cytoplasm of wild relatives of pigeonpea with cultivated types. This resulted in the development of two good CMS sources; one at ICRISAT (Saxena et al., 2005) and another at Gujarat Agriculture University (Tikka et al., 1997). The former CMS was derived from *C cajanifolius* and designated as A_4 system; while the later source was derived from *C. scarabaoides* and designated as A_2 system. These CMS systems are stable and produce fertile hybrids. The hybrids derived from these sources are performing well both in experiment stations as well as in farmers' fields and are likely to make a positive impact on Indian agriculture.

Converting Constraint into an Opportunity

Pigeonpea has a considerable natural out-crossing (Saxena et al., 1990). The first report of this event was published by Howard et al. in 1919 but it was treated as a major constraint in breeding and maintenance of pigeonpea varieties. Since most pigeonpea farmers save their seed for subsequent season's planting and the crop exhibits tremendous variation for most economic traits. This leads to low and inconsistent yields. With the development of CMS lines the pigeonpea breeders have now converted this constraint into an opportunity to increase the yield potential of this crop through hybrids. The prime objective of this endeavor was to enhance the stagnant productivity by exploiting heterosis at commercial scale in different agro-ecological zones of the country. The pigeonpea breeders, therefore, have strong challenges and opportunities ahead of them to develop exceptionally high yielding hybrids to break the yield plateau in this pulse crop.

Like other crops, in pigeonpea also a number of stresses are known to affect its productivity. Since the realized yield in a given environment is the product of interactions of such stress factors with genotypes and other environmental factors, considerable yield variations are always observed. Considering the importance of genotype-environment interaction in determining yield, it is essential to ensure that varieties are adapted to different growing environments. This will allow varieties to express their full yield potential in specific environments. Therefore, relatively more importance should be given to breed hybrids that are adapted at regional levels. The introduction of more than one hybrid in a region will also help in maintaining the much needed genetic diversity.

GMS-based Pigeonpea Hybrids – The Starter Technology

Emphasis in breeding was to make use of natural out crossing in crop improvement and hybrids were an obvious choice. Research interests on hybrid pigeonpea were also kindled by reports of the existence of considerable magnitude of heterosis for seed yield (Solomon et al., 1957; Saxena and Sharma, 1990). An elaborate search for a male-sterility system was made in the germplasm and a breakthrough was achieved by Reddy et al. (1978), who reported plants with translucent anthers, which turned out to be a stable (ms_1) GMS source. Five years later, Saxena et al. (1983) reported another non-allelic (ms_2) source of GMS that was characterized by brown anthers. These male-sterile lines were extensively used in hybrid breeding programmes.

ICRISAT and ICAR joined hands and allocated considerable resources to achieve a breakthrough in hybrid breeding technology of pigeonpea. The outcome of this effort was the release of ICPH 8 in 1991 (Saxena et al., 1992). Evaluation of hybrid in 100 yield trials showed that it was superior to controls UPAS 120 and Manak by 30.5% and 34.2%, respectively. Subsequently, a few more GMS based hybrids were released by ICAR. In 1993, Punjab Agriculture University, Ludhiana, released a short duration hybrid PPH 4 (Verma and Sandhu, 1995) which out-yielded check variety T 21 and UPAS 120 by 47.4% and 32.1%, respectively. A year later Tamil Nadu Agricultural University, Coimbatore, released another short-duration hybrid CoH 1 (IPH 732). It recorded 32% higher yield over control VBN-1 in on-farm trials (Murugarajendran et al., 1995). In 1997, the university released its second pigeonpea hybrid CoH 2 which out-yielded CoH 1 by 13% and Co 1 by 35%. Subsequently, two more pigeonpea hybrids AKPH 4104 and AKPH 2022 were released by PDKV, Akola in 1997 and 1998, respectively. AKPH 2022, recorded 64% superiority over control BDN 2 (Wanjari et al., 1999).

The GMS- based hybrids, though high yielding, could not reach farmers' fields due to inherent constraints associated with maintenance of the male sterile line and hybrid seed production. Niranjan et al. (1998) reported that though cost of GMS- hybrid seed was within affordable limits and the hybrid advantage was also salable, but the technology itself suffers from major bottleneck, when it comes to large scale seed production.

Development of CMS Systems -- a Breakthrough

Considering the limitations in large-scale hybrid seed in production in GMS hybrids, the development of CMS became imperative. The strategy was to induce CMS by placing pigeonpea genome in wild cytoplasm through hybridization. It was believed that the interaction of wild cytoplasm with cultivated nuclear genome would produce male sterility. So far, seven such CMS systems have been bred (Table 1) in pigeonpea with varying degrees of success (Saxena et al., 2010). Of these, A_2 and A_4 systems derived from crosses involving wild relatives of pigeonpea and cultivated types have shown promise because of their stability under various agro-climatic zones and availability of good maintainers and fertility restorers.

Seed Production of Hybrids and their Parents

Availability of genetically pure seeds of improved cultivars is crucial for realizing their productivity in different agro-ecological niches. The benefit of new hybrids cannot be fully realized until sufficient quantities of genetically pure and healthy seeds are commercially produced and sold at a cost affordable to the farmers. An efficient seed production system that could provide quality seeds at economically viable costs is the backbone of any hybrid breeding technology.

Since pigeonpea exhibits natural out-crossing, a safe isolation distance is always essential to produce quality seed of parental lines and hybrids. The commercial seed production of pigeonpea involves large scale seed production of female line (A/B), restorer line (R), and hybrid (A x R) combination. Each set of material demands isolation distance of at least 500 m from other pigeonpea. For seed increase of A/B lines, breeder seed of both A- and B- lines are planted using a row ratio which ranges from 4:1 to 8:1 (female : male), depending upon the insect activity. In case of higher insect activity 8:1 ratio also gives good seed yield. In general, 4:1 row ratio gives optimum seed yield at most locations. At maturity, the B-line should be harvested first and then the pods set on the A-line be harvested. For the hybrid seed production (A x R) also, the row ratios, as in case of A x B seed multiplication, may also be variable. In this programme also the R-line should be harvested first. This will help in enhancing seed purity. Roguing and strict crop monitoring is a critical aspect of hybrid seed production and roguing should be done at seedling and flowering stages.

In 2007 rainy season, a few pilot hybrid pigeonpea seed production programmes were organized in the states of Andhra Pradesh, Madhya Pradesh, Gujarat, Karnataka, and Maharashtra. The quantity of hybrid seed produced in isolations ranged a lot. The highest A x R yield of 2267 kg ha^{-1} was recorded at Indore. A list of locations were reasonably good hybrid yields were recorded is given in Table 2. These observations indicated that the hybrid seed can be produced easily by growers. However, there is a need to understand the hybrid seed production constraints in a particular area. One of the major constraint for poor harvests could be low population of pollinating insects. This needs monitoring before investing large sums in seed production in a particular area.

Hybrid Vigour for Seed Yield

Soon after the development of stable CMS systems several experimental hybrids were produced and evaluated (Saxena et al., 2006). In multi-location trials, the performance of hybrids was encouraging. Among the short-duration hybrids ICPH 2433 recorded highest yield of 2419 kg ha^{-1} and it exhibited high levels of hybrid vigour over all the three controls used in this study. The other promising hybrids were ICPH 2438 (2377 kg ha^{-1}) and ICPH 2429 (2164 kg ha^{-1}). ICPH 2438 produced highest yield at Aurangabad (4533 kg ha^{-1}) and at Nizambad (3472 kg ha^{-1}).

Since in the medium maturing group the resistance to diseases is a primary need, a CMS line ICPA 2043 was developed through backcrossing and the new hybrid combinations were made by crossing known disease resistant restorer lines. Among the medium-duration hybrid Kandalkar (2007) found that CMS-based hybrids recorded standard heterosis up to 156% for grain yield; whereas Saxena et al. (2006) reported yield advantage of 50 to 100% over the popular varieties and local checks. The data (Table 3) indicated that all the hybrids had high levels of resistance to wilt and sterility mosaic diseases. The best hybrid was ICPH 3371 with 3013 kg ha^{-1} yield (62% gain) and no disease incidence. The other promising hybrids in this group were ICPH 3491 (57% superiority), ICPH 3497 (44% superiority), and ICPH 3481 (41% superiority).

The most promising two medium-duration hybrids

GTH-1

The first CGMS based pigeonpea hybrid, GTH-1 was developed at S D A U, S K Nagar, and released by ICAR in 2004 for cultivation in Gujarat state. Parents of this hybrid are GT 288 A (CMS line/female with cytoplasm of *Cajanus scarabaeoides*) and GTR-11 (restorer/male). Based on yield trials during *kharif* season of 2000 to 2003 (Table 4), GTH 1 (1830 kg ha^{-1}) gave 57.40% yield superiority over the best GMS hybrid AKPH 4101 (1183 kg ha^{-1}) and 32% yield superiority over the best local variety, GT 101 (1330 kg ha^{-1}). This hybrid is early in maturity duration (140 days) and very much stable for its fertility restoration. Its flowers are yellow in colour, plant type is indeterminate and seeds are large and white. In multi-locational trials (IHT and AHT). This hybrid gave the highest yields in Central Zone. This hybrid has new been identified and released for cultivation in Central Zone of the India.

Front-line demonstrations:

Front-line demonstrations conducted during kharif 2003 (Table 5) have shown that hybrid GTH-1 gave 25.3% more yield over popular pure line the varieties. Considering the price of pigeonpea grain (Rs.1500/q) additional income of Rs. 7770/ ha was obtained by the farmers by replacing the varieties with this hybrid.

ICPH 2671

Among the available CMS-based hybrids ICPH 2671 is in the advance stages of testing. This hybrid has been found stable for its fertility restoration at all the places where it was tested in the last three years. ICPH 2671 is indeterminate in growth habit with spreading branches. Its flowers are yellow with dense red streaks. The pods are purple in colour. It flowers in 116-120 days and the maturity is achieved in about 180 days. ICPH 2671 is highly resistant to fusarium wilt and sterility mosaic diseases. ICPH 2671 produces commercial seed with dark brown colour and 100-seed weight of 10.8 to 11.2 g. ICPH 2671 was evaluated in multi-location trials during 2005 to 2008 (43 trials) and on an average, it recorded 35.8% superiority over the pure line variety Maruti (Fig 2).

On-farm trials: On-farm validation of newly-bred genotypes is essential to evaluate its performance in large plots under farmers' field conditions. ICRISAT in collaboration with ICAR conducted 923 such trials over three years (Table 6). The plot size for there trials varied for 0.2 to 0.4 hectares. The superiority of hybrid over the years varied from 23-37%. In 2008, these on-farm trials were conducted under both pure as well as intercrop situations (Table 7) and pigeonpea – soybean gave the highest yield advantage (93%) over pure line control variety. In pigeonpea – groundnut and pigeonpea -cotton combinations, the yield advantage of hybrid was 18% and 13%, respectively.

Advantages of Hybrids

Hybrid cultivars in cereals (maize, sorghum, and rice), oilseeds (sunflower), and vegetables (tomato, brinjal etc.) have revolutionized their productivity worldwide. Hybrid pigeonpea also shares the advantages over varieties in the following areas:

- **Increased grain yield:** Results of the trials conducted over three years and several locations indicated that sufficient local of heterosis is available in pigeonpea. The details about the subject are discussed in sections 7 and 8.

- **Enhanced seedling vigour:** Hybrid pigeonpea plants produce substantially greater biomass than those of pure line varieties of the comparable duration. Hybrids utilize inputs such as sunlight, water, and nutrients more efficiently, while maintaining their partitioning at par with the pure lines leading to higher grain yield. In an experiment conducted at ICRISAT, 30-days old seedlings produced 44% more shoot mass and 43% more root mass compared to the pure line cultivars (Saxena et al., 1992). The faster growth rate of hybrid plants help the crop in its initial establishment and development of its canopy much faster than pure lines. This makes hybrids more competitive to weeds and inter-crop situations.

- **Reduced seed rates:** Pigeonpea hybrids produce more number of primary and secondary branches with wider canopy. Results from the agronomic trials conducted at ICRISAT indicated that hybrids exhibit greater plasticity at plant populations ranging from 16 to 66 without adversely affecting the seed yield. This suggests that seed rate of hybrids can be reduced by 40 - 50% without loosing yield per unit area. Reduced seed rate will offset the higher seed cost which the farmer may have to incur while purchasing hybrids.

- **Greater drought tolerance:** Hybrid pigeonpea, by virtue of its greater root mass and depth, have greater ability to draw water from deep soil profiles. This also helps hybrids to tide over intermittent drought conditions prevailing during different phases of growth.

- **Greater disease resistance:** Results of limited experiments show that hybrids offer more resistance to disease attack than pure lines by virtue of their greater resilience (Saxena et al., 1992). Also the hybrids recover faster and assimilate greater biomass. Evaluation of a few wilt and sterility mosaic resistant pigeonpea hybrids and pure line cultivars in disease free and sick plot conditions indicated that under sick conditions in hybrids and pure lines, the level of disease resistance expressed was high with <1% incidence. However, under disease sick and disease free conditions the hybrids vigour differed grossly. The hybrids exhibited an average of 19.7% superiority over pure line cultivars under disease free conditions, while the level of superiority of the hybrids was enhanced to 60% under disease sick conditions. Hence, it is interpreted that in addition to the specific anti-fungal resistance mechanisms, the hybrids have an extra degree of genotypic plasticity which helps them to tolerate and produce higher yields under stress conditions compared to the pure lines. In general the hybrids in most crops express better environmental buffering capacity compared to pure line cultivars. The yield fluctuations brought about by various biotic and abiotic stresses could be reduced by introducing hybrids.

Taking Pigeonpea Hybrids to Indian Farmers

We believe that the CMS-based hybrid pigeonpea technology is ready for delivery. Sometimes a fine-tuning of seed production technology may be needed to suit different environments. The extensive testing of hybrids has demonstrated that the hybrids have greater yield potential. Now, our major responsibility is to take this package to our clients- the farmers. We expect that both small and big holder farmers will show interest in the hybrids. However, since pigeonpea is predominantly cultivated by small farmers, we need to keep the seed costs within the reach of these resource-poor farmers. In India, both public and private seed sectors are strong, and therefore, we have to improve accessibility of hybrid seed to farmers. There is a need to work together in transferring the technology to the farmers.

Evolution of business partnerships: The enactment of new seed policy in 1988 encouraged private sector to engage in seed-related research and development. Following this liberalization, the annual investment of private sector in Indian seed industry increased from US $ 1.2 million in 1987 to US $ 4.7 million in 1995 (Ramaswami et al., 2001). The partnership between ICRISAT and private seed sector seed companies has evolved over time. In the early years, ICRISAT played a nurturing role to the fledgling industry through informal networks. As private seed industry grew, the private sector also became a major channel for delivering high yielding hybrids to farmers.

Strategies for R & D of Hybrid Pigeonpea

The following areas are to be emphasized for planning and implementing a dynamic hybrid pigeonpea breeding programmes.

1. Diversify hybrid parents and develop high yielding hybrids for specific agro-ecological regions.

2. Incorporate resistances to biotic and abiotic stresses, especially wilt, sterility mosaic, phytophthora, and pod borers.
3. Fine tune the hybrid seed production technology for increased efficiency and develop parameters for seed quality assessments of hybrids and parents.
4. Expand research and development base involving NARS and public and private sector.
5. Encourage capacity building of partners in hybrid pigeonpea research and development.
6. Conduct agronomy research for increased productivity.
7. Use biotechnological tools including molecular markers to enhance hybrid breeding efficiency.

Potential Role of Hybrids in Enhancing National Pigeonpea Productivity

To achieve quantum jump in pigeonpea productivity, and has remained low and unchanged for decades. Now a good beginning has been made by ushering into an era of hybrids. The results obtained so far have clearly demonstrated (Table 4 - 7) that in pigeonpea commercial exploitation of hybrid vigour is feasible and advantageous. In 2009, some very exciting results have been obtained from the on-farm trials conducted in Amravati and Yavatmal districts of Maharastra, where three farmers harvested a record yield of over 4 tons ha^{-1}on their farms (Table 8). One of the farmers in Medak district of Andhra Pradesh harvested 33 quintal per ha of grains from his three hectare plot and fetched the profit of over Rs. 83000/- ha. This data clearly showed that the hybrid technology has a potential of breaking the barrier of stagnant yield in pigeonpea. The development of stable CMS systems in pigeonpea is a boon to the breeders and it has provided a platform to enhance the pace of research and development of hybrid pigeonpea. At present both ICRISAT and ICAR are actively involved in technological improvement and its transfer to various developmental agencies. We believe that the ice has already been broken and now it is just a few steps more when the commercialization of pigeonpea hybrids would be a reality in India.

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Fig. 1: Trends of area, production, and productivity of pigeonpea in India in the last five decades.

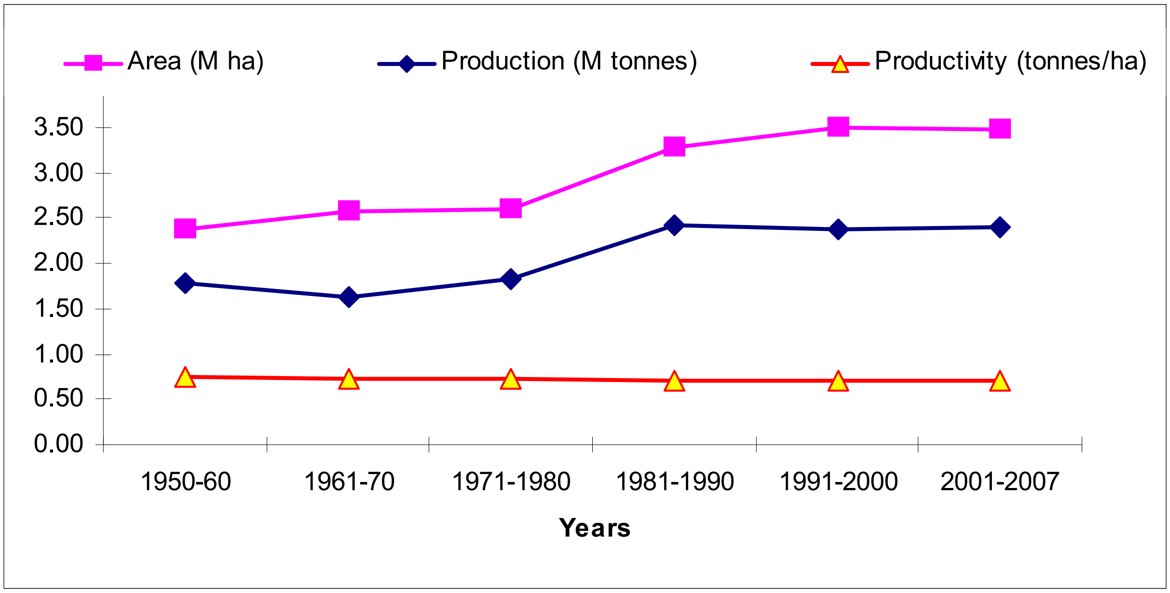

Fig. 2: Performance of hybrid ICPH 2671 in multi-location trials.

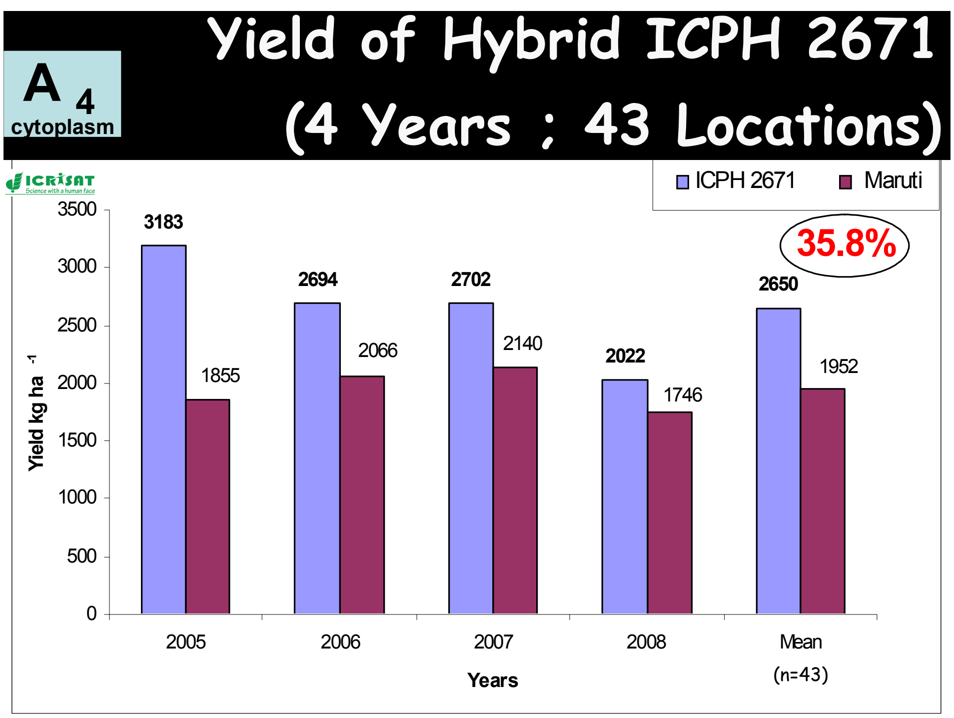

Table 1. List of CMS sources derived from different wild relatives of pigeonpea.

Sl. No.	Wild relative	Designation
1	*C. sericeous*	A_1
2	*C. scarabaeoides*	A_2
3	*C. volubilis*	A_3
4	*C. cajanifolius*	A_4
5	*C. cajan*	A_5
6	*C. lineata*	A_6
7	*C. platycarpus*	A_7

Source: Saxena et al. (2010)

Table 2. Seed production of hybrid ICPH 2671 (A x R) in different locations 2007.

State	Village	Area sown (ha)	Seed yield (kg)	Productivity (kg ha^{-1})
Andhra Pradesh	Shadnagar	1.6	1400	875
	Gadivemula, Nandyal	1.6	1000	625
Andhra Pradesh	Alamur,Nandyal	1.6	10000	625
Andhra Pradesh	MK Puram, Nandyal	1.2	1000	833
Andhra Pradesh	Manapur, Ghanapur	1.2	1275	1063
Andhra Pradesh	Yallur	1.0	1000	1000
	Patancheru	0.4	500	1250
Andhra Pradesh	Medchal	0.4	500	1250
Andhra Pradesh	Eluru-1	1.2	750	625
Andhra Pradesh	Eluru-2	1.2	750	625
Andhra Pradesh	Eluru-3	1.6	1146	716
Andhra Pradesh	Renjal	0.4	700	1750
Andhra Pradesh	Manoharabad	0.68	856	1258
Madhya Pradesh	Indore	0.15	340	2267
Gujarat	Ahmedabad	0.80	850	1063

Table 3. Performance of some new medium-duration disease resistant hybrids at Patancheru.

Hybrid	Yield (kg ha^{-1})	Days to		Seeds pod^{-1}	100-seed mass (g)	Superiority over Asha (%)	Disease reaction (%)	
		flower	mature				Wilt	SM
ICPH 3371	3013	129	187	4.1	11.5	62	0	0
ICPH 3491	2919	129	191	4.2	13.4	57	0	0
ICPH 3497	2686	131	191	4.0	10.9	44	0	15
ICPH 3481	2637	128	185	3.9	11.6	41	0	0
ICPH 3494	2586	123	184	4.0	12.4	39	0	9
ICPH 3477	2497	128	186	4.1	12.6	34	6	0
ICPH 3492	2496	128	186	4.3	12.7	34	0	0
ICPH 3359	2483	131	191	3.8	11.3	33	0	8
ICPH 3486	2479	129	187	3.9	9.3	33	0	0
ICPH 3363	2385	128	187	3.8	12.9	28	0	0
Asha (ch)	1864	129	189	3.8	11.1	-	0	0
SEm	±205.7	± 0.9	± 1.0	± 0.12	± 0.33			
Mean	2448.1	127.8	187.1	4.03	11.70			
CV (%)	11.9	1.0	0.8	4.19	3.98			

Table 4. Performance of pigeonpea hybrid GTH-1 in comparison to check hybrid (AKPH 4101) and check variety (GT 101) in Gujarat state during *Kharif* 2000 to 2003

Season & Year of testing	Name of Trial	Location of trial	Grain Yield of Hybrids / Varieties (Kg/ha)			
			GTH-1	AKPH 4101 (Ch.)	GT-100 (Ch.)	Gt-101 (Ch.)
Kharif - 2000	PHT	S K Nagar	2827	1224	1218	-
		Mean	2827	1224	1218	-
Kharif - 2001	SSHT	S K Nagar	1852	1279	1431	-
		Ladol	644	679	707	-
		Anand	450	825	770	-
		Mean	982	928	969	-
Kharif - 2002	LSHT	S K Nagar	2057	1543	-	1381
		Anand	2106	1759	-	1562
		Bharuch	1906	1662	-	1759
		Vadodara	849	548	-	540
		Derol	2547	1666	-	1782
		Navsari	2346	1698	-	2022
		Mean	1969	1479	-	1508
Kharif - 2003	LSHT	S K Nagar	2537	1444	-	1620
		Bharuch	1144	1130	-	1017
		Vadodara	1111	868	-	910
		Junagadh	2516	2161	-	2344
		Derol	938	608	-	573
		Navsari	1013	390	-	448
		Mean	**1543**	**1100**	**-**	**1152**
Overall Mean			**1830**	**1183**	**1094**	**1330**
Mean (2000 -01)			**1905**	**-**	**1094**	**-**
Mean (2002 -03)			**1756**	**-**	**-**	**1330**
% increase over			**-**	**54.70 (Overall)**	**74 (2000-01)**	**32 (2002-03)**

Table 5. Performance of GTH-1 in Front line demonstrations in *Kharif* 2003

Technology developed	Village	Grain yield (Kg ha^{-1})		% increase of hybrid
		Variety	GTH-1	
CGMS based pigeonpea hybrid GTH-1	Bolundra, Sabarkantha	2150	2800	30
	Dhota, Banaskantha	2210	2650	20
	Kamalpur, Mehsana	1580	2680	69
	Deodar, Banaskantha	2045	2563	25
	Mean	**1996**	**2673**	**33.9**

Table 6. Performance of hybrid ICPH 2671 in on-farm trials in Maharashtra state, 2007-2009.

Year	**Trials**	**Area (ha)**	**Plot size (ha)**	**Hybrid Yield (kg/ha)**	**% Gain**
2007	29	13	0.2 to 0.4	1783	29
2008	782	261	0.2 to 0.4	1025	37
2009	112	43	0.2 to 3.2	1400	23
Total/Mean	923	317	-	1403	30

Table 7. Performance of hybrid ICPH 2671 in OFT's 2008 in different cropping systems.

System	No. of demos.	Area (ha)	Yield (kg ha^{-1})		% Increase
			Hybrid	Maruti	
Sole	637	220	1120	913	23
PP + Maize	87	17	829	598	39
PP + Soybean	29	12	1250	648	93
PP + Cotton	21	8	730	648	13
PP + Groundnut	8	3	916	779	18
Mean	782	261	969	717	37

Table 8. Record yields produced by hybrid pigeonpea farmers in Amravati and Yavatmal districts of Maharashtra in 2009.

Name & Village	Hybrid Name	Area (m^2)	Yield (kg ha^{-1})		% Gain
			Hybrid	Check	
SB Kale, Salod	ICPH 2671	450	3956	2044	94
PK Satav, Nimgaon	ICPH 2671	1012	3951	2469	60
DV Chopde, Kothoda	ICPH 2671	450	4667	3556	31
YS Shrotri, Tamoli	ICPH 2671	450	3889	2278	71
RK Warekar, P'Kawada	ICPH 2740	450	4148	2963	40
VB Kadam, Tamoli	ICPH 2740	338	4444	2667	67
BK Warekar, P'Kawada	ICPH 2740	338	4444	2963	50
Mean			4214	2706	56