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RECENT DEVELOPMENTS IN HYBRID PIGEONPEA RESEARCH

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Abstract

Pigeonpea is a partially cross-pollinated crop with genetic male sterility. These characteristics of pigeonpea have been exploited at ICRISAT Center to develop high yielding hybrids. The feasibility research has revealed that for seed yield, a significant exploitable level of heterosis is present and commercial hybrid seed production in short-duration hybrids is possible. This paper describes recent developments in hybrid pigeonpea research at ICRISAT Center. The data indicate that some short-duration hybrids have a yield potential of over 5000 kg/ha, pointing to a possible breakthrough in pigeonpea yields. Physiological studies showed that increased yield in the hybrids were primarily related to its increased growth rate and biomass production. Experiments have also shown that the hybrids possess a high level of drought tolerance, thereby imparting yield stability in droughted environments.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.], a protein rich subsistence pulse crop of tropical and sub-tropical regions, is among the most important grain legumes in the diet of the people of India. Attempts to improve this crop through breeding started early in this century. Although several selections from hybridization have been identified, even today most of the adapted cultivars are land races or selections from these land races. In experimental plots, it is possible to obtain single harvest yields of these cultivars in the vicinity of 4000 kg/ha, although yields in traditional farming systems remain around 600 kg/ha due to various abiotic and biotic constraints. Recent breeding efforts have incorporated resistance to major diseases(e.g. fusarium, wilt, sterility mosaic) into potentially high yielding adapted cultivars, which could substantially help in reducing this yield gap. However, little progress is apparent in this regard.

Pigeonpea is a partially cross-pollinated crop and traditionally, additive genetic variation has been exploited through pedigree selection for developing high yielding pure lines in different maturity groups. A review of the quantitative genetic studies in pigeonpea by Saxena and Sharma(1990) shows the presence of a substantial level of non-additive genetic variation for yield which can be exploited profitably through heterosis breeding to obtain a quantum jump in grain yield. The recently identified sources of stable genetic male sterility (Reddy *et al.* 1978, Saxena *et al. 1983*) and the presence of partial natural out-crossing have made it possible to explore this potential breeding avenue in pigeonpea. At ICRISAT Center, considerable research efforts have been devoted for identifying heterotic cross combinations and developing economic

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hybrid seed production systems for pigeonpea. This paper discusses the prospects of practical heterosis breeding and some physiological aspects of pigeonpea hybrids.

Pre-requisites for practical heterosis breeding

For any viable commercial hybrid seed production programme there are two pre-requisites, sufficient natural out-crossing and stable male sterile systems. In pigeonpea, natural out-crossing was first noticed by Howard *et al.* (1919) but its utilization in a hybrid breeding programme was ruled out (Royes 1976, Singh 1974) mainly due to the non-availability of male sterility. However, these two necessary mechanisms are now available and this has opened up the possibility of developing hybrids in this crop.

Natural out-crossing

In pigeonpea natural out-crossing takes place as a result of frequent insect visits from one flower to another within and across the fields. Onim (1981) listed 24 species of insects which are capable of effecting cross-fertilization in pigeonpea. Of these, *Megachile* sp. and *Apis mellifera* are the main pollinating vectors (Onim 1981, Williams 1977). Howard *et al.* (1919) were the first to report 14 per cent natural out-crossing in pigeonpea and later several reports have appeared in literature from India and elsewhere (Saxena *et al.* 1990). Studies at ICRISAT have shown that this level of natural out-crossing is sufficient for economic hybrid seed production in pigeonpea.

Male sterility

Two sources of stable genetic male sterility have been reported. One source is characterized by translucent anthers (Reddy *et al.* 1978) and another by dark brown arrow-head shaped anthers (Saxena *et al.* 1983). Male sterility in each of these sources is governed by a non-allelic single recessive gene pair (Saxena *et al.* 1983) and therefore, should be maintained as a heterozygote by harvesting seeds from male sterile plants pollinated by fertile heterozygotes. The prominent anther characteristics in these male steriles provide an effective and easy way of identifying male sterile plants in the field before anthesis.

Yield advantage in hybrids

Production and testing of experimental pigeonpea hybrids for the identification of heterotic cross combinations began at ICRISAT in 1977. The seeds for these experimental hybrids were produced by hand pollinating the male sterile plants. Saxena *et al.* (1986) have summarized the performance of some medium-duration experimental hybrids tested during the years 1977-1981. Standard heterosis (superiority over a control cultivar) for seed yield in different crosses varied from 38.3 to 39 per cent. Of the 106 combinations tested, 9 showed heterosis of more than 20 per cent. The best hybrid (ICPH 2) recorded 32 per cent superiority over the control cultivar. This hybrid performed well in multilocational trials also. In All

India Coordinated Trials, conducted over 7 locations in 1980, ICPH 2 out yielded the standard control by 23 per cent. In 1981 (8 locations) and 1982 (16 locations) this advantage declined to 11.1 and 6.4 per cent respectively over the control. This reduction in the performance of ICPH 2 was due to its high susceptibility to wilt disease (Saxena *et al.* 1986). Therefore, in spite of the high performance, ICPH 2 hybrid was withdrawn from further testing before reaching farmers' fields. However, its performance demonstrated the presence of exploitable hybrid vigour in pigeonpea. It also showed that, in medium-duration hybrids resistance to major diseases such as wilt and sterility mosaic is essential for yield stability.

Since short- duration pigeonpea is becoming important because of its ability to fit into a wide variety of cropping systems and its adaptation to higher latitudes, emphasis in the pigeonpea breeding programme at ICRISAT has shifted towards developing short-duration hybrids. To achieve this, the two male sterile genes have been successfully transferred into promising short- duration genotypes (Saxena *et al.* 1986, Saxena *et al.* 1991). Presently at ICRISAT about 200 short- duration experimental hybrids are made every year using four newly converted male sterile lines. As expected, the level of standard heterosis in various cross combinations varied greatly. The superiority of some promising experimental hybrids over the best check cultivar is given in table 1. Some of the hybrids such as IPH 495, 526, 583 and 732 yielded over 5000 kg/ha, pointing towards a possible breakthrough in yield potential of pigeonpea. These yields were obtained from small plot size (2.16 m^2) and therefore,

Table 1. Performance of some short -duration pigeonpea hybrids at ICRISAT Center during 1988 rainy season.

Hybrid	Days to mature	Yield (kg/ha)
IPH 495	115	5000
IPH 503	113	4822
T 21 (C)	121	2431
UPAS 120 (C)	109	2431
SE	±1.1	±714
CV (%)	1.5	32
IPH 526	116	5282
IPH 540	111	4767
UPAS 120 (C)	107	2435
T 21 (C)	109	2151
SE	± 1.1	± 520
CV (%)	1.3	22
IPH 583	122	5326
IPH 656	127	4815
ICPL 161 (C)	131	2786
UPAS 120 (C)	109	1987
SE	± 1.2	± 838
CV (%)	1.5	36
IPH 732	129	5591
IPH 719	117	4691
T 21 (C)	124	2869
UPAS 120 (C)	109	1760
SE	± 1.2	± 679
CV (%)	1.4	26

Table 2. Grain yield of short-duration pigeonpea hybrid ICPH 8 and control cultivars in different zones over years.

Zone	Trial	Year	No. of trials	Yield (kg ha^{-1})			% increase over	
				ICPH 8	UPAS 120	Manak	UPAS 120	Manak
North West plains	EACT[a]	1987-88	5	1889	1486	—	27.1	—
	EPHYT	1984-85	4	2626	2239	2416	17.3	8.7
	EPHYT	1985-86	2	3152	1866	2689	68.9	17.2
	EPHYT	1987-88	4	2392	1913	1811	25.0	32.1
	Station	1981-82	1	3900	2225	—	75.3	—
	Trials	1983-84	1	3560	2569	2715	38.6	31.1
		1984-85	2	3952	2738	2717	44.3	45.4
		1985-86	2	1742	1463	—	19.1	—
		1986-87	7	2953	2114	2137	39.7	38.2
		1987-88	8	3411	2479	2523	37.6	35.2
Zonal weighted mean			30	2851	2100	2342	35.0	31.0
Central	EACT	1986-87	10	829	640	609	29.5	36.1
	EACT	1987-88	4	2171	1556	—	36.7	—
	EPHYT	1984-85	8	2315	1730	1284	33.8	80.3
	EPHYT	1985-86	4	1193	929	841	28.4	41.9
	EPHYT	1987-88	3	1500	1147	1047	30.8	43.3
	EPHYT	1986-87	1	2134	1270	1312	69.1	63.6
Zonal weighted mean			30	1558	1163	930	32.9	52.5
South	EACT	1986-87	4	695	439	347	58.3	100.8
	EACT	1987-88	2	861	650	—	32.5	—
	EPHYT	1984-85	3	1421	1035	824	37.3	72.5
	EPHYT	1985-86	3	1529	1305	1377	13.5	2.1
	EPHYT	1987-88	3	1311	1182	1272	10.9	3.1
	Station	1985-86	1	1493	1301	—	14.8	—
	Trials	1986-87	3	1813	1079	1510	68.0	20.1
		1987-88	11	1676	1666	1613	0.6	3.9
Zonal weighted mean			30	1422	1216	1262	23.6	27.3
North West Hill	EACT	1986-87	2	1564	1499	1194	4.3	31.0
North West Hill	EACT	1987-88	1	1679	1153	—	45.6	—
West	EACT	1986-88	1	2057	1413	1588	45.6	29.5
Overall weighted mean			100	1989	1525	1354	30.5	34.2

a. EACT = Extra-early Arhar All India Coordinated Trial
EPHYT = Early Pigeonpea Hybrid Trial

may have been over-estimated to some extent. Yet, a clear superiority of the hybrids over the control cultivars, grown under the similar conditions, was evident.

Among the short-duration hybrids developed at ICRISAT Center, ICPH 8 appears to be the most promising. Saxena *et al.* (1989) summarized the performance of this hybrid in 100 yield trials conducted in diverse environments from 1981 to1987 (Table 2). In north-west plains of India, ICPH 8 was evaluated in 36 trials and on average the hybrid (2851 kg/ha) was found to be 35 per cent superior over UPAS 120 (2100 kg/ha) and 31 per cent superior over Manak (2342 kg/ha). In the central zone the hybrid 1558 kg/ha) expressed 33 per cent and 53 per cent superiority over UPAS 120 and Manak, respectively. In the 30 yield trials conducted in southern zone, ICPH 8 was 24 per cent superior to UPAS 120 and 27 per cent over Manak. Over all the trials conducted in different zones the superiority of the hybrid over UPAS 120 was 31 per cent and over Manak 34 per cent.

The degree of superiority expressed in the experimental hybrids shows that a high level of heterosis is present in this crop which could be encashed by adopting appropriate breeding procedures.

Hybrid seed production systems

For producing large quantities of hybrid seed of selected cross combinations, the male sterile and pollen parents must be grown in isolation. On account of the wide range of out-crossing among pigeonpea genotypes reported (Saxena *et al.* 1990), the isolation specifications are also equally variable. The FAO (Agric. Series No. 55), however, recommends an isolation distance from a minimum of 180 m to a maximum of 360 m (Ariyanayagam 1976). No information is available on isolation requirement for male sterile genotypes. However our experience of ICRISAT center indicates that a distance of 150 to 200m is safe for hybrid seed production and maintenance of male sterile lines in pigeonpea.

Experiments conducted at ICRISAT Center indicated that full seed set is obtained if one fertile row is planted after each six male sterile rows (Saxena *et al.* 1986). Since male sterility in pigeonpea is genetic in nature, manual labour for roguing of fertile segregants within the male sterile rows is required. For this the first bud that appears on each plant must be opened and the male sterile plants tagged, while the fertile segregants must be rogued out before anthesis. In the absence of sufficient pod load in the beginning of the reproductive phase, the sterile plants continue to flower for a considerable period. In the pollinator rows, where flowering stops after its full potential pod-set is achieved, the flowering stage can be maintained by periodic removal of immature pods and providing irrigations. Thus the flowering period of the parents can be increased and even with a low population of pollinating insects sufficient hybrid seed can be obtained. It is possible to produce more than one hybrid in a

Table 3. Multiple harvests of cross-pollinated seed of hybrid ICPH 8 in a seed production isolation block at ICRISAT Center during 1985-86 season.

Harvest number	Date of harvest	Seed yield (kg/plot)
1	October 19, 1985	28.0
2	November 25, 1985	24.5
3	January 22, 1986	7.3*
4	March 10, 1986	13.3
	Total	73.1

* High pod fly damage

Area	: 0.11 ha
Planting date	: June 25, 1985
Spacing	: 75 X 25 cm
Ratio	: 1 Male : 6 Female

single isolation block by using a common male parent and more than one male sterile lines with similar flowering behaviours.

For hybrid seed production, identification of fertile sibs at an early flowering stage is costly but essential. The problem could be solved if there were some marker genes closely linked with the male sterile gene, as reported in lettuce (Lindquist 1960) and watermelon (Watts 1962). At present no such linked marker is known in pigeonpea.

Under conducive environments, the pigeonpea plants can produce several flushes of pods within a season in a multiple harvest system (Chauhan *et al.* 1987). The perennial nature of this crop can also be exploited profitably to produce quality hybrid seed at low cost. At ICRISAT, in an experiment designed to assess the feasibility of multiple harvests of cross-pollinated seeds in the 1985/86 season, four harvests were taken within a cropping season (Table 3). In a 0.11 ha hybrid seed production block of ICPH 8, a total of 73 kg of hybrid seed was harvested from four pickings, thus reducing the cost of hybrid seed production substantially by eliminating the need to rogue fertiles from the sterile rows in subsequent crops. The same seed production nursery can be left for use in the following year(s). However, the plants under this system should be ratooned at a manageable height as they will grow 3-4 meters tall making insect control and harvesting very difficult. This system, however, can be applied only in frost and disease free conditions or with disease resistant parental lines. Recently a joint study has been initiated by ICRISAT and Tamil Nadu Agricultural University (Coimbatore) on the cost of hybrid seed production in pigeonpea. The data indicated that in a single harvest one kilogram of seed was produced at the cost of Rs. 6.25 (Murugarajendran, *et al.* 1990)

Physiological basis of hybrid vigour

Understanding the physiological basis of heterosis is important as it will not only help in rapid identification of heterotic cross combinations but also in the development of improved varieties. In pigeonpea, such an information has been lacking. To determine the physiological basis of heterosis in hybrids, the growth and yield characteristics of the hybrid ICPH 8 were compared with its parents and other short-duration genotypes at Gwalior, Hisar and Patancheru. The maximum advantage in the yield of the hybrid was seen at Gwalior where it yielded 76 per cent more than the best parent (Fig. 1). The increased yield of hybrid was

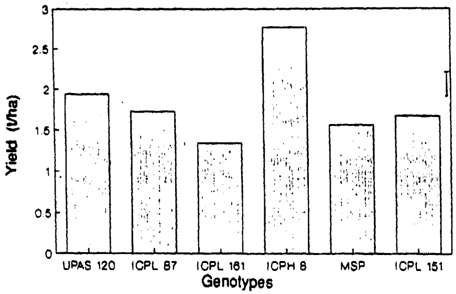

Fig. 1 Seed yield of six short-duration pigeonpea genotypes (1 = UPAS 120; 2 = ICPL 87; 3 = ICPL 161; 4 = ICPH 8; 5 = MS Prabhat; 6 = ICPL 151) Gwalior, rainy season 1986/87

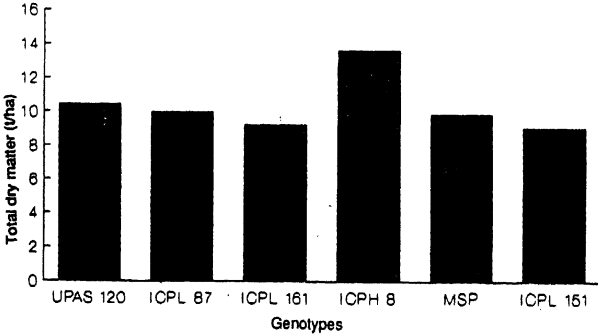

Fig. 2 Biomass production of six short-duration pigeonpea genotypes (1- = UPAS 120; 2 =-ICPL 87; 3=ICPL 161; 4 = ICPH 8; 5=MS Prabhat; 6= ICPL 151) Gwalior, rainy season 1986/87