Hybrid pigeonpea: Accomplishments and challenges for the next decade

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Abstract: Release of the world's first commercial pigeonpea hybrid is considered a milestone in the history of legume breeding. At present three commercial hybrids with yield advantages of 30 -50% are available. This has been possible due to success breeding of (i) a stable CMS system, (ii) quality fertility restorers, and (iii) standardized seed production technology. To sustain the achievements of this breakthrough, it is essential that superior hybrids are bred at regular intervals. In this communication an attempt has been made to highlight the achievements of hybrid breeding and consolidate strategies to develop new high yielding hybrids and their seed technology using the latest breeding and genomics tools.

Key words: hybrid, male sterility, new approaches, pigeonpea, seed production

Introduction

Although the green revolution saved millions from hunger but it is also considered responsible for pushing pulses in the corner as far as their research and development is concerned, resulting in the stagnation of production and productivity. Pigeonpea (*Cajanus cajan* (L.) Millsp.) also suffered during this phase and its decade-old productivity stagnation has now become a serious concern. Releasing the first ever commercial pigeonpea hybrid represents a breakthrough towards genetic enhancement of yield. This note briefly discusses the major accomplishments achieved in breeding hybrids and strategies to sustain this momentum in the next decade.

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Accomplishments

Hybrid technology. Development of hybrid technology started at ICRISAT in 1974 from scratch and it involved breeding of three major components - a cytoplasmic-nuclear male sterile (CMS) line, its maintainer, and fertility restorers. Besides this, information on seed production, genetic diversity, and quantum of hybrid vigor was also generated. The CMS system was developed by integrating nuclear genome of cultivated type into the cytoplasm of a wild species (4). The fertility restorers were identified from germplasm (7). Large scale hybrid seed production studies revealed that it is easy but needs insect pollinators. The on-farm validation at 94 locations, on average produced 1019 kg ha^{-1} of hybrid seed (Table 1). With the recommended seeding rate of 5 kg ha^{-1}, a healthy seed-to-seed ratio of 1 : 200 was achieved. Since in pigeonpea hybrid quality cannot be judged through grow-out tests, molecular markers (SSR) based purity tests were successfully developed and deployed (1, 5).

The first hybrid. The first commercial pigeonpea hybrid ICPH 2671, produced by crossing ICPA 2043 with ICPR 2671, was released in 2010 (6). In 21 multi-location trials it recorded 47% superiority over the check. In All India Coordinated Trials, the hybrid (2564 kg ha^{-1}) was 31% superior to the control. ICPH 2671 is highly resistant to diseases and tolerant to drought and water-logging. In the on-farm trials (Table 2) conducted in Maharashtra (782 trials), Andhra Pradesh (399 trials), Karnataka (184 trials), Madhya Pradesh (360 trials), and Jharkhand (288 trials) ICPH 2671 recorded 30% - 60% superiority over the best local cultivar. Overall, in all five states, ICPH 2671 was 46.6% better than the check in its productivity. Recently, two hybrids, ICPH 3762 (8) and ICPH 2740 (10), have also been released in India and these have also recorded > 30% yield advantages over the control in farmers' fields. The performance data of the three hybrids have shown that high yields can be achieved and the persistent yield plateau in pigeonpea can be smashed.

Table 1. The first pigeonpea hybrid (A × R) seed yields (kg ha^{-1}) recorded for ICPH 2671 in six Indian states

State	Locations	Highest yield	Mean yield
Andhra Pradesh	34	1750	998
Gujarat	4	1669	1179
Karnataka	2	1900	1138
Madhya Pradesh	9	3040	1674
Maharashtra	5	1017	603
Odisha	40	1040	523
Total / mean	94	-	1019

Table 2. Performance of pigeonpea hybrids (yield, kg ha^{-1}) in the on-farm trials conducted in different Indian states

Hybrid	State	Farmers (no.)	Hybrid yield	Control yield	Standard heterosis (%)
ICPH 2671	Andhra Pradesh	399	1411	907	55
	Karnataka	184	1201	951	26
	Jharkhand	288	1460	864	69
	Madhya Pradesh	360	1940	1326	46
	Maharashtra	782	969	717	35
	Total/mean	2013	1396	953	46
ICPH 2740	Andhra Pradesh	47	1999	1439	39
	Gujarat	40	1633	1209	35
	Maharashtra	230	1525	975	56
	Madhya Pradesh	13	1814	1217	49
	Total/mean	330	1743	1210	44

Table 3. Demonstration of exceptionally high yields (kg ha^{-1}) of pigeonpea hybrids by some farmers under irrigation in the Indian state of Maharashtra

Locations	Area (m^2)	Hybrid yield	Control yield	Gain (%)
Kothoda	450	4667	3556	31
Nimgaon	1012	3951	2469	60
Salod	450	3956	2044	94
Tamoli	450	3889	2278	71
Mean	-	4116	2587	59

The challenges and strategies

The hybrid pigeonpea technology is now established and taking it to the doorsteps of the farmers is the biggest challenge before us. The extensive on-farm testing of hybrids in seven states has given positive signals to farmers about the potential of hybrids and their demand is on increase. Therefore, issues related to seed availability need attention from all corners. In this context, it is essential to convince both public and private companies about the financial viability of this technology. Therefore, besides interacting with them, on-farm seed production programs should be organized at strategic locations. In addition, to achieve maximum profitability suitable agronomic interventions should to be disseminated among farming community.

To meet important research challenges aimed to double the hybrid yields and improve the efficiency of production technology in the next decade, the key approaches are briefly outlined in the following passages.

Diversify hybrid parents. This is most important factor in breeding hybrids. The historical outbreak of southern corn leaf blight disease in the USA (11) gave a strong lesson to breeders about the significance of cytoplasmic diversity in hybrid breeding. In pigeonpea only two cytoplasm sources have been used and it necessitates breeding of more CMS lines with greater cytoplasmic diversity. For new male parents the primary gene pool of pigeonpea should be exploited. High frequency of fertility restoring genes in the germplasm (7) will benefit the program. Besides this, crossable wild relatives should also be used to generate diverse fertility restorers.

Establish heterotic groups. Grouping of germplasm into diversity-based heterotic groups is of immense value. So far in pigeonpea only seven heterotic groups based on hybrid performance have been reported by Saxena and Sawargaonkar (3) and they suggested crossing between diverse groups for achieving greater heterotic effects for seed yield. To avoid G × E effects in establishing heterotic groups, it is proposed that in future the potential germplasm should be classified on the basis of diversity information generated through both traditional as well as genomic approaches.

Explore temperature sensitive male sterility (TGMS). The 'two parent hybrid technology' has various advantages over the 'three line'. This include elimination of fertility restorers and B-lines, utilization of greater variability, and production of more number of hybrids in a short time. In pigeonpea TGMS is of recent origin (2); and for the adoption of this technology in India, suitable seed production environments can be found easily (9). Efforts should also start to transfer this trait into diverse genetic backgrounds.

Use of genomics. The genomics tools that are simple, rapid, and cost effective can now be used to judge the genetic purity of hybrids and their parents. Besides this, genomics should be used to identify fertility restoring genotypes among germplasm and segregating breeding populations. The genomics should also be used to establish heterotic groups for breeding high yielding hybrids. This technology once fully developed should be made available to NARS partners and seed industry.

Breed hybrids for specific adaptation. In India many farmers take agriculture as a challenging business and invest resources to reap more profits. During extensive on-farm testing, it was observed that in certain regions/areas the farmers harvested exceptionally high yields from hybrids. Our records showed that in the Maharashtra state some farmers harvested about 4000 kg ha^{-1} from ICPH 2740 (Table 3) with > 50% superiority over the control. Therefore, to reap the genetic potential of the hybrids, it is important to develop locally adapted cultural recommendations for different cropping systems.

Improve seed technology. It is vital that quality hybrid seed is produced in greater quantities economically and with ease. To achieve this, seed production hot spots need to be identified. In addition, agronomical and ecological factors responsible for enhancing seed set should be investigated.

Summary

A breakthrough in pigeonpea breeding technology was achieved after 39 years of intensive research by ICRISAT and ICAR. The seed-to-seed ratio of 1:200 to 1:300 achieved in pigeonpea is high enough to make a commercial impact. This means that to replace about 20% (= 800,000 ha) of the pigeonpea area in India with hybrids, only 4000 ha of certified seed program would be required. In turn, it would add 40,000 t - 60,000 t of additional grain. At present it does not appear to be a difficult task but to achieve this, a firm commitment on the part of research institutions and seed industry is necessary. Further, to sustain the benefits of this technology, it is essential that strong R & D strategies are development and implemented at national level. The key for success, however, will be an efficient coordination among various public and private agencies.

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