Pigeonpea Perspective in India

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Paper presented during the '1st Philippine Pigeonpea Congress'. Mariano Marcos State University, Batac, Ilocos Norte, Philippines. December 16-18, 2014

Abstract

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Pigeonpea occupies a prominent place in Indian rainfed agriculture. It is an integral component of in various agro ecologies of the country mainly inter cropped with cereals, pulses and oilseeds and millets. It is the second most important pulse crop next to chickpea, covering an area of around 4.42 m ha (occupying about 14.5% of area under pulses) and production of 2.86 MT (contributing to 16% of total pulse production) and productivity of about 707 kg/ha. It is mainly consumed as dry split dhal throughout the country besides several other uses of various parts of pigeonpea plant. Enhancing the productivity of the crop assumes specific significance in India mainly to combat protein malnutrition as it is the main source of protein to the predominant vegetarian population. Based on the crop duration and climatic condition the crop is grouped under four agro ecological zones with varied plant type requirements and location specific constraints for each zone. Systematic crop improvement efforts were launched at ICRSIAT since its inception in 1972. It focused during first decade (1972 to 1980) on collection, evaluation, maintenance and sharing of germplasm and yield enhancement research. During 1980 to 2000 ICRISAT research priorities were development of stable sources of resistance for wilt and Sterility Mosaic Diseases which are highly devastating and endemic in India in almost all the agro ecologies of pigeonpea cultivation. From 2000, concerted efforts are in progress on CGMS based hybrid development. Spectacular achievement by ICRISAT in recent past in the crop is deciphering its genome sequence and it has ushered pigeonpea in to genomic era. Subsequently lot of genomic information is in the process of development through molecular approaches like Genome Wide Association Studies (GWAS), Nested Association Mapping (NAM). Multiparent Advance Generation Inter Crosses (MAGIC) and Introgression Libraries (IL) etc. These approaches are under process of utilization for crop improvement.

1. Introduction:

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is cultivated in tropical and sub-tropical areas between 300N and 300S latitude. It is an important grain legume of Asia (especially, the Indian subcontinent), Latin America and Eastern and Southern Africa. Globally, it is grown on ~5 million hectares (m ha) in about 82 countries of the world. Pigeonpea has a unique place in Indian farming and India accounts for about 90% of the global production. It is the second most important pulse crop next to chickpea, covering an area of around 4.42 m ha (occupying about 14.5% of area under pulses) and production of 2.86 mt (contributing to 16% of total pulse production) and productivity of about 707 kg/ha. It is mainly consumed as dry split dhal throughout the country besides several other uses of various parts of pigeonpea plant. It is an excellent source of protein (20-22%), supplementing energy rich cereal diets in a mainly vegetarian population (Saxena et al. 2010). It is mainly grown as intercrop with urdbean, moonbean, castor, sorghum, soybean, cotton,

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maize and groundnut in states, Maharashtra, Karnataka, Andhra Pradesh, Telangana, Madhya Pradesh, Uttar Pradesh, Gujarat, Jharkhand, Rajasthan, Odisha, Punjab and Haryana. Pigeonpea is a multi-purpose crop that fits very well in the context of sustainable agriculture. In addition to food, it is used as fodder, feed, and fuel and has functional utility (for making baskets, huts, fences, etc.). However, the current production of 2.86 million tons of pigeonpea in India cannot meet the domestic demands. Due to gap between the production and consumption the per capita availability of pigeonpea has come down from 70 gms to 35 gms. Therefore India is compelled to import pigeonpea from other countries. Despite the fact that a large number of high yielding varieties and have been released, productivity in the crop remains stagnant around 700 kg/ha as compared to its potential yield (1500-3000 kg/ha). This gap may be attributed to several biotic and abiotic factors. Since it is mainly a rainfed crop, unfavorable rainfall (Delayed, erratic, improper distribution) leads to terminal drought or heavy down pour. Non adoption of improved management practices and lack of proper research and commercial perspective for the crop influence the low productivity to a greater extent.

2. Agro ecologies of pigeonpea cultivation in India: Broadly the country can be divided in to four agro ecologies based on the duration of the crop.

North West Plain Zone (NWPZ) - includes Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions), Western Uttar Pradesh (except Jhansi division), and Tarai region of Uttaranchal.

North East Plain Zone (NEPZ*)* - includes Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal, Odisha, Assam, Sikkim and plains of far eastern states.

Central Zone (CZ) - includes Madhya Pradesh, Maharashtra, Chhattisgarh, Gujarat, Jhansi division of Uttar Pradesh and Kota and Udaipur division of Rajasthan.

South Zone (SZ) - includes Andhra Pradesh, Telangana, Karnataka and Tamil Nadu.

3. Brief history of pigeonpea research in India:

The first scientific pigeonpea breeding effort in India was made by Shaw in 1933 who described morphological and agronomic traits of 86 elite field collections (Shaw et al. 1933). Almost similar efforts were made by Mahata and Dave who identified early and late maturing high yielding types. Such crop improvement activities involving field collections and their evaluation continued for more than two decades without any significant impact on the productivity. Considering high importance of pigeonpea ICAR started All India Coordinated Pigeonpea Improvement Project in 1965.Under these mega project crop improvement activities were simultaneously launched in 31 research centers in diverse agro ecological zones. Till now 120 varieties are released in the crop and currently 26 centers are working under AICRIP on pigeonpea.

Systematic crop improvement efforts were also launched at ICRSIAT since its inception in 1972. It focused during first decade (1972 to 1980) on collection, evaluation, maintenance and sharing of germplasm and yield enhancement research. During 1980 to 2000 ICRISAT research priorities were development of stable sources of resistance for wilt and Sterility Mosaic Diseases which are highly devastating and endemic in India in almost all the agro ecologies of pigeonpea cultivation. From 2000, concerted efforts are in progress on CGMS based hybrid development. ICRISAT developed varieties *viz.,* ICP 8863, ICPL 87119, ICPL 85063, ICPL 332, ICPL 84031, ICPL 85010, ICPL 151 and ICPL 88039 which are released by ICAR and NARS partners and are widely popular among all the states of India. ICP 8863 (Maruti) first wilt resistant variety stabilized livelihoods of farmers in central and southern zones. ICPL 87119 (Asha) a wilt and SMD resistant variety widely popular in the country and till to day occupies largest area.

ICRISAT also released first world GMS based hybrid of the world ICPH 8 in the year 1991. To make hybrid technology commercially viable a stable CGMS system was developed in the crop and this was followed by the development of an economical hybrid seed production technology. So far ICRISAT in collaboration with National Food Security Mission of India, Indian Council of Agricultural Research, and State Agricultural Universities has released hybrids ICPH 2671 and ICPH 2740 for cultivation in India. These hybrids have recorded 30 to 40% yield advantage over varieties in farmers' fields. ICRISAT mission and goal is to develop hybrids for different maturity groups and adaptive to diverse agro ecological niches. Spectacular achievement by ICRISAT in recent past in the crop is deciphering its genome sequence and it has ushered pigeonpea in to genomic era. Subsequently lot of genomic information is in the process of development through molecular approaches like Genome Wide Association Studies (GWAS), Nested Association Mapping (NAM). Multiparent Advance Generation Inter Crosses (MAGIC) and Introgression Libraries (IL) etc.

While there is an impressive growth in pigeonpea production in India it is challenged by a number of constraints which include several abiotic and biotic stresses.

a. Abiotic:

1. Waterlogging and Salinity: Pigeonpea, a predominantly rainy-season crop experiences waterlogging in high rainfall regions and in soils with low permeability spreading over North-eastern Plains Zone (Uttar Pradesh, Bihar, West Bengal, Assam, Orissa) and Central Zone (Madhya Pradesh and Maharashtra). Waterlogging and salinity has been recognized as one of the major constraints to pigeonpea cultivation.

2. Drought: The inherent deep root-system of pigeonpea imparts high degree of drought tolerance; however, moisture stresses at reproductive phase do severely limit productivity, and sometimes even no yields are realized. This stress also limits symbiotic N fixation.

b. Biotic:

1. Insect pests: Pod fly and Pod borer
2. Diseases: sterility mosaic, *Fusarium* wilt and *Phytophthora* blight

c. Economic: Lack of stable input and output markets, increased price of cash inputs, non-availability of timely credit, labour scarcity, lack of extension support and awareness on improved Varieties and hybrids

d. Policies: Distorted price policies favouring wheat and rice, lack of procurement at Minimum Support Price

e. Input supply and mechanization:

1. Timely availability of quality seeds.
2. Availability of fertilizers and pesticides.
3. Availability of low cost harvesters for reducing the drudgery

f. Infrastructure constraints: Improved storage facilities, post-harvest processing, and value addition.

4. Strategies to enhance production and productivity of Pigeonpea:

Pigeonpea like most other grain legume crops has lost genetic variability for high yield potential traits during the process of its domestication for survival. It is this lost variability that needs to be regenerated (Singh et al. 2014). Most present day plant breeding efforts in developing high yielding varieties aim at defect elimination i.e., developing resistant varieties to biotic (Wilt, SMD, *Phytophthora*, Pod borers etc.) and abiotic (moisture stress, high or cold temperature tolerance) stresses. The present day plant type of Pigeonpea, which is like a semi tree in habit is a hardy plant, and survives under harsh environment, but with more vegetative and woody growth with less sink capacity. Systematic studies to rebuild the plant type to improve the genetic yield potential of Pigeonpea are very limited.

In view of above, the following strategies are under progress for genetic enhancement in the crop:

1. Utilization of genomic resources for developing varieties/ hybrids with resistance for biotic and a biotic stresses.

Due to availability of reference genome by deciphering the genome sequence of the crop in the year 2012 (Varshney et al. 2012) pigeonpea is now equipped with wealth of genomic resources. Diversity analysis of released cultivars in the country indicates the prevalence of limited genetic diversity compared to the vast diversity available in the land races and wild relatives. It offers a very good scope for genetic improvement in the crop by tapping the concealed diversity. Genomic resources now available in the crop are to be exploited to hasten crop improvement. Different approaches are already in progress for crop improvement. Broadly the approaches are enlisted below.

- Mining superior alleles by re-sequencing of wild species.
- Fine mapping for drought tolerance and fertility restoration.
- Developing superior lines through genomic selection
- Identification of candidate genes associated with hybrid vigour using epigenomics & mitochondrial genome sequencing.
- Identification of candidate genes and functional markers for water-logging tolerance.

2. Breeding and Development of Varieties/Hybrids with pests and disease resistance for different agro ecologies.

Pigeonpea is widely cultivated in India in varied agro ecological situations and with diversified cropping systems and crop duration. Owing to climate change there is drift in rainfall pattern and distribution. Hence the varietal requirement scenarios are changing. There is a need to intensify breeding of adaptable lines to changed environments.

Recent crop improvement efforts led to development of stable cytoplasmic and genetic male sterile System in the crop and hybrids are developed for different niches (Saxena et al. 2014). Seed production technology as also standardized for large scale production of commercial seed. There is an immediate need for exploitation of hybrid vigor by breeding heterotic hybrids for different zones in the country to improve productivity and production (Saxena et al. 2013). The overall approaches with location specific constraints are detailed below.

1. Development of medium duration varieties/hybrids with wilt and SMD resistance for central and southern zones.
2. Breeding and development of extra early genotypes with 120 days maturity to fit in to

pigeonpea and wheat cropping systems in North Western Plain Zone with water logging tolerance.
3. Breeding and development of genotypes with > 180 days maturity with frost resistance for North Eastern Plain Zone.

3. Breeding and development of super early genotypes for different cropping situations for horizontal expansion in the crop

Due to photo and thermo sensitivity and long duration pigeonpea cultivation could not be extended for different cropping systems and cropping patterns. But recently completely day neutral and photo insensitive varieties are developed which can be sown in any part of the year offers a chance for the horizontal expansion in the crop to different cropping systems (Vales et al. 2012). One of the possible areas of expansion is rice fallows, Vast areas of rice-fallows (about 10 million ha) available in eastern India (Jharkhand, Bihar, Chhattisgarh, Odisha and West Bengal) offer opportunities for expanding pigeonpea area. Hence there is a need to develop these varieties adapted to the different niches by concerted breeding efforts.

4. Exploiting transgenic technology for *Helicoverpa* resistance

Pod borer (*Helicoverpa armigera*) continued to remain a major and challenging insect-pest of pigeonpea. It has been not possible to develop varieties with high levels of resistance to pod borer due to non-availability of sources with high levels of resistance in germplasm. Higher levels of resistance have been observed in some wild species and efforts are being made to exploit these wild species in improving pod borer resistance. There is a need for development of pod borer resistant cultivars through application of transgenic technology. Concerted efforts are needed on using different transgenes and promoter options for developing transgenic events and their evaluations for effectiveness and biosafety.

Key partners and their roles

Partner	Role
ICRISAT	Basic and strategic research, development and utilization of genomic resources for crop improvement, development of improved germplasm, supply of germplasm and breeding materials to partners, international networking, capacity enhancement of partners, facilitating transfer of technologies.
IIPR and IARI	Basic and strategic research, development and application of genomic resources, development of improved germplasm, supply of germplasm and breeding lines to partners; development of ICM technologies, transfer of technologies.
NBPGR	Supply and utilization of genetic resources.
NIPGR	Development of genomic resources.
SAUs	Basic and strategic research, utilization of genomic resources in crop improvement, development of regionally adapted cultivars and production technologies, transfer of technology.
National and State Seed Corporations, Private seed sector	Seed production
DOA & NGOs	Transfer of technology

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