An overview of chickpea breeding programs in India

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Abstract: India currently accounts for nearly 70% of the global chickpea production and consumption. There has been a large shift in chickpea area from north to south over the past four decades. The chickpea production has increased substantially in the recent years. Over 200 improved varieties have been released from different parts of India. The major constraints to chickpea production include moisture stress, temperature extremities, root diseases, pod borer, and weeds. Transgenics are being developed for enhancing pod-borer resistance. Integrated breeding efforts are being made to develop varieties with improved resistance/tolerance to key abiotic and biotic stresses, suitability to mechanical harvesting and tolerance to herbicides.

Key words: abiotic stresses, biotic stresses, chickpea breeding, breeding achievements, chickpea varieties

Current status of chickpea production

Chickpea, locally known as Bengal gram, Gram or Chhola, has been under cultivation in India from ancient times. It is the most important pulse crop of India contributing to about 40% of domestic pulse production. It is mainly gown rainfed (68% area) and highly valued for its ability to improve and sustain soil fertility. Being a rich source of protein, it plays an important role in ensuring nutritional security to the common agrarian people. The decreasing per capita availability of pulses in India from 69.0 g in 1961 to 31.6 g in 2011 has created an alarming situation calling for concerted and expeditious efforts in improving productivity of pulse crops.

India is the largest producer of chickpea accounting for about 70% of the global share. During 2011-12, India produced 7.58 million tons chickpea from 8.87 million ha area with an average yield of 912 kg ha^{-1}.During the past five decades (1960-2010), chickpea production in India has increased from 6.25 to 8.25 million tons despite a slight decline in the area from 9.28 to 8.75 million ha (4). The trends in area, production and yield of chickpea during the past 40 years are presented in Fig. 1.

Growing chickpea in rotation with cereals was a general practice in India and particularly in northern India (2).With the advent of input intensive *Green Revolution* technologies, a dramatic shift in major cropping systems took place in northern India. The area of pulse crops like chickpea was largely replaced by cereals. During 1964-1965 to 2008-2009, the chickpea area in northern India (Punjab, Haryana, Uttar Pradesh and Bihar states) declined by 4.4 million ha, while increased in central and southern India (Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka) by 3.5 million ha (5).

India is a major producer as well as consumer of chickpea. Despite large domestic production, India has to import chickpea to bridge the gap between demand and production. In recent years, India has also started exporting chickpea, mainly large and extra-large seeded kabuli types to Middle East and other neighboring countries. However, the import invariably exceeds export. For example, during 2006 to 2010, India has an average export of 173,000 tons and export of 132,000 tons per year (4).

Key constraints to chickpea production

Abiotic stresses. Over 68% of the chickpea area is rainfed and soils of rainfed area are generally with low organic carbon content, poor fertility level and water holding capacity. As chickpea is largely grown on conserved soil moisture as a rainfed crop during post-rainy season, the crop often experiences moisture stress towards the end of the season. In addition, heat stress at the reproductive stage has become a major constraint to chickpea production because of a large shift in chickpea area from cooler long-season environments (northern India) to warmer short-season environments (central and southern India), increased area under late sown conditions due to increased cropping intensity, and an expected overall increase in temperatures due to climate change (5). Frost or low temperatures during flowering sometimes result in substantial reduction in yield in northern and central India. Chickpea in northern India sometimes show excessive vegetative growth and lodging when it is sown under irrigated conditions or when there are frequent winter rains. Chickpea is a poor competitor to weeds at early growth phase and may incur heavy yield losses if weeds are not managed. Soil salinity, alkalinity and acidity also affect chickpea productivity in some areas.

Biotic stresses. Fusarium wilt (*Fusarium oxysporum* f. sp. *ciceris* Matuo & K. Sato) and collar rot (*Sclerotium rolfsii* Sacc.) are the important root diseases of chickpea throughout India. Dry root rot (*Rhizoctonia bataticola* (Taubenh.) E.J. Butler) has emerged as a major disease in central and southern India where chickpea growing season is dry and warm. Ascochyta blight (*Ascochyta rabiei* (Pass.) Labr.) and botrytis grey mold (*Botrytis cinerea* Pres.) are the important foliar diseases of chickpea in northern India where chickpea growing season is cool and humid.

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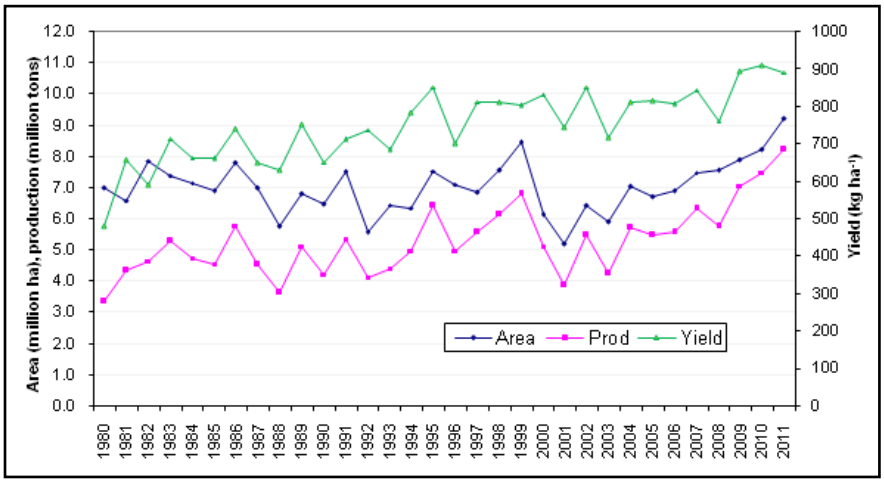

Figure 1. Trends in chickpea area, production and yield in India from 1980 to 2011

The viral diseases, rust (*Uromyces ciceris-arietini*) Grognot, root nematodes (*Meloidogyne* sp.) can also cause substantial yield losses in some areas. Among insect pests, pod borer (*Helicoverpa armigera* Hubner) is the most important pest of chickpea throughout India. Termites (*Odontotermes* spp.), cutworm (*Agrotis* sp.) and leaf miner (*Liriomyza cicerina* Rondani) are also important in some chickpea growing areas. As in other pulses, bruchid (*Callosobruchus chinensis* L.) is the major pest during storage of chickpea.

Socioeconomic factors. A large number of farmers in India have small land holdings. They have limited input resources available and tend to give first priority to staple cereals (rice, wheat, maize) and high value crops (potato, sugarcane) for allocation of resources. The benefits of available improved cultivars and crop production technologies have not been fully realized at farmers' fields as their adoption, particularly crop management practices, remained low in several states of India.

Chickpea breeding in India

Chickpea breeding work was initiated in India as early as in 1930 and an All India Coordinated Pulses Improvement Project (AICPIP) was launched in 1967 to ensure sharing and multi-location evaluation of breeding lines. The Directorate of Pulses Research (DPR) was established in 1984 at Kanpur (India) which was further upgraded to the level of Indian Institute of Pulses Research (IIPR) in 1993 with a mandate of basic, strategic and applied research on a group of pulse crops including chickpea. AICPIP was also trifurcated and All India Coordinated Research Project on Chickpea (AICRPC) came into existence in same year.

Chickpea cultivation is wide spread as it is grown from 32^0 N in northern India in cool and long season (> 140-170 days crop duration) to 10^0 N in southern India under warm and short season (90-100 days crop duration). For the convenience of evaluation and release of locally adapted varieties, India has been divided intofive agro-ecological zones (Fig. 2) namely, north hill zone (NHZ), north west plain zone (NWPZ), north east plain zone (NEPZ), central zone (CZ) and south zone (SZ). The best performing genotypes developed at various research institutions are pooled and evaluated in multi-location trials in all five agro-ecological zones. A variety can be released for one or more zones by a Central Variety Release Committee or for a state or part of the state by a State Variety Release Committee.

The chickpea breeding is aimed at developing locally adapted cultivars with high yield potential, acceptable grain quality and resistance/tolerance to key abiotic and biotic stresses prevalent in the target area.

Salient achievements

India has a long history in chickpea breeding and the world's largest network of chickpea breeding programs. Over 20 research stations located in various parts of India have active chickpea breeding program. These belong to State Agricultural Universities (SAUs), Indian Institute of Pulses Research (IIPR) and Indian Agricultural Research Institute (IARI) and are linked to AICRPC (Fig. 2). Excellent progress has been made in chickpea breeding in India (3, 8). The Indian chickpea breeding program has a strong collaboration with International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and greatly benefited by its presence in India. A total of 206 chickpea varieties have been released in India during 1921 to 2011 (4 during 1921-1940, 17 during 1941-1960, 33 during 1961-1980, 85 during 1981-2000 and 67 during 2001-2011), with 38 from the materials supplied by ICRISAT. Some old varieties, such as Dahod yellow, Chaffa, Radhey and Annegiri, are still cultived. Currently, > 90 varieties are in seed production chain. About 43% of the indent of breeder seed during 2011-2012 was for the varieties developed with ICRISAT.

One of the most significant achievements of chickpea breeding is the development of varieties with high resistance to fusarium wilt, now mandatory for release of a new chickpea variety in India. Excellent progress has been made in developing early maturing varieties (e.g. ICCV 2, ICCC 37, JG 11, JG 14, KAK 2, DCP 92-3, BGD 72) with high yield potential. The early maturing varieties escape terminal drought and heat stresses and helped in expansion of chickpea area to southern India, where growing season is short (90-100 days) and warm (6).

The development of kabuli chickpea varieties, which remained a low priority for decades, has received high attention during the recent years. Few kabuli varieties (L551, ICCV 2, BG 1003, BG 1053) with medium seed size (< 30 g 100 seed^{-1}) were released in India, before the release of the first large-seeded kabuli variety, PKV Kabuli 2 (popularly known as KAK 2), in 2001. KAK is an early maturing fusarium wilt resistant variety with a seed size of about 38g 100 seed^{-1}. This is currently the most popular chickpea variety in India. Several large-seeded (31 - 45 g 100 seed^{-1}; e.g. JGK 1, IPCK 2002-29, IPCK 2004-29, JGK 2, Vihar, LBeG 7 andVirat) and also extra-large seeded (46-60 g 100 seed^{-1}; e.g. JGK 3, KRIPA, PKV Kabuli 4-1, IPCK 02 and MNK 1) kabuli varieties have been released in India during the past decade. They have contributed to expansion of kabuli chickpea area in India and their recent export.

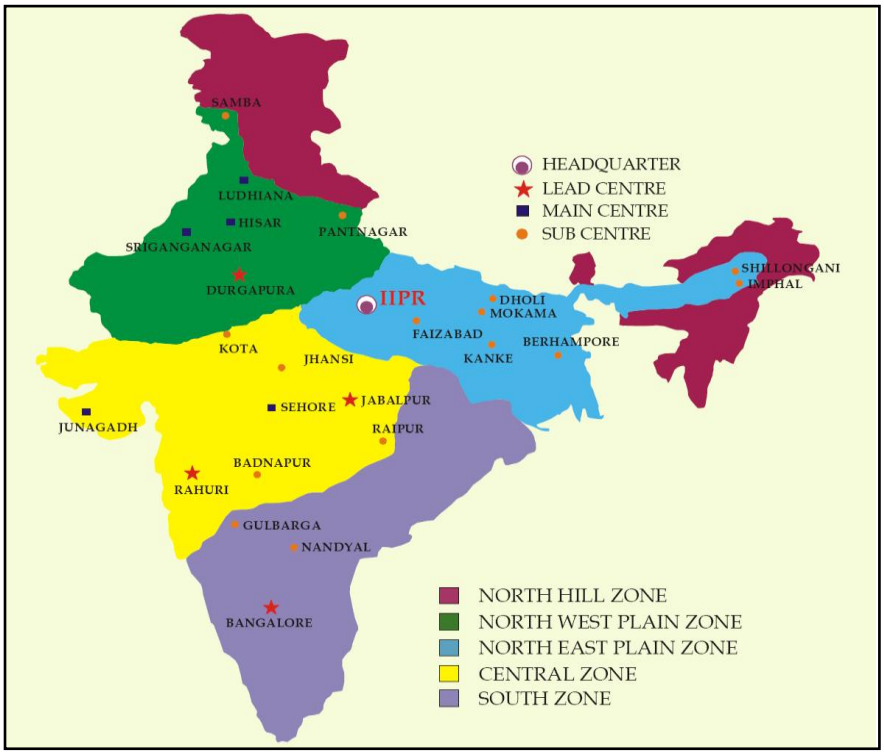

Figure 2. Chickpea research network in India (Adpoted from AICRP on Chickpea Report)

Chickpea varieties (RSG 888, Vijay) tolerant to terminal moisture stress became popular in drought prone areas of the country. Recently, a heat tolerant chickpea variety JG 14 (ICCV 92944) has been released and several sources for heat tolerance have been identified (1, 7). In northern India, where chickpea crop attain more vegetative growth and subsequently show lodging leading to huge yield loss or sometimes failure of crop, variety DCP 92-3 can be grown successfully. Similarly, variety Karnal Chana 1 (CSG 8962) can be grown in areas of mild level of soil salinity.

Development of varieties resistant to pod borer remained a challenge as the level of resistance available in the germplasm are very low. Therefore, transgenic approach is being used for development of pod borer resistant cultivars.

The new priority traits where chickpea breeding efforts have recently started include heat tolerance, herbicide tolerance and suitability to mechanical harvesting.

Future prospects

- There is a need to develop varieties with tall and erect or semi erect growth habit which will be suitable for mechanical harvesting. In addition, higher amount of solar light interception on these varieties will help in enhancing photosynthetic activities and in reducing humidity inside crop canopy which will help in minimizing losses due to foliar diseases.

- Broadening of the genetic base by bringing genes from wild *Cicer* species and primitive landracesto develop suitable plant types with durable resistance to major biotic and abiotic stresses.

- Integration of molecular markers in chickpea breeding programs for improving efficiency and precision.

- Development of herbicide tolerant varieties for promoting resource conservation (zero or minimum tillage) technologies and reducing cost of cultivation as manual weeding is becoming very expensive.

- Germplasm of cultivated and wild species need to be evaluated systematically for identification and utilization of sources of resistance to emerging diseases like collar rot and dry root rot.

- In view of climate change, development of varieties tolerant to terminal drought and heat stresses needs special attention. Breeders should join hands with physiologists and molecular biologists to tackle these problems effectively.

- Development of extra-large seeded (100-seed weight > 50 g) kabuli chickpea varieties with resistance to major diseases and tolerance to frost and low temperatures at flowering.

- Development of early to extra-early maturing varieties for late sown conditions i.e. harvest of rice or other rainy season crops to increase cropping intensity.

- Development of transgenic for resistance to *Helicoverpa* pod borer.

- Development of varieties with improved nutrient use efficiency, particularly phosphorus use efficiency. ■

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