Enhancing the Productivity and Production of Pulses in India

C. L. Laxmipathi Gowda, S. Srinivasan, P. M. Gaur and K. B. Saxena

Pulses are major sources of proteins among the vegetarians in India, and complement the staple cereals in the diets with proteins, essential amino acids, vitamins and minerals. They contain 22-24% protein, which is almost twice the protein in wheat and thrice that of rice. Pulses provide significant nutritional and health benefits, and are known to reduce several non-communicable diseases such as colon cancer and cardio-vascular diseases (Yude *et al,* 1993; Jukanti *et al,* 2012). Pulses can be grown on range of soil and climatic conditions and play important role in crop rotation, mixed and inter-cropping, maintaining soil fertility through nitrogen fixation, release of soil-bound phosphorus, and thus contribute significantly to sustainability of the farming systems .

India is the largest producer and consumer of pulses in the world. Major pulses grown in India include chickpea or bengal gram (*Cicer arietinum*), pigeonpea or red gram (*Cajanus cajan*), lentil (*Lens culinaris*), urdbean or black gram (*Vigna mungo*), mungbean or green gram (*Vigna radiata*), lablab bean (*Lablab purpureus*), moth bean (*Vigna aconitifolia*), horse gram (*Dolichos uniflorus*), pea (*Pisum sativum* var. arvense), grass pea or khesari (*Lathyrus sativus*), cowpea (*Vigna unguiculata*), and broad bean or faba bean (*Vicia faba*). More popular among these are chickpea, pigeonpea, mungbean, urdbean and lentil. In general, pulses are mostly grown in two seasons: (i) the warmer, rainy season or kharif (June-October), and (ii) the cool, dry season or rabi (October-April). Chickpea, lentil, and dry peas are grown in the rabi season, while pigeonpea, urdbean, mungbean, and cowpea are grown during the kharif season. Among various pulse crops, chickpea dominates with over 40 percent share of total pulse

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production followed by pigeonpea (18-20%), mungbean (11%), urdbean (10-12%), lentil (8-9%) and other legumes (20%) (IIPR Vision 2030).

Though India is the world's largest producer of pulses, it imports a large amount of pulses to meet the growing domestic needs. During 2009-10, India imported 3.5 million tons of pulses from the countries like Australia, Canada, and Myanmar. Thus, India is the largest importer, producer and consumer of pulses. On the other hand, India is also the largest pulses processor, as pulses exporting countries like Myanmar, Canada and Australia do not have adequate pulses processing facilities.

Large shares of pulses import, including desi chickpeas, pigeonpea, mungbean, urdbean, and kidney bean come from Myanmar. Importers favor Myanmar because it offers varied pulses with qualities similar to those produced in India, low freight rates, and relatively fast delivery. Canada and Australia are major suppliers of dry peas and kabuli chickpeas to the Indian market, each supplying about one-third of India's pulses imports. Most kabuli chickpeas come from Mexico, Australia, Canada, Turkey and Iran. Nepal and Syria account for the largest shares of Indian lentil imports.

It has been estimated that India's population would reach 1.68 billion by 2030 from the present level of 1.21 billion. Accordingly, the projected pulse requirement for the year 2030 is 32 million tons with an anticipated required growth rate of 4.2% (IIPR Vision 2030). India has to produce not only enough pulses but also remain competitive to protect the indigenous pulse production. In view of this, India has to develop and adopt more efficient crop production technologies along with favorable policies to encourage farmers to bring more area under pulses.

Area, production and yields of pulses in India

India ranks first in the world in terms of pulse production (25% of total worlds production) (FAOSTAT 2010). Madhya Pradesh, Maharashtra, Uttar Pradesh, Andhra Pradesh, Karnataka and Rajasthan are the major states growing pulses in India. These six states contribute 80% of total pulse production and area (Directorate of Economics and Statistics, Department of Agriculture and Cooperation, 2010).

More than 90% of lentil area is covered by Madhya Pradesh and Uttar Pradesh states which contribute more than 70% of country's production during 2010 (Directorate of Economics and Statistics, Department of Agriculture and Cooperation, 2010). Pigeonpea is mainly grown in Maharashtra, Karnataka and Andhra Pradesh states (>60% area in India) with 60% of production (1.4 million tons) coming from these three states. Madhya Pradesh has the highest area (38%) under chickpea, followed by Maharashtra (16%), Karnataka (12%), Rajasthan (11%), Andhra Pradesh (8%) and Uttar Pradesh (8%). Andhra Pradesh leads in the total pulse productivity with an average increase of 81-100% in the yield of two major pulses, chickpea and pigeonpea in the past two decades (1991 to 2010). This significant increase has surpassed the national average increase in the total productivity.

Average yield of pulse crops in India is low compared to the world average. However, the average yield of pulse crops in the country has increased gradually over the period and is 690 kg ha^{-1} in 2010-11 which is 56% higher compared to yields during 1950 (Figure 1). Interestingly during 2010-11, India produced 18.1 m ton of pulses from 26.3 m ha with a productivity of 690 kg ha^{-1}, which is the highest of all time. Yield of kharif pulses ranges between 393 and 512 kg ha^{-1}. But, the yield of Rabi pulses ranges between 654 and 756 kg ha^{-1}. Mostly pulses are grown as rainfed or with limited irrigation, but due to the availability of improved high yielding varieties farmers are growing pulses as an irrigated crop.

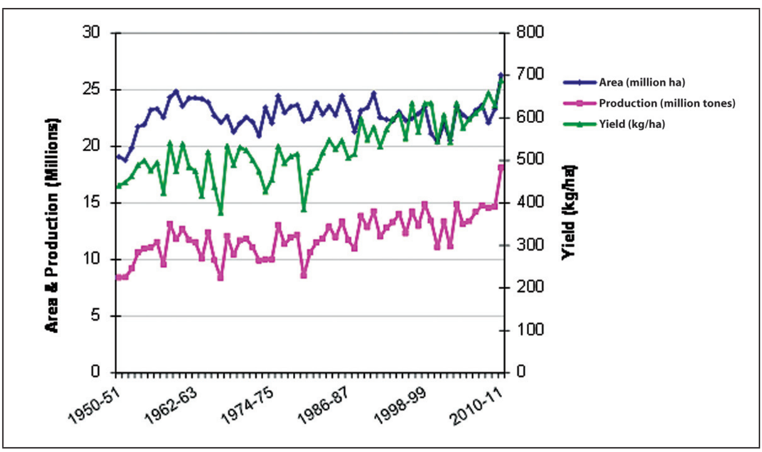

Figure 1: Area production and productivity of pulses in India

Net daily pulses availability for Indians has increased slightly from 32g per capita in 2000 to 37g per capita in 2009. Percentage share of pulses in net food grain availability has also increased slowly from 7% to 8.33% during this period. These data show that the availability of pulses has increased in the past decade with the increasing emphasis on development of improved varieties and supportive policies of the Government in India. over a period of 60 years (Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation 2010).

The expansion of irrigated agriculture in northern India has led to displacement of pulses by wheat, rice, and maize in large area. Area under pulses declined from 10.12 million ha to 8.16 million ha (about 20%) in north India (Figure 2). On the other hand, area of pulses increased from 11.34 to 15.01 in central and south India during the same three decades. Among pulses, chickpea area has decreased by more than 50% in north India, considering the base year 1971-75.

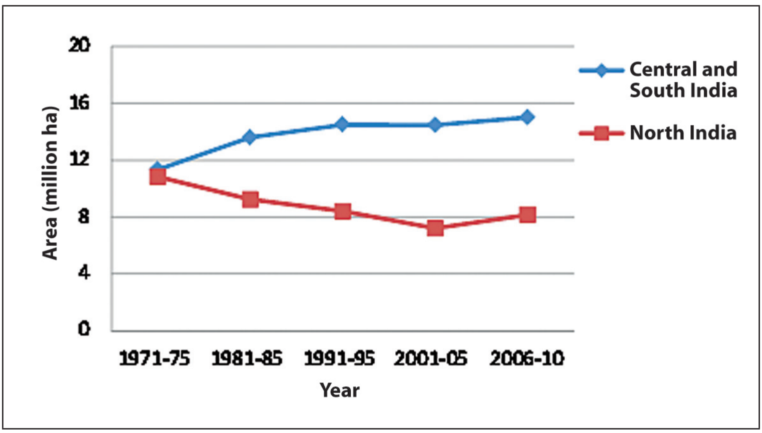

Figure 2: Shift in area of pulses from Northern India to Central and Southern India

There has been a major shift in chickpea area (about 3.0 million ha) from northern India (cooler, long season environment) to southern India (warmer, short season environment) during the past four decades. The short-duration varieties developed through ICRISAT and Indian NARS partnership have played a key role in expanding area and productivity of chickpeas in central and southern India. Among all major pulses of northern India, chickpea suffered maximum loss of 63% area (from 4.98 million ha in 1971 to 1.85 million ha in 2010), mainly due to replacement by wheat.

Constraints to pulse production

a. Production constraints

Production of major pulses is constrained by both biotic and abiotic stresses. For example, pod borers (*Helicoverpa armigera*), fusarium wilt, root rots, ascochyta blight and botrytis gray mold are some of the major biotic constraints to increasing the productivity of chickpea. The major constraints to productivity in pigeonpea are biotic stresses such as pod borer, pod fly, Fusarium wilt, and sterility mosaic disease. Similarly, pod borer, aphids, cutworm, powdery mildew, rust and wilt are the major pests and diseases affecting lentil production in India. The richness of legumes in N and P, makes them attractive for insect pests and diseases (Sinclair and Vadez, 2012).

Most of the pulses in India are grown in low fertility, problematic soils and unpredictable environmental conditions. More than 87% of the area under pulses is rainfed. Drought and heat stress may reduce seed yields by 50%, especially in arid and semi-arid regions. Another major problem is salinity and alkalinity of soils which is high both in semi-arid tropics and in the Indo-Gangetic plains. With recent changes in the global temperatures the grain yield is likely to be drastically affected by temperature extremities. Poor drainage/water logging during the rainy season causes heavy losses to pigeonpea on account of low plant stand and increased incidence of phytophthora blight disease, particularly in the states of UP, Bihar, West Bengal, Chhattisgarh, MP and Jharkhand.

b. Socio-economic constraints

Even though India is the largest pulses producer in the world, it imports large amount of pulses from rest of the world. Farmers in India treat pulses as secondary crops. Until recently the government also gave less importance to pulses compared to the staple cereals. In general farmers' access to inputs is limited, both because of low purchasing power and accessibility to markets to sell the excess produce of pulses. Because of this situation, the farmers give first priority to staple cereals and cash crops for allocating inputs and the second priority to pulses. As a result, pulses continue to be grown on poor soils with low inputs. In addition, there is lack of policy support and post-harvest innovations related to pulse crops. Availability of quality seed of improved varieties and other inputs is one of the major constraints in increasing the production of grain legumes (David *et al*, 2002).

Strategies to improve pulse productivity and production

There are a few available technologies that can increase the productivity and production of pulses. A few examples are given in this paper, mostly from chickpea and pigeonpea where the authors have experience. Similar technologies are available for most major pulses grown in India.

a. Short-duration, high-yielding varieties

Matching crop maturity duration to available cropping window, including soil moisture availability, is a major strategy to avoid drought stress. Hence, emphasis in crop improvement programs has been to develop high-yielding, short-duration cultivars which escape terminal drought. These short duration varieties provide opportunities for inclusion of a given crop/ variety in the cropping systems with a narrow cropping window or new production niches.

Development of short-duration and wilt resistant chickpea varieties has led to the adoption of chickpea new niches of southern India, and in rainfed rice-fallow lands (Gowda and Gaur, 2004; Gaur *et al*, 2008). For example, early-maturing, chickpea varieties, particularly JG 11, KAK 2, JAKI 9218, and Vihar have brought a chickpea revolution in Andhra Pradesh state of India, where the production has recorded 9-fold (95,000 to 884,000 tons) increase over the past 10 years (2000-2009), as a result of a 5-fold increase in area (102,000 to 602,000 ha) combined with a 2.4 fold increase in yield levels (583 to 1407 kg ha^{-1}) (Gaur *et al*, 2012). The key factors for this significant increase in chickpea area and production in central and southern India are: (i) Introduction of high yielding, short-duration, Fusarium wilt resistant varieties adopted to short-season, warmer environments of southern India; (ii) High adoption of improved cultivars and production technologies ; (iii) Successful Introduction of commercial cultivation through mechanized field operations and effective management of pod-borer; and (iv) Availability of grain storage facilities to farmers at local level at affordable cost. Andhra Pradesh was once considered beyond the limits of chickpea cultivation, due to warm and short-season environment, but now has the highest average yield (1.4 tons ha^{-1}) levels in India. More than 80% of the chickpea area in Andhra Pradesh is occupied with improved short-duration cultivars (JG 11, KAK 2, JAKI 9218, and Vihar) (Gaur *et al*, 2012).

b. Improved varieties with drought tolerance

The drought tolerant varieties can provide cost-effective long-term solutions against adverse effects of drought. Returns to investment in breeding for drought tolerance are likely to be higher compared to those in other drought management strategies. A wider dissemination of drought-tolerant material would provide sustenance to the livelihoods of farmers who are more vulnerable to shocks of crop failure. On the other hand even though the potential economic benefits of drought-tolerance breeding research are attractive, farmers may not benefit from it if appropriate institutional arrangements are not in place for multiplication and distribution of seeds of improved varieties. This is more so in the case of large seeded pulses whose seed requirement is very high.

Marker-assisted back-crossing (MABC) approach has been successful in many crops including cereals (Varshney *et al,* 2006) and legumes (Varshney *et al,* 2010). Root traits, particularly rooting depth and root biomass, are known to play an important role in avoidance of terminal drought through more efficient extraction of available soil moisture. A genomic region that contained QTL for root traits and several other drought tolerance related traits was identified in chickpea. MABC was initiated at ICRISAT to introgress this major genomic region in three cultivars (JG 11, Chefe and KAK 2) in collaboration with the national programs in India, Kenya, Ethiopia, Tanzania. Recently, as a part of Accelerated Crop Improvement Program (ACIP) of Department of Biotechnology (Government of India), several marker-assisted breeding programs have been initiated, including MABC (marker-assisted back-crossing) to incorporate drought tolerance in to high yielding varieties.

c. New niches

Pulse crops have great diversity of maturity durations that enable their cultivation in many niches and different production systems to increase production. A few examples are given below, but there are many more in other crops and niches that can be exploited successfully.

(i) Chickpea in rice fallows

The Indo-Gangetic Plains (IGP) spread over South Asia's four countries-Bangladesh, India, Nepal and Pakistan- is agriculturally one of the most important regions of the world. About 14.3 million ha of the rice area in IGP remains fallow during the winter season. These rice-fallows offer a huge potential for expansion of the area of rabi pulses such as chickpea, lentil and grasspea. Large-scale on-farm trials conducted by several State Agriculture Universities in five states of India (Chhattisgarh, Jharkhand, Orissa, West Bengal and eastern Madhya Pradesh) have clearly shown that short-duration varieties of chickpea and lentil can be successfully grown after rice harvest, and with reasonably high yield levels of 1 to 2.5 ha^{-1}. For example, short-duration desi and kabuli chickpea varieties were found suitable, and the farmers preferred the *kabuli* varieties ICCV 2, KAK 2 and JGK 1 in most areas as they fetch high market prices. More recently, a heat tolerant chickpea variety JG 14 has been found to be highly adapted to late-sown conditions in the rice fallow area in the states mentioned above.

(ii) Pigeonpea in rice-wheat cropping systems

Rice–wheat cropping system is popular in the Indo-Gangetic Plain region of India. However, continuous mono-cropping of cereals has lead to depletion of soil fertility and increased incidence of pests and diseases, and is posing a serious threat to sustainability of the entire rice-wheat cropping system. The inclusion of legumes in rice–wheat cropping system would greatly help restore soil fertility and reduce other associated problems. Several on-station and on-farm trials during 1999-2002 in Haryana and Western Uttar Pradesh with extra-short duration pigeonpea varieties (such as ICPL 88039, now released as VP Arhar 1) indicated that pigeonpea can be grown profitably in place of rice during the kharif season (sown in late-May and harvested in late October or early November), allowing timely sowing of wheat crop. Pigeonpea yields were 1.5 to 3 tha^{-1}, with an average of 2 t ha^{-1}. As pigeonpea adds nitrogen through BNF and leaf fall (contributing about 40-50 kg N to the system), the succeeding wheat crop needed less N fertilizers. The net economic returns under pigeonpea-wheat system were found greater compared with the rice–wheat system (Singh *et al,* 2005).

(iii) Pigeonpea at high altitudes

Extra-short duration pigeonpea was successfully cultivated up to the elevation of 2000 m above sea level in Uttarakhand. A pilot study in collaboration with Vivekananda Parvathiya Krishi Anusandhan Sansthan (VPKAS), Almora and the Department of Agriculture, Uttarakhand, with several on-farm trials across different elevations in the state during 2007-10 indicated that pigeonpea variety 'VL Arhar-1' (ICPL 88039) can be grown successfully in low and medium hill regions (Saxena *et al,* 2011). VL Arhar-1 showed high adaptability to high elevation regions and produced as high as 1,800 kg ha^{-1} of grains. Since the extended periods of cold and frost can severely damage the foliage and flowers of pigeonpea, its cultivation should be limited to only low and mid hill regions. Extra-short duration pigeonpea cultivar VL Arhar 1 is now extensively cultivated in Uttarkhand.

d. Seed systems

Despite a long list of improved pulses varieties released for cultivation, their impact has not yet been fully realized by the resource-poor farmers in many states in India. The accessibility of smallholder farmers to quality seed of improved pulses varieties is constrained by both inadequate demand creation and limited supply. This situation is also compounded by unfavorable and inadequate policy support and regulatory frameworks, inadequate institutional and organizational arrangements, and deficiencies in production and supply infrastructure and farmers' socio-economic situation (Rubyogo *et al*, 2007).

Numerous constraints limit the performance of seed systems in India including limited access of smallholder farmer to seed of improved varieties; limited supplies of quality (breeder, foundation and certified) seed of farmer and market-preferred varieties; lack of co-ordination among national seed production organizations and policy making institutions.

On the seed supply side, grain legume seed business generally does not attract large seed companies since profit margins are low. More than 95% of lentil seed in India (the leading global lentil producer) comes from the informal sector (Materne and Reddy, 2007). The situation with respect to other pulses in India is similar. The seed replacement rate in India varies from 14% in chickpea to 35% in soybean (www.seednet.gov.in), thus indicating that a majority of the farmers still use their own saved seed. This situation is due to several factors including: the low seed multiplication rate of legumes; the reuse of grains from previous harvest as seeds and; often demand for specific varieties adapted to more narrow agro-ecologies and consumers' needs. Furthermore, when seed production takes place, it is often in higher potential areas, with seed stores being concentrated in zones of higher population density or those with better infrastructure (i.e. not the remote, stress-prone areas).

As small and medium seed companies are emerging and gaining strength, they are also creating effective demand for pulses seed. However their capacities are still limited by the inadequate and discontinuous access to foundation seed, inadequate capital investment, and lack of appropriate marketing strategies including delivery systems targeting remote and small scale farmers (Rubyogo *et al,* 2011). Public and private partnership would be the best approach to increase the availability of foundation seed need for subsequent seed classes.

In the developing countries such as India, particularly for pulses, the formal seed sector is highly subsidized and evolving at different stages of development. The informal seed sector is and will remain the dominant player in legumes. In recent past, development partners and researchers have realized the importance and significance of quality seed in agriculture and several projects have been implemented or are in progress to improve seed availability of improved farmer-preferred varieties to farmers. The main issue in resolving access to quality seed would be a thorough understanding and critical assessment of the status of existing seed sector (both formal and informal), their bottlenecks and comparative advantages and complementarity.

e. Input supply (micro-nutrients and fertilizer application)

Legumes fix atmospheric nitrogen. However, availability of quality of Rhizobium inoculum is limiting. Phosphorous is becoming a limiting macro-nutrient which will affect the pulses production. A common difficulty in recovering P from the soil is that it is not readily available to plants because P reacts with aluminum, iron and calcium in the soil to form complexes. These nutrients are essentially insoluble resulting in very little movement of P in the soil solution, and none of the complexes can be taken up directly by roots (Sinclair and Vadez 2002). The use of phosphate solubilizing bacteria (strains from the genera of *Pseudomonas*, *Bacillus* and *Rhizobium* are among the most powerful P solubilizers) as inoculants simultaneously increases P uptake by the plant and thus crop yields (Khan *et al*, 2009).

A recent study by ICRISAT indicated that soils in many states in India are deficient in micro-nutrients such as boron, sulfur, zinc and magnesium (Wani *et al*. 2012). Application of small quantities (0.5 to 2 kg ha^{-1}) has resulted in 40-120% increase in grain yield. Hence, making these micro-nutrient fertilizers easily available to smallholder farmers in remote areas will go a long way in enhancing productivity and production of pulses**.** Under a mission to boost productivity of rainfed agriculture through science-led interventions in Karnataka (called the Bhoochetana project) the improved management practices (including application of micronutrients) have increased the yield by 31-57% in green gram, 26-38% in pigeonpea and 27-39% in chickpea during 2010-11. Similarly in 2011-12 black gram and green gram grain yields increased by 33-42% in response to improved management when compared to farmers management (Wani *et al*, 2012).

f. Response to irrigation

In many areas, grain legumes are grown under moisture stress conditions. Crops such as cowpea, pigeonpea, and chickpea are grown where soil water may be substantially limiting. Yields are necessarily limited by the amount of water available to support growth. Supplemental irrigation with a limited amount of water, if applied to rainfed crops during critical stages can result in substantial improvement in yield and water productivity. A recent review by Sinclair and Vadez (2012) has quantified this relationship. Results have shown that by doubling the available soil water from 150mm to 300mm will double yield to 3.52 t ha^{-1} (Sinclair and Vadez, 2012). This shows the great potential for enhancing the legume crop yields through providing irrigations. Studies have showed that in chickpea and lentil supplemental irrigation can significantly increase seed yields and water use efficiency (WUE) (Zhang *et al*, 2000; Oweis *et al*, 2004). In both chickpea and lentil, yields increased linearly with the amount of water applied. While supplemental irrigation is not always available, where it is available, it is a means of significantly increasing grain legume yields and WUE (Siddique *et al*, 2012).

g. Mechanization

Many pulses are harvested by hand in India because the available cultivars are not suited to mechanical harvesting. In developed countries, such as Australia, Canada and USA, pulses like chickpea, lentils etc. are harvested mechanically. With continuously increasing labor cost, manual harvesting has become an expensive field operation for many crops including pulses in India and farmers are increasingly opting for mechanical harvesting where it is feasible. The farmers, particularly in Andhra Pradesh, are demanding chickpea cultivars suited to mechanical harvesting. The current chickpea cultivars are not suited to mechanical harvesting because the plant height is not adequate and the branches are close to ground due to semi-spreading growth habit. Development of chickpea cultivars with 30 to 40% more height than the existing cultivars and semi-erect to erect growth habit will make the cultivars suited to mechanical harvesting (Gaur *et al*, 2012). Availability of cultivars suited to mechanical harvesting will reduce production cost and attract farmers towards increased pulses cultivation.

The other production practice where cost of cultivation can be reduced substantially is by promoting use of post-emergence herbicides in controlling weeds by developing herbicide tolerant cultivars. In general, pulses are sensitive to herbicides and manual weeding is currently the only option for weed control.

Management of weeds in pulses is becoming expensive and in some cases uneconomical due to high labor cost involve in manual weeding. Herbicide-tolerant cultivars offer opportunity of controlling weeds through need-based applications of herbicides. Weed management through herbicides is not only economical but also facilitate zero-tillage or minimum tillage methods.

Conclusion

India needs around 32 million tons of pulses by 2030, to feed the estimated population of about 1.68 billion. Global supply of pulses is limited, as India happens to be the largest producer and consumer of pulses. Hence, India needs to produce the required quantity, but also remain competitive to protect indigenous pulses production. Improved technologies (improved, high yielding varieties and appropriate crop management practices) are available. However, a concerted effort by farmers, researchers, development agencies, and government are needed to ensure that India becomes self-sufficient in pulses in the next 5-10 years. The recent efforts and programs initiated by the government are bearing fruits, and it is hoped that this momentum is sustained and strengthened to make India self-sufficient in pulses.

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