Carrying capacity of Indian agriculture: pulse crops

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India is the largest producer, consumer, importer and processor of pulses in the world. Ironically, the country's pulse production has been hovering around 14–15 Mt, coming from a near-stagnated area of 22–23 M ha, since 1990–91. For meeting the demand of the growing population, the country is importing pulses to the tune of 2.5–3.5 Mt every year. Strong upward trend in the import of pulses is a cause of concern, since an increase in demand from India has shown to have cascading effect on international prices, thus draining the precious foreign exchange. By 2050, the domestic requirements would be 26.50 Mt, necessitating stepping up production by 81.50%, i.e. 11.9 Mt additional produce at 1.86% annual growth rate. This uphill task has to be accomplished under more severe production constraints, especially abiotic stresses, abrupt climatic changes, emergence of new species/ strains of insect-pests and diseases, and increasing deficiency of secondary and micronutrients in the soil. This requires a two-pronged proactive strategy, i.e. improving per unit productivity and reducing cost of production. This article describes the present availability of pulses, demand projections in different time-frames, future challenges, and technology drivers for increasing pulse production in the country. A scheme has also been suggested for achieving self-sufficiency in pulses by 2050.

Keywords: Climate change, growth projections, pulses, technology drivers.

Introduction

PULSES are the basic ingredient in the diets of a vast majority of the Indian population, as they provide a perfect mix of vegetarian protein component of high biological value when supplemented with cereals. Pulses are also an excellent feed and fodder for livestock. Endowed with the unique ability of biological nitrogen fixation, carbon sequestration, soil amelioration, low water requirement and capacity to withstand harsh climate, pulses have remained an integral component of sustainable crop production system since time immemorial, especially in the dry areas. They also offer good scope for crop diversification (grow profitably in relatively low-input management conditions) and intensification (short growing period).

During 2009–10, the country produced 14.66 Mt of pulses from 23.00 M ha area, with an average yield of 637 kg/ha. The third advanced estimates for the year 2010–11 provided by the Department of Agriculture and Co-operation projected pulses production at 17.29 Mt, which is quite encouraging. These figures make India the largest producer of pulses in the world. With the large population dependent on pulses for protein requirements, India is also the largest consumer and importer of pulses. Ironically, the country's pulse production has been hovering around 14–15 Mt, coming from a near-stagnated area of 22–23 M ha, since 1990–91. During this period, an additional population of 350 million has been added, which led to a sharp decline in the availability of pulses from 41 in 1990–91 to 33 g/capita/day in 2009–10, doubling its import (from 1.27 to 2.35 million) and resulting in skyrocketing prices. Shortfall in pulses has been attributed to a number of factors, the major ones being the increasing population, rising income, geographical shift, abrupt climatic changes, complex disease–pest syndrome, socio-economic conditions and poor marketing opportunities.

Present status

India is the largest producer of pulses in the world, with 24% share in the global production. The important pulse crops are chickpea (48%), pigeonpea (15%), mungbean (7%), urdbean (7%), lentil (5%) and fieldpea (5%). The major pulse-producing states are Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka and Andhra Pradesh, which together account for about 80% of the total production. The area under chickpea has increased from 6.4 M ha in 1993–94 to 7.97 M ha in 2008–09. Similarly, in pigeonpea, the area increased slightly from 3.53 M ha to 3.73 M ha and production from 2.69 Mt in 1993–94 to 3.08 Mt in 2007–08. But area and production of pigeonpea declined in 2009–10 to 2.66 M ha and 2.47 Mt respectively. There was a positive growth in production of chickpea and pigeonpea in Andhra Pradesh, Karnataka and Maharashtra because of significant increase in area and productivity during the period. In Andhra Pradesh, the area under chickpea has increased from 71 thousand ha in 1991–93 to 619 thousand ha in 2007–09, and productivity from 621 to 1264 kg/ha. In

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Maharashtra, the area increased from 569 thousand ha in 1991–93 to 1273 thousand in 2007–09, and the production from 288 to 975 thousand tonnes in the same period. Similarly, in Karnataka, the area under chickpea increased 3.1 times and production increased 4.8 times during the same period.

In case of pigeonpea, the area increased from 333 thousand ha in 1991–93 to 435 thousand ha in 2007–09 in Andhra Pradesh, 1014 thousand ha to 1102 thousand ha in Maharashtra, and 470 thousand ha to 624 thousand ha in Karnataka. There was positive growth in area, production and productivity of lentil in Bihar, Madhya Pradesh and Uttar Pradesh, the major lentil-growing states. Area under lentil has increased from 1.18 M ha in 1993–94 to 1.81 M ha in 2007–08, while production has increased from 0.75 Mt to 0.91 Mt during 2006–07, which has been reduced to 0.81 Mt in 2007–08. Presently, mungbean and urdbean occupy 3.77 and 3.24 M ha area respectively, in the country which was hovering at 3.00 M ha each in 1990–93. This coupled with positive growth in productivity has led to an increase in production to 1.56 and 1.52 Mt in mungbean and urdbean. Rajasthan has shown an impressive growth in area under mungbean from 366 thousand ha in 1991–93 to 872 thousand ha in 2007-09 due to development of short-duration, yellow mosaic-resistant varieties with higher level of productivity. Maharashtra has also shown a significant increase in area. In the case of urdbean, Uttar Pradesh has shown progressive increase both in area and production. Highest increase in productivity of chickpea during 1991–93 to 2007–09 has been recorded in Andhra Pradesh (105%), followed by Karnataka (52%), Maharashtra (48%) and Gujarat (44%), whereas in pigeonpea Andhra Pradesh (94%), Karnataka (85%), Maharashtra (65%) and Gujarat (19%) recorded significant improvements. Madhya Pradesh recorded significant growth in lentil, whereas it also showed impressive performance in fieldpea. Madhya Pradesh showed 24% increase in productivity in area under urdbean. For mungbean, Andhra Pradesh (13%), Uttar Pradesh (18%), Madhya Pradesh (8%) and Maharashtra (6%) showed impressive perform in production. The trend in productivity and production of pulses indicated the potential of existing technology for further increase in pulse production in some states in the country[1].

Demand projections

Over last 100 years, India's burgeoning population has seen a fivefold increase. Projections made by the government, with the present growth rate of 1.45%, show that the population will increase to 1613 million by 2050, surpassing China (1417 million). The consumption requirements alone for the 1613 million people, on normative requirement of 14.60 kg pulses/capita/yr as recommended by National Institute of Nutrition, Hyderabad, works out to be 23.55 Mt, which in terms of production requirements would be about 26.50 Mt, assuming seed, feed and wastage as 12.5% of the gross output.

As against total pulse requirements of 18.33 Mt for 2009–10, the domestic production is only 14.60 Mt. The annual import of 2–3 Mt provides only partial relief and checks escalation in the market price. By 2050, the domestic requirement would be 26.50 Mt (Table 1), necessitating stepping up production by 81.50%, i.e. 11.9 Mt additional produce at 1.86% annual growth rate. The additional production of 7.90 Mt has to come through productivity enhancement and the rest (2.50 Mt) from horizontal expansion in area. The growth rate of pulse production was just 1.52% in the 1980s and 0.59% in the 1990s. It has significantly increased to 1.42% during 2001–08. At present the growth rate in production is only 0.6%. The growth rate in the total area under pulses was negative both in the 1980s and 1990s. Assuming that the area remains constant, as seen during last four decades, 2.05% annual growth rate in productivity will be required to achieve 26.5 Mt by 2050 (Figure 1). As discussed above, some states like Andhra Pradesh, Maharashtra and Karnataka have already demonstrated high productivity growth in chickpea (51–125%) and pigeonpea (64–110%) during 1991–93 to 2006–08. This assures that the targets as shown in projections can be achieved with appropriate technology back-up and special efforts for promotion of production in the country.

Challenges ahead

Changing climate

The predicted changes in temperature and their associated impacts on rainfall and consequent availability of water to crops and extreme weather events are all likely to affect substantially the potential of pulse production[2]. The most worrying part of the prediction is the estimated increase in winter and summer temperatures by 3.2° and 2.2°C respectively, by 2050. Such abnormal rises will surely have an adverse impact on pulse production in the form of a reduction in total crop-cycle duration. Most of the pulses like mungbean and urdbean are short-duration crops (65–75 days). Further reduction in crop duration will amount to a lower yield per unit area. Among pulses,

Table 1. Requirement, production and import of pulses in India

Year	Population (million)	Requirement (Mt)	Production (Mt)	Import (Mt)
2000–01	1027	16.02	11.08	0.35
2004–05	1096	17.10	13.13	1.31
2009–10	1175	18.33	14.60	2.83
2020–21	1225	19.10		
2050–51	1613	26.50		

pigeonpea is sensitive to abrupt fluctuations of temperature, either lower or higher extremes leading to massive flower drop. This negative impact of temperature extremities is, however, largely compensated by regular fresh flush of flowers that keep on appearing during the developmental stages concomitant with favourable temperatures. However, at extreme temperatures the serious adverse impact was observed on pod setting. Daily maximum temperature above 25°C is considered as the threshold level for heat stress in cool-season pulse crops, as it affects seed yield by reducing flowering, fertilization and seed formation. Cool-season pulses such as chickpea, lentil and lathyrus have reasonably high tolerance to heat which enables them to set pods, but filling of pods is seriously jeopardized at high temperature leading low productivity. During the past few years, an abrupt rise in temperature has been observed in January and February in North India, which led to poor yield in winter pulses. In an experiment on fieldpea variety HUDP 15, it was observed that high temperature (> 25°C) coincided with the onset of reproductive phase. It affected not only total biomass, but also reduced pod setting by 30%, seeds per pod on 41% and seed weight by 36%, and as a result the overall productivity reduced drastically (48%).

Geographical shift in area

A significant regional shift in the area of the pulses has been witnessed during the post-green revolution period. The area under cultivation of pulses in the northern plains has presently (2006–10) remained below half compared to the total area that existed almost four decades ago (1971–75; Figure 2). On the contrary, the area in Central and South India has been consistently increasing and has now almost doubled. This has been more conspicuous in the case of chickpea. The area under chickpea decreased from 5.1 M ha to 2.06 M ha in North India, and increased from 2.39 M ha to 5.2 M ha in Central and South India (Figure 3).

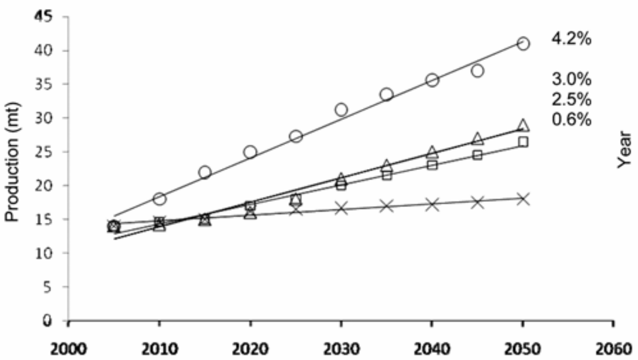

Figure 1. Production growth rate in pulses to meet projected requirements.

Emerging new insect-pests

Pulses are highly prone to an array of insect pests and diseases. There is clear evidence that climate change is altering the distribution, incidence and intensity of pests and diseases. In the past, gram pod borer (*Helicoverpa armigera*) has been a major pest of pigeonpea in most parts of the country. Now the pod fly (*Melanogromyza abtusa*) is emerging as a serious pest of pigeonpea in Central and South India. Similarly, spotted pod borer (*Maruca vitrata*) has now become a major pest of short-duration pigeonpea both in North and Central India. Thrips are emerging as a major threat for mungbean and urdbean cultivation in India. Viral diseases are also assuming epidemic forms in major pulse crops. Therefore, an appropriate IPM strategy needs to be developed to manage new insect-pests. Further, strong forecasting and forewarning modules are necessary to predict the incidence of these pests well in advance.

Deteriorating soil health

Most of the cultivated areas have started showing signs of stress with production fatigue and deterioration of soil

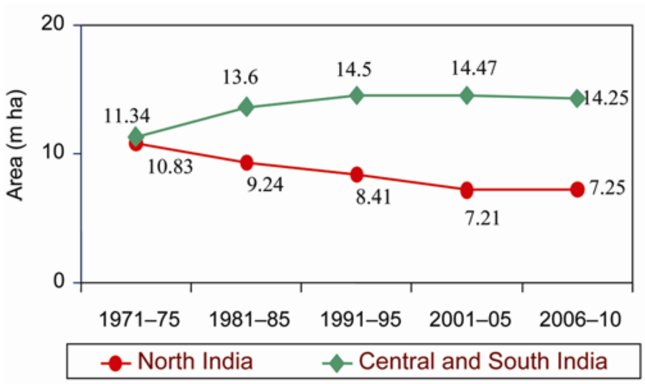

Figure 2. Geographical shift of total pulses: North versus Central and South India.

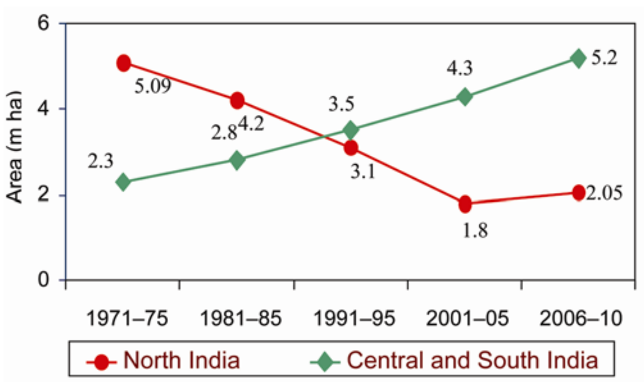

Figure 3. Geographical shift in chickpea area.

health. In many such areas, yields have started declining because of deceleration in total factor productivity, decline in organic matter content in soil and emergence of multi-nutrient deficiencies. An experimental result shows that deficiency of micronutrients, especially sulphur and zinc is widespread among pulse-growing regions. Out of 137 pulse-growing districts, 87 districts show 20–60% sulphur deficiency. About 50% pulse-growing districts having Zn deficiency[3]. These nutrients are important for increasing pulse production in the country. About 40% of the pulse-growing regions have low-to-medium population of native *Rhizobium*. Appropriate measures are required for sustained pulse production by maintaining soil health with diversification, balanced fertilization and use of bio-fertilizers.

Success story of chickpea cultivation in Andhra Pradesh

Andhra Pradesh has not been the traditional chickpea-growing area of the country till 1993. However, there has been phenomenal increase in area, production and productivity of chickpea in the state. The area has increased from 71 thousand ha in 1991–93 to 619 thousand ha in 2007–09 (more than eight times), and productivity from 621 to 1264 kg/ha (more than double). This phenomenal increase has never been witnessed in any crop in such a short span in any part of the country. This could be possible due to development of appropriate varieties with shorter duration, availability of quality seeds of improved cultivars, government efforts in creating necessary, infrastructure for cultivation and effective transfer of technologies. Now chickpea has been regarded as a remunerative crop of Andhra Pradesh. These efforts need to be multiplied for other pulse crops in different parts of the country.

Approaches for achieving self-sufficiency in production of pulses in India by 2050

In order to achieve self-sufficiency in pulses, the projected requirement by the year 2050 is estimated at 26.5 Mt. To meet this requirement, the productivity needs to be enhanced to 978 kg/ha, and an additional area of about 3.0 M ha has to be brought under pulses besides reducing post-harvest losses. This uphill task has to be accomplished under more severe production constraints, especially abiotic stresses, abrupt climatic changes, emerging insect-pests, and secondary and micronutrient deficiency in the soil[4]. This requires a proactive strategy from researchers, planners, policy-makers, extension workers, market forces and farmers aiming not only at boosting the per unit productivity of land, but also at reduction in the production costs. The strategies given in Table 2 require immediate attention, which can have substantial bearing on pulse production without further constraining natural resources.

Technology drivers for achieving self-sufficiency in pulses

Adoption of existing technology for bridging the yield gap

Farmers generally apply sub-optimal doses of fertilizers, insecticides and limited irrigations for pulses after meeting the requirements of wheat, rice and vegetable crops. Therefore, wide gaps also exist between yields realized in experimental plots, frontline demonstration plots and farmers' fields. Large-scale on-farm demonstrations conducted in the last 5 years have clearly shown superiority of new technologies over the local practices. Adoption of these technologies can increase pulse production by at least 13–42% in the country (Table 3). Improved varieties of different pulse crops hold promise to increase productivity by 20–25%, whereas package technology comprising improved varieties and integrated management of nutrients and pests has shown 25–42% yield advantage over the farmers' practices in a large number of frontline demonstrations conducted across the country. Improved production technologies like raised bed planting, ridge furrow planting, seed treatment with *Rhizobium*, application of sulphur @ 20 kg/ha, pre-emergence application of pendimethalin @ 1–1.25 kg/ha, foliar spray of 2% urea/DAP, and bio-intensive IPM modules have been advocated after experimentation and large-scale frontline demonstrations. Under complex rainfed areas, the farmer participatory research (FPR) needs to be developed and involve farmers more closely in on-farm research. Farmer-participatory testing will help refine the technologies, pinpoint and eliminate adoption constraints. Large-scale demonstrations on farmer's fields need to be conducted with the involvement of extension agencies of ICAR, SAUs, KVKs, etc. These efforts may easily push average productivity from 637 to 737 kg/ha, which means expected production of 17.69 Mt by 2020.

Institutional support

Improving seed replacement rate: Inadequate supply of quality seeds of improved varieties remains one of the greatest impediments in bridging the wide gap between potential and harvested yields. The breeder seed production has increased from 4100 q in 1998–99 to 13,400 q in 2009–10. However, the efforts have been inadequate in meeting the seed requirement mainly due to poor conversion of breeder seeds into foundation and certified seeds, resulting in the poor availability of quality seeds. The fluctuating market prices of pulse grains sometimes resulted into poor conversion. High market prices during

Table 2. Proposed strategies to meet target

Strategy	Target	Production target by 2050 (Mt)
Productivity enhancement	Improving productivity from 637 to 978 kg/ha	22.5
Horizontal expansion	Bringing 3.0 M ha additional area under pulses	2.5
Minimizing post-harvest losses	Saving 1.5 Mt loss in production	1.5
Total		26.5

Time-frame

Approach	Time-frame	Target	Drivers	Targeted production	
Productivity enhancement	2011–2025	Increase in productivity from 637 to 787 kg/ha	Existing technologies, institutional support	18.10 Mt (2025)	
	2025–2040	Increase in productivity from 787 to 937 kg/ha	New technology	21.55 Mt (2040)	
	2040–2050	Increase in productivity from 937 to 978 kg/ha	New technology	22.50 Mt (2050)	
Horizontal expansion	2011–2025	Increase in area from 23 to 24 M ha (additional area 1.0 M ha)	Cropping system manipulation, crop diversification and multiple cropping system	Additional production 0.8 Mt (2025)	
	2025–2040	Increase in area from 24 to 25.5 M ha (additional area 1.5 M ha)	New Niches (rice fallows, kharif fallows of Bundelkhand, foothills of Terai, etc.)	Additional production 0.9 Mt (2040)	
	2040–2050	Increase in area from 25.5 to 26 M ha (additional area 0.5 M ha)	Intercropping of short-duration pulses	Additional production 0.25 Mt	
Minimizing post-harvest losses	2011–2025	6% reduction in existing level of post-harvest losses	Custom-hiring of machines for harvesting and threshing	Promotion of pulses in high-productivity zones	Additional production 0.8 Mt (2050). Total additional production 2.5 Mt
	2025–2040	16% reduction in existing level of post-harvest losses	Ensuring availability of machines at Panchayat level	0.6 Mt reduction in existing level of post-harvest losses	
	2040–2050	30% reduction in existing level of post-harvest losses	Infrastructure support for processing and storage	1.5 Mt reduction in existing level of post-harvest losses	

Table 3. Yield advantage (%) from improved technologies of pulse crops under frontline demonstrations (2006–09)

Technology	Chickpea	Pigeonpea	Lentil	Mungbean	Urdbean	Fieldpea
Improved varieties	22.4	24.7	23.6	23.3	21.9	20.0
Sulphur application	15.4	17.4	20.3	19.0	19.9	24.1
Rhizobium inoculation	13.4	13.5	21.0	11.1	14.2	13.2
Weed management	40.0	30.0	24.7	29.6	18.3	26.4
IPM	19.9	28.1	13.1	20.4	17.6	20.2
Full package	24.9	34.6	41.9	33.9	27.8	40.1
Number of demonstrations	3480	3773	1454	1640	1098	686

harvesting affect the procurement of seed by seed corporations, as most of seed agencies depend on the farmers for multiplication of foundation and certified seeds. Sometimes, seed growers sell the produce in local markets if they get better price, which ultimately affects the whole seed chain for the coming years. This can be explained with one example, when seed agencies organized multiplication of mungbean seed in the summer/spring season of 2009–10 at the farmer's fields. The market price of mungbean at the time of harvesting reached to Rs 70/kg and farmers preferred to sell the produce to local markets as seed growers were not able to pay them at market price. Further, seeds of pulse crops are vulnerable to stored grain pests, and lack of safe storage facilities are formidable barriers for seed multiplication by private seed growers.

Presently, the total supply of quality seeds of pulse varieties is around half of the present requirement of 13 lakh q, assuming 15% seed replacement rate. Therefore, necessary infrastructure needs to be strengthened at the seed corporations. For seed multiplication of foundation and certified seeds, there is need to identify private seed growers. The intention should be to double the national seed production while making seed readily available to farmers by virtue of a decentralized approach. Advance seed planning is required for each state, rolling out seed plans with appropriate emphasis to the newly released varieties. Seed buffer of improved varieties must be maintained at the State Seed Corporation level. Public–private partnership needs to be promoted in seed business; farmers' participatory seed production needs to be encouraged for farmer-to-farmer seed spread. These efforts will adequately improve seed replacement rate.

Provision for life-saving irrigation in pulse-growing districts

There has been a high degree of risk in the production of pulses. More than 87% of the area under pulses is presently rainfed. The mean rainfall of major pulse-growing states such as Madhya Pradesh, Uttar Pradesh, Gujarat and Maharashtra is about 1000 mm, and the coefficient of variation of rainfall is 20–25%. Moisture stress is the oft-cited reason for crop failure, and many a times accompanied by low yields. A quantum jump in productivity can be achieved by applying life-saving irrigation, especially in rabi pulses grown on residual moisture. Rain water harvesting and for life-saving irrigation is necessary for yield stability and higher productivity. For this, farm ponds and community reservoirs need to be created in every village of the pulse-growing districts of the country. Provision of micro-irrigation through sprinklers or drip should also be made at the Panchayat level.

Ensuring availability of critical inputs

Although good results have been obtained in research stations, the adoption of integrated nutrient management technologies by farmers is dismal at the farm level. Application of micronutrients in deficient soil is important for increasing pulse production in the country. About 40% of the pulse-growing regions have low to medium population of native *Rhizobium.* Seed inoculation with bio-fertilizer (*Rhizobium*; low cost input) can increase pulse productivity by 10–12%. Vesicular arbuscular mycorrhizae offer promise for improving supply of phosphate and micronutrients like zinc for a variety of pulse crops. Phosphate solublizers are yet another group of hydrotropic organisms which may have applicability in rainfed pulse production systems, particularly in soils with poor phosphorus availability. Lack of quality culture in adequate quantity is one of the major constraints in popularization of bio-fertilizers. Therefore, efforts are needed to ensure availability of critical inputs like bio-fertilizers, sulphur, zinc, bio-pesticides, etc. at the state level.

Mechanization for pulse production

Machines are essential for important agricultural operations like planting, harvesting, intercultivation, etc. Ridge planting of pigeonpea, and raised-bed planting of kharif and rabi pulses proved to be important techniques for raising productivity. Designing farm implements is required for tilling, sowing and fertilizer application, and other operations to reduce cost of production. These machines need to be made available either through cooperatives or custom hiring.

Policy support for value chain

The Government of India initiated several developmental programmes to accelerate growth in pulse production. Pulses were brought under the ambit of the Technology Mission in 1990, and subsequently converged into Integrated Scheme on Oilseeds, Pulses, Oilpalm and Maize (ISOPOM). A large number of frontline demonstrations on newly released varieties and production technologies are being organized by National Agricultural Research System (NARS). Seed production and distribution systems have been strengthened with a provision of financial assistance. Some of the critical inputs like bio-fertilizers, bio-pesticides, gypsum (as a source of S), Zn and sprinkler irrigation units have been subsidized to make their use/application feasible. In 2007, GoI launched the 'National Food Security Mission' under which pulses are covered. The mission aims at increasing pulse production by 2 Mt by 2011–12. Amongst various interventions, quality seed production and capacity building receive high priority under the mission, which are being executed by ICAR. Besides improving production base and advocating improved crop management practices, good investment in research is required to develop high-yielding and multiple disease-resistant varieties/hybrids, transgenics against *Helicoverpa armigera*, and drought and efficient input use systems. Provisions should be made for easy credit, insurance, attractive Minimum Support Price (MSP) with procurement and appropriate incentives (subsidies). Necessary infrastructure needs to be created for processing and value-addition. Innovative institutional models of marketing like *Amul*, *Parag*, *Dhara*, etc. need to be established for monitoring and executing the value chain of pulses from production to consumption.

New technologies

Improved varieties/hybrids/transgenics

Compared to cereals, yield breakthrough in pulses has not been achieved, although breeding efforts in the past were rewarding in terms of insulation of varieties against major diseases (bringing stability), reducing crop duration (promoting crop diversification and intensification) and improving physical grain quality (seed size and colour). For a major breakthrough in yield, there is urgent need to broaden the genetic base by strengthening pre-breeding and developing core sets of germplasm; harnessing hybrid vigour through development of CMS-based hybrids in pigeonpea; mapping and tagging of genes/QTLs and marker-assisted selection for resistance to insect pests and diseases, yield and grain quality; gene pyramiding for stable resistance; development of transgenics in chickpea, pigeonpea and *Vigna* for problems hitherto unsolved through conventional means like *Helicoverpa* pod borer and drought, and genomic research for understanding the structure and function of genes. High-yielding and input-responsive genes are yet to be searched and transgressed in common varieties[5].

Good agronomic practices

It has been amply demonstrated that good agronomic practices alone can lead to increase in yield to the tune of 25–40%. However, development of efficient production technologies is further required with special emphasis on inter-cropping. There is also a need to develop appropriate production technologies for non-traditional areas and the cropping systems involving pulses, i.e. relay cropping rice fallows, summer/spring cultivation. Since the availability of labour for farm operations is reducing and cost of labour is increasing, there is need to develop crop management technologies for reducing the cost of production. Efforts are also needed to develop production technologies with innovative plant geometry to harness the energy sources. Depending upon amount and distribution of rainfall, pulses could be grown under double cropping (annual rainfall > 750 mm); intercropping (600–750 mm) and mono-cropping (< 600 mm rainfall) systems. Efficient intercrops for pulses need to be identified and popularized among the farmers[6].

Integrated disease and pest management

Insulation of crops against biotic stresses is most critical in enhancing crop productivity. *Fusarium* wilt is a serious problem in pigeonpea, chickpea and lentil, causing substantial yield loss. Host-plant resistance is the best option. However, non-availability of seeds of wilt-resistant varieties and existence of pathogenic variability call for integrated approach of wilt management. A glaring example of containing pigeonpea wilt has been well demonstrated in Maharashtra. This could be possible by ensuring fungicide treatment of seeds being sold to farmers, adequate production and distribution of *Trichoderma* and creating awareness about the wilt-resistant varieties. *H. armigera*, the key pest of chickpea and pigoenpea, continues to cause heavy losses. IPM modules for management of this dreaded pest have been developed and field-tested. These modules will be effective only after ensuring accurate forewarning and forecasting of disease and pest epidemic. Integrated management of diseases and pests including use of resistance cultivars, use of healthy seeds, modification of cultural practices, judicious use of fungicides and bio-control agents may contribute substantially in stabilizing the yields. Therefore, it is imperative to refine and modify the IPM modules according to the needs.

Improved machines for harvesting, threshing, processing and transportation

At present, post-harvest processing of pulses is mainly handled by the private sector. Installation of efficient, small dal chakkies/processing units in villages on subsidized rates will reduce the cost of processing and hence ensure their ready availability at cheaper rates. Distribution of seed-storage bins to the farmers at subsidized rates and mass awareness campaign for adoption of scientific methods of storage of pulses at the village level are likely to reduce losses from stored grain pests in pulses. Efforts to minimize the post-harvest losses in pulse crops must be made in the national interest.

Area expansion

Pulses have tremendous scope for area expansion. Short-duration varieties of pulses can fit well in various cropping systems. About 2.5 M ha additional area can be brought under different pulses through cropping system manipulation, like mungbean and urdbean as catch crop in summer/spring under cereal-based cropping systems of IGP, intercropping short-duration pulses (mungbean, urdbean, cowpea) in sugarcane, millets cotton, etc. advocating new cropping systems such as pigeonpea–wheat in the north, rice–lentil in the east and urdbean–rice in the southern peninsula. Out of 10.5 M ha rice fallows of eastern (Uttar Pradesh, Bihar, West Bengal, Assam), Central (Chhattisgarh) and southern states (Andhra Pradesh, Karnataka, Tamil Nadu), 2.5 M ha can be utilized by expanding lentil, mungbean and urdbean cultivation.

Minimizing post-harvest losses

Post-harvest losses in pulses during harvest, transport, threshing and storage are estimated[7] to be 15–20%. Storage losses alone[8] account for 7.5%. A mass awareness programme to educate farmers about scientific storage and distribution of seed-storage bins will considerably reduce spoilage of grains and ensure better-quality grains. Similarly, installation of efficient and modern dal mills in the production hub is expected to increase dal recovery by 8–10%. At village/Panchayat level, the mini dal mills developed by IIPR, CIAE, CFTRI and other institutions need to be popularized so that the farmers can get higher return from their produce, store them for a longer period and generate self-employment.

Public–private partnership

Besides public institutions (ICAR, SAUs), development departments and other organizations like NGOs, seed companies, farmers' associations, civilized societies and private entrepreneurs should also be involved in promoting pulse production by way of quality seed production, transfer of technology, processing and value addition, and supply of critical inputs.

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