Pulses Production Technology: Status and Way Forward

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India is the largest producer and consumer of pulses in the world. However, pulses production has been stagnant at between 11 and 14 million tonnes over the last two decades. Per capita pulses consumption over the years has come down from 61gm/day in 1951 to 30 gm/day in 2008. This paper analyses the status of pulses production technology, constraints in cultivation of pulses and the possibilities of increasing production. It emphasises the expansion of area under short duration varieties, development of multiple disease/pest resistance varieties, use of micro-nutrients like zinc and sulphur and increase in area under rabi pulse crops to increase pulses production. The minimum support price is not effective for pulse crops; prevailing market prices should be taken into account while fixing the MSP to bridge the gap between demand and supply.

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Introduction

Pulses in India have long been considered as the poor man's only source of protein. Pulses are grown on 22-23 million hectares of area with an annual production of 13-15 million tonnes (mt). India accounts for 33% of the world area and 22% of the world production of pulses. The major pulse crops grown in India are chickpea, pigeonpea, lentil, moongbean, urdbean and fieldpea. About 90% of the global pigeonpea, 65% of chickpea and 37% of lentil area falls in India, corresponding to 93%, 68% and 32% of the global production, respectively (FAOSTAT 2009). Due to stagnant production, the net availability of pulses has come down from 60 gm/day/person in 1951 to 31 gm/day/person (Indian Council of Medical Research recommends 65 gm/day/capita) in 2008.

Demand-Supply Gap

Even though recent years have seen diversification in consumption patterns away from pulses to livestock, vegetables and other meat products, India is short of supply by 2 to 3 mt annually (Table 1, p 74). Pulses are not only a low cost source of protein for majority of Indian consumers; they are also a low cost substitute for vegetables in periods of high prices of vegetables. An improvement in pulses production technology can reduce the cost of production and hence prices, and create scope for further increase in demand for pulse crops by replacing some portion of the disproportionately high level of cereals in the consumption basket for a balanced diet. There is scope for decreasing imports and increasing exports of pulses and also increasing the use of pulses in value added products such as papad, snack food and in the confectionery industry, etc.

The demand-supply gap is also reflected in the higher prices in recent years – retail price of pigeonpea reached as high as Rs 120 per kg and other pulses remained above Rs 70 per kg for more than six months. The recent price hike is the result of the simultaneous occurrence of lower stock levels and less domestic production both in domestic and global markets, and to some extent speculative activity in the commodity futures markets. Keeping this in view, the National Food Security Mission (NFSM) has targeted an increase in pulses production by 2 mt by 2012. Since the last 10 years, the minimum support price (MSP) announced for all pulse crops has been below the market price. For example, the current MSP is below Rs 30 per kg, while the market price is hovering around Rs 100 for pigeonpea. The government has never treated the MSP as an effective tool for increasing pulses production; it is of the opinion that market forces will take care of acreage allocation and production of pulses. High volatility in prices for long periods, low productivity, and stagnation in production technology have acted as disincentives for pulses production (Reddy 2006).

Table 1: Sources of Supply of Pulses in India

Year	Kharif Area (Million Ha)	Kharif Prodn (Million Tonnes)	Kharif Yield (Kg ha)	Rabi Area (Million Ha)	Rabi Prodn (Million Tonnes)	Rabi Yield (Kg ha)	Total Area (Million Ha)	Total Prodn (Million Tonnes)	Total Yield (Kg ha)	Imports (Million Tonnes)	Exports (Million Tonnes)	Total Consumption (Million Tonnes)
2000-01	10.7	4.5	417	9.7	6.6	684	20.4	11.1	544	0.4	0.2	11.2
2001-02	10.7	4.8	453	10.9	8.5	762	21.7	13.4	609	2.2	0.2	15.4
2002-03	10.0	4.2	417	10.6	7.0	661	20.5	11.1	543	2.0	0.2	13.0
2003-04	11.7	6.2	528	11.8	8.7	745	23.4	14.9	637	1.7	0.2	16.5
2004-05	11.3	4.7	417	11.4	8.4	735	22.8	13.1	577	1.3	0.3	14.2
2005-06	10.6	4.7	439	11.8	8.5	716	22.4	13.1	585	1.6	0.4	14.3
2006-07	10.7	4.8	449	12.5	9.4	751	23.2	14.2	612	3.7	0.4	17.5
2007-08	11.5	6.4	557	12.1	8.4	709	23.6	14.8	688	2.8	0.2	17.4
2008-09	10.4	5.0	484	12.6	9.2	726	23.0	14.2	617	2.3	0.1	16.4

Source: Department of Agriculture and Cooperation (2009).

Export-Import Scenario

Depending on the domestic shortfall in pulses production, India's net imports of pulses have ranged from 1 mt to 3 mt, while exports are one-tenth of the volume of imports. Imports of pulses increased from 0.58 mt to 3.1 mt between 1994-96 and 2007-09 and are projected to increase to 4 mt by 2012 (Table 1). The share of peas, chickpeas, pigeonpea and moong was higher in total imports. Peas, chickpeas, beans and pigeonpea showed increase in imports during 1994-96 to 2007-09 (Table 2). India also has a comparative advantage in the export of lentils, as it has been the largest export item among pulses during the last 10 years (Reddy 2006). Pulses shortfall may increase to 6.8 mt by 2020-21 and the anticipated increase in per capita consumption of pulses is from 9 kg per year in 2007-08 to 10.9 kg by 2020-21 (Joshi 2009). Overall, the above figures indicate that India needs to increase domestic production of peas, chickpeas, beans and pigeonpea as substitutes for surging imports, and lentils for export promotion.

Table 2: Change in the Trend of Import of Pulse Crops between 1992-94 and 2007-09

Commodity	Import (qty in Tonnes) 1994-96	2007-09	% Change
Peas	1,72,180	9,28,101	439
Chickpea	87,390	4,35,681	399
pigeonpea	96,200	3,59,094	273
Moong	33,570	2,20,080	556
Other beans	23,220	1,38,987	499
Lentils	30,040	87,488	191
Beans of the spp	40,730	45,009	11
Kidney beans	22,470	35,906	60
Urad	35,140	33,111	-6
Small red beans	190	21,857	11,403
Broad beans	30	63	110
Total pulses	5,79,120	23,05,377	298

Source: FAOSTAT (2009).

Sources of Growth

The growth rate of pulses production was just 1.52% in the 1980s and 0.59% in the 1990s. It has significantly increased to 3.42% during 2001-08 (Table 3). Growth rate in the total area under pulses was negative both in the 1980s and 1990s, while it was positive during 2001-08. Growth in yield of pigeonpea has been significantly higher (2.74%) during recent years, due to wider adoption of long duration varieties. While rapid growth in the production of chickpea has mainly been through higher growth of area in south India with the expansion of area under rice fallows, the growth rate in yield and area in case of other pulse crops is still quite low.

Table 3: Growth Rate of Major Crops in India

Commodity	1981-90 Area	Prodn	Yield	1991-2000 Area	Prodn	Yield	2001-08 Area	Prodn	Yield
Chickpea	-1.41	-0.81	0.61	1.26	2.96	1.68	4.7	5.51	0.77
Pigeonpea	2.3	2.87	0.56	-0.66	0.89	1.55	0.91	3.66	2.74
Total pulses	-0.09	1.52	1.61	-0.6	0.59	0.93	1.91	3.42	1.65
Total foodgrains	-0.23	2.85	2.74	-0.07	2.02	1.52	0.48	2.09	2.82
Rice	0.41	3.62	3.19	0.68	2.02	1.34	-0.14	1.87	2.0
Other pulses	0.02	3.05	3.03	-1.61	-1.58	0.04	0.76	1.59	0.82
Wheat	0.46	3.57	3.1	1.72	3.57	1.83	1.29	1.36	0.08

Source: Department of Agriculture and Cooperation (2009).

The yield of pulses has remained virtually stagnant for the last 40 years (539 kg/ha in 1961 to 544 kg/ha in 2001 to 617 kg/ha in 2009) (Table 1). India's rank in productivity is 24th in chickpea, 9th in pigeonpea, 23rd in lentil, 104th in dry bean, 52nd in field pea and 98th in total pulses (FAOSTAT 2009). Productivity of pulses has also slightly increased in recent years, basically due to the expansion of area of rabi pulses, higher growth in yield of pigeonpea and higher growth rate in prices of pulses (20.9% per annum for chickpea, 32.9% per annum for urad, 5.8% per annum for pigeonpea from 2004-08) compared to prices of other crops, which encouraged higher input use. As revealed in Table 1, yield levels of kharif pulses (417 kg/ha to 557 kg/ha) is lower than rabi pulses (684 kg/ha to 751 kg/ha). It indicates that rabi pulse crops like chickpea, lentil, moong and urad and long duration pigeonpea have a higher potential in expanding the production of pulse crops. In north India, rice-wheat crop rotation is predominant, and there is little scope for replacing wheat with rabipulse crops, while in south India, there are vast patches of rice fallows, which can be utilised for sowing rabipulse crops, as there is no strong competitive crop in the rabi season.

Pulses can enrich soil fertility by fixing nitrogen. It has been estimated that chickpea can fix (convert atmospheric nitrogen to organic nitrogen which can be available for subsequent crops) up to 140 kg nitrogen per hectare in a growing season, although measured values are usually in the range of about 20-60 kg nitrogen per hectare (Reddy 2004). It has been well established that long duration pigeonpea in northern India can fix in the order of 200 kg nitrogen per hectare when grown over a 40 week period. Pigeonpea can also have substantial residual effects on subsequent crops. For example, medium-duration pigeonpea grown at the International Crop Research Institute for Semi-Arid Tropics (ICRISAT) (Asia Center) could benefit a subsequent maize crop to an extent equivalent to 40 kg nitrogen per hectare. Taking into account these externalities (fertility improvement and sustainability) in pulses production, there is a need to provide incentives (subsidies for seed, etc) for expansion of area under pulses production.

History of Pulses Research, Development and Extension

In view of the success of the All India Coordinated Project on Maize in 1967, the Indian Council of Agricultural Research (ICAR) sanctioned an All India Coordinated Pulses Improvement Project (AICPIP) to conduct coordinated research in all the nine pulse crops. These coordinated research efforts concentrated on coordinating the research in several aspects of varietal development, integrated nutrient development, cropping systems, host plant resistance, integrated pest and disease management, biological nitrogen fixation, drought tolerance and other crop-specific and region-specific research. The impact of the varieties and technologies developed under the AICPIP becomes visible when 15-25% improvement in yield is achieved under the Front Line Demonstrations (FLDs) conducted every year across the zones, though diffusion of technology at the field level is not significant.

To enhance adoption of improved technology, a centrally sponsored National Pulses Development Project (NPDP) is in operation since the Eighth Plan (1985-86). Programme implementation, coordination, policy formulation, feed back mechanisms and monitoring, etc, is ensured by the Directorate of Pulses Development. To provide further impetus, the pulses sector has been brought under the ambit of the Technology Mission on Oil seeds and Pulses (TMOP) since 1990. During the Tenth Five-Year Plan, it was proposed to implement the Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) after merging four centrally sponsored ongoing schemes on oilseeds, pulses, palm oil and maize to make the programme more integrated and financially sound (Ministry of Agriculture and Cooperation 2004), with major emphasis on seed production, distribution and adoption of improved technology. These integrated research and extension efforts which aimed at better utilisation of fallow areas have been successful, and area under pulses has increased significantly in rice fallows in some parts of the country (Ali 2004), but benefits have been limited to localised areas with irrigation facilities.

Considering the importance of pulses in food security, the NFSM was launched during the Eleventh Five-Year Plan (2008-12) targeting important foodgrain crops – rice, wheat and pulses. The primary objective of the pulses component of the mission is to increase production of pulses by 2 mt through increase in area and productivity. The mission targets an area of 17 million hectares under pulses in 171 identified districts. Close to 4.05 million hectares is to be added to the area under cultivation by 2011-12 through the utilisation of rice fallows and inter-cropping with wider-spaced crops.

The mission aims at achieving the additional production of 2 mt by 2011-12 through increased adoption of improved and proven crop production and protection technologies such as hybrids and high yielding varieties, integrated management of nutrients, pests, weeds and improved tillage and other farm implements. The objective is to ensure adequate infrastructure for higher productivity by bridging yield gaps. NFSM is promoting agricultural technology and best practices that farmers have successfully adopted in other regions. The mission employs existing institutions to carry out its activities. It aims to strengthen the Agriculture Technology Management Agency (ATMA), an autonomous body with a mandate to assign specific programmes to various implementing agencies at the district level. Pilot projects have been provided to promote innovations in programme design and implementation, like the development of a methodology of mass propagation of hybrid pigeonpea seeds through ICRISAT (through seed village concept), to contain the menace of *neelgai*.

Constraints in Pulses Production

Even with the best efforts, pulses production and productivity has been stagnant. Due to the low productivity-low input nature, pulses are grown as residual/alternate crops on marginal lands after taking care of food/income needs from high productivity-high input crops like paddy and wheat by most farmers. Also, they grow as rainfed crops with little or no modern yield enhancing inputs. The low priority accorded to pulse crops may be related to their relatively low status in the cropping system. As a crop of secondary importance, in many of these systems, pulse crops do not attract much of the farmer's crop management attention. In addition to this, these crops are adversely affected by a number of biotic and abiotic stresses, which are responsible for a large extent of the instability and low yields. The following section deals with different technology constraints in pulses production, and strategies to overcome them (Table 4).

Table 4: Important Biotic and Abiotic Stresses Identified in Major Pulse Crops of India

Crop	Seasons	Stress	
		Biotic	Abiotic
Chickpea	Timely sown	FW, root rot, chickpea stunt, BGM, pod-borer	Low temperature
	Early sown	FW, root rot, AB, or chickpea stunt, pod borer	Terminal drought, salt stress
	Late sown	FW, pod borer	Terminal drought, cold
Pigeonpea	Kharif-early	FW, PB, pod-borer complex	Waterlogging
	Medium late	FW, SM, pod-borer complex	Cold, terminal drought, waterlogging
	Pre-rabi	FW, ALB, Pod fly	Cold, terminal drought
Moong	Kharif	MYMV, CLS, WB, sucking insect pests	Pre-harvest sprouting, terminal drought
	Zaid	MYMV, root and stem rot, stem agromyza, sucking insect pests	Pre-harvest sprouting, temperature stress, drought
	Rabi	PM, Rust, CLS	Terminal drought
Urad	Kharif	MYMV, anthracnose, WB, LCV	Terminal drought
	Zaid	MYMV, root and stem rot, stem agromyza	Pre-harvest sprouting, temperature stress, drought
	Rabi/rice fallow	Spot	Terminal drought
Lentil		FW, root rot, rust	Moisture, temperature

FW= Fusarium wilt, PB= Phytophthora blight, SM= Sterility mosaic, ALB= Alternaria leaf blight, MYMV= Moongbean yellow mosaic virus, BGM= Botrytis gray mould, AB= Ascochyta blight.
Source: Reddy (2006).

Abiotic Constraints

There has been a high degree of risk in pulses production. More than 87% of the area under pulses is presently rainfed. The mean rainfall of major pulse growing states such as Madhya Pradesh (MP), Uttar Pradesh (UP), Gujarat and Maharastra is about 1,000 mm and the coefficient of variation of the rainfall is 20-25%. Moisture stress is the oft-cited reason for crop failures. Terminal drought and heat stress results in forced maturity with low yields. Drought stress alone may reduce seed yields by 50% in the tropics. A quantum jump in productivity can be achieved by applying life saving irrigation especially in rabi pulses grown on residual moisture. Two genes – "efl-1" and "ppd" have been identified for early flowering and maturity to escape drought stress (ICCV-2 in south India). In collaboration with ICAR, ICRISAT has developed a unique short-duration (chickpea) variety ICPL-87. In a detailed impact study, Bantilan and Parthasarathy (1998) found that the variety/management package resulted in an average 93% yield increase over the system it replaced. This could have been tackled on two fronts – development of varieties tolerant to moisture stress and bringing more area under irrigation. Irrigated area under pulses has virtually remained stagnant at 13% of the total area. Availability of adequate soil moisture for crop growth depends on rainfall, water holding capacity and depth of soil in rainfed areas. In south India, water holding capacity of the soil often limits grain yield to the extent of 50% of that possible under irrigation on Alfisols. On the contrary, on vertisol soils, higher water holding capacity causes growth reduction up to 5-20%. Higher evapo-transpiration in south India during the rabi season causes severe constraints to chickpea yield under drought. Another major problem is salinity and alkalinity of soils. Salinity and alkalinity is high both in semi-arid tropics and in the Indo-Gangetic plains in irrigated areas, which is a cause for concern, as most pulses are susceptible to salinity and alkalinity.

Grain yield is mainly influenced by temperature. Cold is an abiotic stress, limiting the grain yield of pulse crops. All hot season pulses are sensitive to low temperatures, but generally these are not exposed to low temperatures. On the other hand, cool season pulses (chickpea) are often subjected to chilling temperatures especially in areas of north India. However there has not been much improvement in the development of chilling and frost tolerant varieties.

Poor drainage/water stagnation 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. Ridge planting has been found very effective in ensuring optimal plant stand and consequently higher yield. A simple ridger already available can effectively be used for this purpose. Since most pulse crops are drought tolerant, most of the research efforts have been confined to develop genotypes and associated production technologies to suit dry land conditions. Consequently, germplasm suited to high rainfall and irrigated conditions are lacking.

Biotic Constraints

More than 250 insect species are reported to affect pulses in India. Among these, nearly one dozen cause heavy crop losses. On an average 2-2.4 million tonnes of pulses with a monetary value of nearly Rs 6,000 crore are lost annually due to ravages of insect pest complex. Among them, pod borer (*helicovera armigera)* causes the most harm, followed by pod fly, wilt and root rot. Recently many successful trials have been conducted to control pod borer through using nuclear polyhedrosis virus (HANPCV), which has been found to be more efficacious in bringing about higher and quick mortality. In on-farm trials, *bacillus thruringiensis Berliner (Bt) var. kurstaki* has also been tested on pod borer, and field demonstrations resulted in 10-12% reduction in avoidable loss as against 11% in the use of a chemical pesticide. However, the successful release of Bt chickpea/pigeonpea varieties from either public or private research will take some more years. Another important pest affecting pulses are nematodes, among which root-knot nematodes are important in terms of spread and damage to crop yield, which have been effectively controlled by bio-agents. Trials at the Indian Institute of Pulses Research (IIPR) in infested fields have shown avoidable yield losses ranging 10-40% in irrigated and 15-30 % in rainfed areas from control of nematodes by utilising bio-agents (seed treatment with *trichoderma* sp) and chemicals recent developments of these bio-pesticides can also reduce harmful chemical residue in grains, which ultimately improve the quality of foodgrains. Research in insect pests has been concentrated only on *helicoverpa armigera*, multiple resistance varieties need to be developed in future to simultaneously control many pests.

Among important diseases, wilt in chickpea, sterility mosaic virus (SMV) in pigeonpea, yellow mosaic virus (YMV) and powdery mildew (PM) are common and more damaging. A few varieties possessing vertical resistance to one or two diseases such as wilt resistance in chickpea (ICP-8863) released by ICRISAT have had the highest impact in terms of adoption. Its adoption in northern part of Karnataka state, the primary target zone, has increased from 5% in 1987 to almost 80% now. It has resulted in stabilisation of production, expansion of crop area and increased incomes. Other varieties such as JD-315, KWR-108, ICCV-10 and H-82-2 have had limited success; SMV resistant in pigeonpea (Bihar and Pusa-9), YMV resistant in moongbean (PDM 84-139, PDM-54, Narendra Moong-1, Pant Moong-1, -2 and -4) and urdbean (Pant-U-19, Uttara, Narendra and Urd-1), PM resistance in pea (HFP-4, Shika, IM-9102 and DMR-11) and rust resistant in lentil (DPL-62,DPL-84 and Pant-L-406) varieties have been developed. The number of varieties released and adopted by farmers is given in Table 5 with their main characteristics.

Table 5: Improved Varieties of Pulses Released from 1991-2005

	Number of Varieties Released		
Year	1991-97	1998-2005	Major Characteristics
Pigeonpea	20	13	Tolerance to pod borer, pod fly, wilt, phytopthera blight, pre-rabi, 20-22 q/ha short duration (95 to 100 days), long duration (170-190 days)
Moong	21	19	Resistance to YMV, powdery mildew, jassids and whitefly, spring, medium to bold seeded
Urad	17	15	Tolerance to YMV, powdery mildew, rabi season, 12q/ha, 70-80 days to maturity
Lentil	9	4	Tolerance to rust and wilt, bold seeded, early maturing, 18-24 q/ha, 110 days to maturity
Pea	5	11	Resistance to powdery mildew, rust and leaf miner, 23q/ha, 95 to 100 days to maturity
Cowpea	11	10	Early maturing varieties, resistance to yellow mosaic virus, 12q/ha, some are for fodder purpose
Chickpea	18	34	Res to ascochyta blight, tolerance to wilt and root rot irrigated area, bold seeded, tolerance to pod borer, 25 to 30 q/ha, 75 to 100 days to maturity

Source: Department of Agricultural and Cooperation (2009).

Integrated Pest Management

By nature, pulse crop is attacked by more than one disease and pest at a time; hence there is a need for multiple disease resistant varieties. Recent developments in integrated pest management (IPM) have given wider scope for cost-effective control of multiple pests and diseases. IPM is essentially a farmer activity of using one or more management options to reduce pest population below the economic injury level, while ensuring productivity and profitability of the entire farming system. A variety of chemical, biological and cultural methods have been found to reduce pest and disease damage. Properly planned cropping systems involving crop rotation or intercropping of non-host and host crops, different agronomic practices like use of solar energy by summer ploughing preceding kharif pulses are cost effective components of IPM. However, farmers are hesitant to use IPM as it needs community approach and takes time to yield results. Since IPM is knowledge intensive, systems approach involving various disciplines to evolve an Integrated Crop Management (ICM) should be the goal in the future.

Physiological Limitations

There is a general feeling that pulses (C-3 plants) suffer from inherently low yield potential and are a physiologically inefficient group of plants compared to cereals (C-4 plants) such as sorghum and maize. However Aggarwal et al (1997), reviewed the comparative advantages of C-3 and C-4 group of plants and argued that C-3 and C-4 plants seem to compete on fairly even terms in hot dry environments. The fact that C-3 plants usually do better in cool climates suggests that C-3 plants are better for rabi season. However, the disturbing future is that the harvest index (HI) in pulses is low compared to cereals. HI is defined as seed yield per unit of recoverable biomass. In pulses it is only 15-20% compared to 45-50% in case of cereals such as wheat and rice. Low HI results from excessive vegetative growth, but can be overcome by early partitioning of dry matter into seeds (Saxena and Johansen 1990) and evolving biotechnology and genomic tools to incorporate good features of C-4 plants into C-3 plants.

Pulses in general have a high rate of flower drop. In pigeonpea, over 80% of the flowers produced in a plant are shed; by decreasing flower drop, yield can be increased considerably. This can be done either by breeding lines which retain a large proportion of flowers producing pods or through physiological manipulations, such as spray of hormones which reduce flower drop. Physiological studies at ICRISAT, involving removal of flowers and young pods of pigeonpea, have shown that plants compensate for the loss of flowers and young pods by setting pods from later formed owners, which otherwise would have dropped. This compensatory mechanism provides substantial plasticity of adaptation to intermittent adverse conditions such as moisture stress or insect attack, which are common in warm rainfed areas of south India. Recent increase in yield levels in pigeonpea is due to release of long duration (annual) varieties, which maximise utilisation of assimilates in filling the available sink of a large number of flowers (Rego and Wani 2002).

Biofertilisers and Irrigation

Another important practice widely applied is that of "growing of short duration legumes" such as moongbean, cluster bean, cowpea and horse gram in widely spaced crops and incorporation of their biomass after harvesting (green manuring), which increases the yield of subsequent crops. Rotation of legumes with non-legumes is another practice to derive benefit from the nitrogen fixed by the *rhizobium*-legume interaction and to meet at least 50% of the nitrogen requirement of most of the cropping systems. About 40% of the pulses growing regions have low to medium population of native *rhizobium*. Seed inoculation with biofertiliser (*rhizobium*) (low cost input) can increase pulses productivity by 10-12%. Lack of quality culture in adequate quantity is one of the major constraints in popularisation of biofertilisers. *Vesicular-arbuscular mycorrhizae* (VAM) offer promise for improving supply of phosphate and micronutrients like zinc for a variety of pulse crops. Phosphate solubilisers are yet another group of hydrotropic organisms, which may have applicability in rainfed pulses production systems, particularly in soils with poor phosphorus availability. Combined use of culture, like dual inoculation of rhizobium and VAM resulted in higher seed yield of crops than with rhizobium alone.

Even though good results have been obtained in research stations, the adaptability of integrated nutrient management (INM) technologies by farmers is dismal at the farm level. More emphasis should be given to evolve and identify suitable biofertiliser strains for major pulse based cropping systems for different agro-climatic conditions through integrated approaches of the agronomist, biotechnologist and microbiologist. The most effective way is to deliver appropriate *rhizobia* to seedlings where and when it is required; it is also possible to popularise superior nodulating varieties of pulse crops (Malhothra 2002). An experimental result shows that deficiency of micronutrients, especially sulphur and zinc is widespread among pulse growing regions. A very encouraging response to the application of sulphur and zinc has been found with a cost benefit ratio of 10-21%.

Irrigation is an important input in any cropping system. Pulses are generally cultivated as rainfed crops due to less irrigation response than competing crops like cereals. However, experimental results at IIPR show that one irrigation at a critical stage could substantially improve productivity. At the ICRISAT centre, grain yield increased in response to irrigation by nearly 50% in sole pigeonpea and more than doubled in intercropped pigeonpea with two irrigations given at the vegetative and flowering stages after the harvest of the cereal crop in years of scarce rainfall (Sharma and Jodha 1982). However, in northern parts of India where temperatures and evaporation are low with good amount of winter rainfall, responses to irrigation have not been very large. In view of good response for supplemental irrigation to pulse crops, government should encourage policies to provide supplemental irrigation. Plants of certain pulses (pigeonpea) still have wild traits like indeterminate growth habits, which cause intra-plant competition for photosynthesis resulting in poor partitioning to yield components, which reduce grain yield of the crop. These crops need to be fully domesticated. Domestication of these pulses through restructuring of plant is a difficult task and inputs from physiologists, biochemists, breeders and geneticists are necessary in the development of desirable plant types.

Exploitation of Heterosis Breeding in Pulses

The quantum of yield advances made through breeding in cereals such as maize, sorghum, millets, etc, is much higher than that of pulses. This difference in case of pulses arises primarily due to lack of commercial exploitation of hybrid vigor due to lack of mass pollen transfer mechanism and non-availability of effective male-sterility system. With the exception of pigeonpea (ICPH-8) the hybrid vigor for yield has not been exploited in all other pulse crops. The adoption of these hybrids, however, is limited due to

Table 6: Zonal Weigted Mean Seed Yield of Hybrid ICPH-8 and Controls UPAS-120 and Manak (1981-89)

Zone	Years	No of Trails	Yield (t/ha) ICPH-8	UPAS-120	Manak	% in Yield Over ICPH-8 UPAS-120	Manak
North-west plains	6	36	2.85	2.10	2.34	35.0	31.0
Central	4	30	1.56	1.16	0.93	32.9	52.5
South	4	30	1.42	1.22	1.26	23.6	27.3
North-west hills	1	2	1.56	1.50	1.19	4.3	31.0
Western	1	1	2.06	1.41	1.59	45.6	29.5
Mean			1.99	1.53	1.35	30.5	34.2

Source: Saxena et al (2000).

seed production limitations posed by genetic nature of male sterility (Saxena et al 2000) even though ICPH-8 was found to be more promising. It was released for cultivation in the central zone of India in 1981. Evaluation from 100 trials showed ICPH-8 to be superior to controls, UPAS-120 and Manak by 30.5% and 34.2% respectively, in productivity (Table 6, p 77).

There is still further scope for enhancing genetic improvement in pulse crops through biotechnology. Mutation breeding has contributed about 10% of the total improved varieties of pulses and is supplementing the conventional breeding programme. The mutant variety, Pant Moong-2, with resistance to YMV disease is very popular in north India (Pawar and Panday 2001). There is good scope for development of ideal plant type especially chickpea and pigeonpea, in line with rice developed by the International Rice Research Institute (IRRI) in collaboration with other research organisations with the leadership of ICAR. Specific efforts in this direction are already in place by both national and international organisations with respect to chickpea.

Post-Harvest Technology

Post-harvest losses account for 9.5% of total pulses production. Among post-harvest operations, storage is responsible for the maximum loss (7.5%). Processing, threshing and transport cause 1%, 0.5% and 0.5% losses, respectively. Among storage losses, pulses are also most susceptible to damage due to insects (5%) compared to wheat (2.5%), paddy (2%) and maize (3.5%) (Deshpande and Singh 2001). Appropriate storage structures (metal storage bins) need to be popularised. One can also increase the processing efficiency in dal mills. Due to recent advances in processing technology, the net availability of end products in modern dal mills has been increased to 70-75% compared to 65-66% in traditional dal mills. Propagation of IIPR mini-dal mills through the formation of pulses producer and processor associations is one of the components of NFSM, which will not only decrease post-harvest losses but also increase rural employment.

Socio-economic Constraints

Pulses production in India is characterised by a very high degree of diversity as indicated both by the number of crops, and their spatial distribution into varied agro-climatic conditions. Most of these crops are region-specific in the sense that a single state or a cluster of few states accounts for the bulk of the area and production of a specific pulse crop. Pulses such as pea, lentil, khesari and even chickpea indicate their regional distribution pattern. This diversity has several implications. In the first place it places serious limits to a single national policy for the promotion of pulses production in the country, and for the promotion of regional crop specific strategies to pulses development programmes. However, in view of the meagre resources available to pulses development as a group, this diversified approach may mean spreading the resources too thinly and in turn making the effort inconsequential. This dilemma may partly explain the absence of any major thrust on research on pulses, which in turn is partly responsible for their stagnation. The structure of pulses production is also characterised by the dominance of two crops, viz, chickpea and pigeonpea, which together account for more than one-half of total pulse area in India. Hence if these two crops suffer from adverse climatic conditions, it significantly reduces the production of pulses. The decline of chickpea in particular and pigeonpea and other crops in major pulse growing states like UP, Punjab, Haryana and Bihar clearly support this possibility.

Indo-Gangetic Plains and Rice Fallows

Pulses have been introduced in the Indo-Gangetic plains with the development of short duration varieties of pigeonpea (150-170 days) such as UPAS-120, Manak, AL-15, AL-201, etc. These enable their introduction in the irrigated areas of Punjab, Haryana, Delhi and western UP under pigeonpea-wheat based cropping system. Similarly, short duration (60-70 days) varieties of moongbean having synchronised maturity and resistance to YMV (PDM-11, PDM-54) offer good scope for their introduction as catch crop in rice-wheat system.

A study by Reddy (2006) compared cost-benefits from pulse based cropping systems with rice-wheat cropping systems in UP on farmers' fields under irrigated conditions, and the results are presented in Table 7. The figures clearly depict that pulse based cropping systems were less input intensive, required less labour, water, pesticides and fertilisers. But both gross returns and net returns per hectare were higher (given the higher prices of pulse crops) for pulse based cropping systems compared to rice-wheat systems. Benefit-cost ratio is also higher for pulse based cropping systems. Even rice-pulse crop sequence is better than the rice-wheat cropping system. Overall, pulse based cropping systems are more suitable for resource poor farmers and water scarce regions. Hence policy options have to be evolved to incorporate at least one pulse crop in cropping systems to enhance returns from irrigated farming systems. However, these findings are only applicable in irrigated conditions.

Table 7: Economics of Pulse-Based Cropping Systems vs Rice-Wheat Cropping Systems under Irrigated Conditions

Crop Rotation	Gross Return (Rs/ha)	Cost (Rs/ha)	Net Return (Rs/ha)	B/C ratio	Fertiliser (Rs/ha)	Pesticide (Rs/ha)	Labour (Man days)	Irrigation Charges (Rs/ha)	GR/Unit Water
Moong-lentil	42,540	13,685	28,855	3.2	160	500	122	700	60.8
Maize-lentil	37,000	9,985	27,015	3.7	320	500	72	700	52.9
Urad-wheat	45,000	25,310	19,690	1.8	1,688	0	182	5,600	8
Pigeonpea+sorghum	25,820	6,548	19,272	3.9	40	225	74	700	36.9
Pigeonpea-wheat-moong	51,500	32,730	18,770	1.6	1,688	300	268	6,500	7.9
Moong-wheat	43,500	25,310	18,190	1.7	1,688	0	182	5,600	7.8
Paddy-veg pea	52,000	35,022	16,978	1.5	2,700	1,650	221	12,600	4.1
Paddy-lentil	41,400	26,871	14,529	1.5	1,660	1,500	162	7,700	5.4
Paddy-wheat-moong	60,190	46,129	14,061	1.3	3,188	1,000	308	12,600	4.8
Paddy-wheat	45,190	38,497	6,693	1.2	3,188	1,000	222	12,600	3.6

Source: Reddy (2006).

It should be noted that the scope for introduction of pulse crops in rice-fallows (mostly un-irrigated) needs to be exploited with supplemental irrigation, considering the higher profitability and scope for pulse crops as rabi crop in the cropping systems. Table 8 (p 79) depicts the extent of rice-fallows, which can be put under pulse crops in the rabi season. There is vast area of fallow land in MP (78% of kharif rice area, which accounts for 4.4 million ha), Bihar (2.2million ha) and in West Bengal (1.7 million ha), which are most suitable for pulses cultivation.

Table 8: State-wise Estimates of Rice Fallow (Mostly Unirrigated) Area during Rabi (1999-2000)

State	Kharif-Rice Area ('000 ha)	Rabi-Fallow ('000 ha)	Rice-Fallow Area as % of Kharif Rice Area	% of Total Rabi-Fallow Area
MP	5,596	4,382	78.3	37.6
Bihar	5,974	2,196	36.8	18.9
WB	4,617	1,719	37.2	14.8
Assam	2,234	539	24.1	4.6
UP	6,255	353	5.6	3.0
Others	15,508	2,463	15.9	21.0
Total	40,184	11,652	29.0	100

Source: ICRISAT(2009).

The major future expansion of area under pulse crops may take place in rice fallows, where there is no other crop to compete, however there are limitations on the successful propagation of these crops in this system. Most of the farmers in south India, where large areas of rice fallows are located, are not aware of the potential economic benefits of using fallows for legume cultivation. In many cases, the farmers were found to have not only inadequate but also incorrect information about recommended pulse production technology. Governments should provide various incentives to increase area under pulses in rice fallows.

Other Issues in Increasing Production

Lack of Seed Availability: In any crop, generally an increase in the production and productivity is brought about by the wider availability and adoption of improved varieties of seeds. Nearly 400 improved varieties of different pulse crops have been released for cultivation since the inception of coordinated pulses improvement programme in 1967. But at present, only 124 varieties are in the production chain. Among them a dozen are popular among farmers. The wide gap between the requirement of certified/quality seeds and its distribution in India is a matter of great concern. The seed replacement ratio is very low (2-5%), while the required seed replacement ratio is 10%. By the year 2025, 4,487.2 quintals (qt) of breeder seeds, 59,838.3 qt of foundation seeds and 7,48,000 qt of certified seeds of chickpea, and 49.4 qt of breeder seeds, 2,201 qt of foundation seeds and 91,740 qt of certified seeds of pigeonpea will be required (Reddy 2005). Under NFSM, breeder and foundation seed production has been entrusted to IIPR (Kanpur), while production of certified seeds is entrusted to National Seed Corporation and other state organisations for timely supply to farmers at affordable prices.

Lack of Cash and Credit: Cash is a key element for enabling small farmers to shift from low input-low output to high input-high output agriculture. But access to credit by these farmers is low because of their low asset base and low risk bearing ability. Further, credit facilities for pulse crops both from formal and informal sources are limited due to unstable returns.

Marketing: Markets for legumes are thin and fragmented due to scattered production and consumption across states. Farmers/village traders sell their marketed surplus immediately after harvest, while some large traders/wholesalers trade between major markets and hoard pulses to take advantage of speculative gains in the off-season. Due to this, farmers do not benefit from the higher market prices of pulses. Also, for certain pulses like khesari, demand is localised and markets are underdeveloped. In recent years, there have been improvements in market information and infrastructure, and the price spread between consumer price and producer price is reducing, especially in the harvest season.

Crop-Specific Strategies

After reviewing the all India coordinated pulses projects and also research work at IIPR Kanpur, the following crop specific strategies to increase area under pulses is suggested:

Chickpea: There is a remote possibility for increasing area under chickpea in north India. The past trends indicate that as soon as the area develops irrigation facilities, the chickpea area gets diverted to other more remunerative crops like wheat, mustard, sunflower, sugar cane, potato, etc. There are some possibilities of increasing the area under chickpea in the states of Maharashtra, Karnataka, Andhra Pradesh and Gujarat in partial replacement of rabi sorghum and also rice fallows. If a thrust is given, it should be possible to cover about 0.3-0.4 million hectare areas under this crop.

Pigeonpea: There are four distinct possibilities of area under this crop (i) Popularisation of short duration varieties of pigeonpea in sequence with wheat under irrigated conditions in the states of UP, Haryana, Punjab and northern parts of MP. (ii) Replacement of uneconomic crops like cotton in Gujarat and Karnataka and millets such as sorghum, pearl millet, finger millet, etc, in Andhra Pradesh, Maharashtra and Tamil Nadu. (iii) Popularisation of rabi pigeonpea in the states of Orissa, Gujarat, West Bengal, Bihar and eastern UP, and (iv) There is a very large scope of increasing area through inter-cropping of pigeonpea with soya bean in MP, Maharashtra and Rajasthan; and with cotton, sorghum, pearl millet and groundnut in the states of AP, Maharashtra, Karnataka, Gujarat, MP and UP. It is expected to get additional coverage under pigeonpea by at least 1 million hectares by the turn of the century.

Urdbean and Moongbean: There should be propagation of urdbean/moongbean as a summer crop after the harvest of rabi crop specially potato, sugar cane, mustard and wheat under irrigated conditions in the states of Bihar, UP, Punjab, Haryana, West Bengal, Orissa, Andhra Pradesh, Karnataka and MP and also after the harvest of kharif paddy in the states of Andhra Pradesh, Orissa, Karnataka and West Bengal. There is some scope in kharif fallows before the sowing of rabi sorghum, rapeseed, mustard, safflower, rainfed wheat, rabi sunflower in the states of Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu, MP, UP, Bihar and Gujarat. In some regions, there is scope for intercropping with spring planted sugar cane, with maize, sorghum and pigeonpea, etc. All these practices have the potential to bring an additional area under both these pulse crops to the extent of about 2 million hectares.

Lentil: There has been a constant increase in area under lentil. Further, there are possibilities for expansion of area under this crop especially after the harvest of paddy crop in rainfed areas in UP, Bihar and West Bengal. It is presumed that an area of about 0.2 million hectares can be brought under this.

Peas: There are remote possibilities of expansion of area under this crop. Like chickpea, this crop also faces competition with wheat in irrigated areas. However, there is still some scope for area expansion under this crop in UP, MP and Bihar at the tail end areas of canals where enough water is not available for growing wheat crop.

Rajmash and Broadbeans: These crops possess a very high yield potential with the use of high levels of inputs like fertiliser and irrigation. Yield levels up to 2.5 tonnes per hectare can easily be obtained in these crops. The potential areas are eastern UP, Bihar, West Bengal, Orissa, MP, Maharashtra and Gujarat. It may be possible to cover about 0.1 million hectares area in four to five years time. However, these crops have a limited preference from consumers.

Farmers' Production Strategies and Gaps in Technology

Some results of the farmers' level of technology are given in this section (Reddy 2006). Farmers have been applying sub-optimal doses of fertilisers, pesticides and number of irrigations for pulses after meeting the requirements of wheat, paddy and vegetable crops. For pigeonpea and chickpea, most farmers applied 40kg/ha urea. To address the problem of wilt and pod borer, farmers used pesticides. Only occasionally some farmers applied farm yard manure at the rate of 2t/ha. For kharif pulses generally there is no application of irrigation. For rabi/spring pulses grown only in irrigated conditions, the number of irrigations depends on the availability and cost of irrigation. Generally the numbers of irrigations given at critical stages have been thus: for lentil three times, for chickpea two times, for fieldpea two times, for urd/moong (spring) three to four times have been given at critical stages. Economic returns far exceed the cost of irrigation and fertilisers, while the response for pesticide on pod borer and wilt is not certain.

The improved variety of pigeonpea (early) (UPAS-120) has recorded a yield increase of 44.4% over local varieties, chickpea variety (BG-256) recorded a yield increase of 43.6% over local varieties, and field pea (HFP-4) recorded the highest yield increase, i e, 54.5%. Improved varieties of lentil, moongbean and urdbean showed yield increases of around 30-35%. Overall with the adoption of improved varieties, gross returns increased more than the increase in costs, thereby increasing the cost-benefit ratio. In pigeonpea (late), it was found that 51.1% of the farmers used improved seeds, 42.2% used fertilisers, 25.4% used insect pest control, and 17.7% used seed inoculation with fungicides and 22.2% followed seed treatment with rhizobium culture. Non-availability of improved varieties and rhizobium culture are major reasons for their non-adoption.

Experience of on-farm research at ICRISAT in the Thadnapally district Sangareddy, in Andhra Pradesh shows that with adequate institutional support, easy supply of inputs and necessary credit facilities ensured by different government agencies, the improved technology can be effectively transferred with substantial gains in productivity of rainfed crops. However, it requires new farmer participatory approaches to increase the adoption under very complex situations. Another approach, which is most suitable under complex rainfed areas, is the farmer participatory research (FPR) developed to involve farmers more closely in on-farm research. Farmer-participatory testing will help refine the technologies, pinpoint and eliminate adoption constraints.

Conclusions

In short, to increase area and production of pulse crops we need crop specific and region specific approaches, which should be adopted in the overall framework of systems approach. The major thrust areas to be addressed are as follows (i) Replacement of cereal crops in the prevailing rice-wheat cropping systems with high yield varieties of pulses. (ii) Inclusion of short duration varieties of pulses as catch crop. (iii) Development of multiple disease and pest resistant varieties. (iv) Reducing storage loses and improving market information and infrastructure. (v) Linking MSP to market prices can bridge the gap between demand and supply. (vi) Developing high nitrogen fixing varieties, which will play a crucial role in sustainable agriculture, and (vii) Coordination of research, extension and farmers to encourage farmer's participatory research.

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