

# **SESSION 1**

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# AUGMENTATION OF PULSES PRODUCTION

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Pulses are “basic ingredient” in the diets of a vast majority of Indian population as they provide a perfect mix of high biological value when supplemented with cereals (Table 1). Each plant of the pulse crop is virtually nature’s mini nitrogen factory, which enables it to meet its own requirement and also benefit the succeeding cereal crop. Pulses are also an excellent fodder for livestock. Besides their dietary value and nitrogen fixing ability, pulses also play an important role in sustaining intensive agriculture by improving physical, chemical and biological properties of soil and are considered excellent crops for diversification of cereal based cropping systems.

The progressive decline in per capita availability of pulses (69 g in 1961 to 37 g in 2004) in India is a matter of great concern. This is attributed to the steady marginalisation of their cultivation in the wake of the “Green Revolution” and burgeoning population. With assured supply of cereals at an affordable price, the main focus of policy makers and planners now is on nutritional security. To alleviate protein-energy malnutrition, a minimum of 50 g pulses/capita/day is required in addition to other sources of proteins such as cereals, milk, meat, eggs, etc.

**Table 1: Share of Pulses in Nutrition Supply**

Per Caput/day	World	Asia	India
Energy (Kcal)	56.00	51.90	117.40
Protein (g)	3.50	3.10	6.90
Fat (g)	0.40	0.40	1.00

To make up this shortfall in supply besides further demand from burgeoning population, about 19.6 million tonnes of pulses are required by 2007, which is expected to touch 28 million tonnes by 2020. This can only be achieved by improving productivity and using additional areas for pulse production through diversification coupled with favourable Government policies.

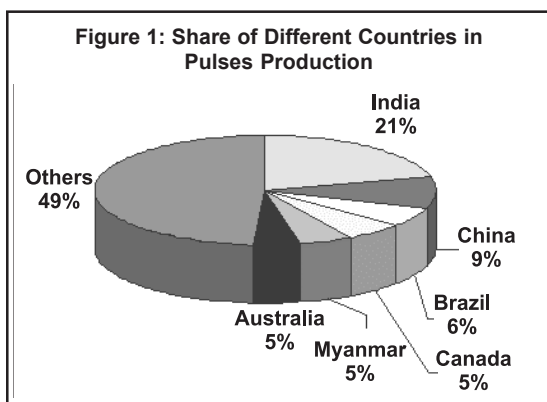
## Global and National Scenario

Globally, pulses are the second most important group of crops after cereals. In 2002, the global pulse production was 55.16 million tonnes from an area of 69.78 million ha with an average yield of 791 kg/ha (FAOSTAT 2002). The latest triennium production (1999-2001) averaging 54.41 million tonnes showed substantial growth of 1.42% per annum over 42.32 million tonnes recorded in 1980-82 (Table 2). Comparative data for the eighties and nineties reveal that the phenomenal growth was restricted only during the first decade (1980-82 and 1990-92) followed by near stagnation in the second decade. The share of developed countries in the global pulse production is around 15.80 million tonnes (29%). At present, the developing countries account for 87% of the total pulse area and contribute 71% to the global production with an average yield of 645 kg/ha, which is far behind the average yield of 1734 kg/ha harvested by the developed countries.

During the eighties, the growth was due to area as well as yield increase whereas in nineties, the yield growth was leveled off and area growth

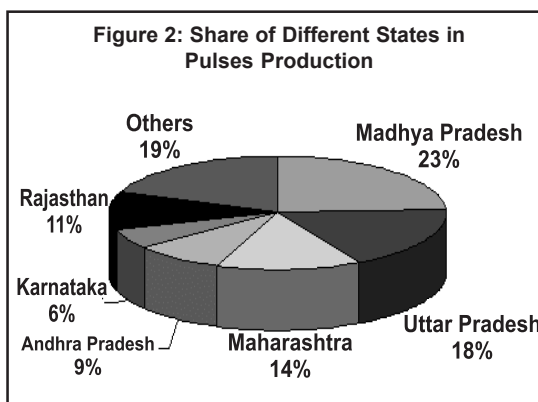
**Table 2. Area, production and yield of total pulses by regions (FAO 2001)**

Region	Area {m ha}			Production (mt)			Yield (kg/ha)		
	1980-82	1990-92	1999-2001	1980-82	1990-92	1999-2001	1980-82	1990-92	1999-2001
World	62.08	67.47	69.00	42.32	54.45	54.41	682	807	789
Asia	35.01	35.30	35.41	21.87	23.93	25.41	625	678	721
India	22.85	23.54	22.00	10.24	13.05	13.63	448	554	619
Developing	52.78	56.73	59.88	31.89	35.82	38.60	604	639	645
Developed	9.30	10.74	9.12	10.43	18.63	15.80	1127	1736	1734

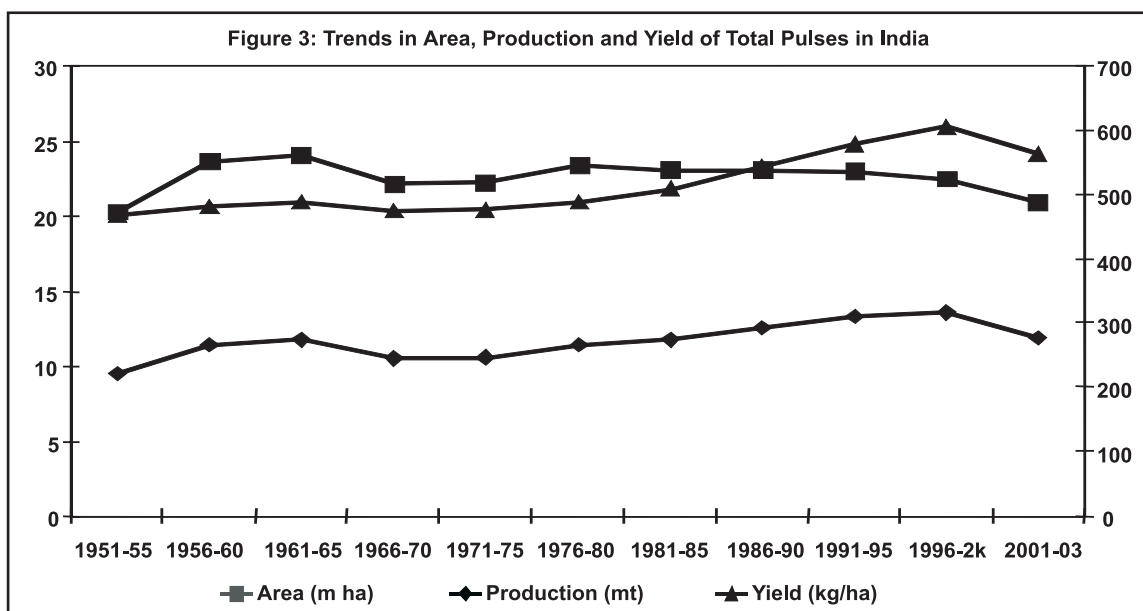


slowed down. Asia accounts for 51% of the global pulse area and 47% of its production. Positive growth was recorded for pulse production in Asia in both the decades and mainly attributed to growth in yield despite near stagnation of pulse production areas. Major pulse producing countries (Figure 1) in order of their contributions are India, China, Canada, Brazil, Australia, Nigeria, France, Myanmar, USA, Turkey and Mexico with about 68% of the production (FAOSTAT 2002).

The latest estimate reveals that pulses are grown in 22.6 million ha area in the country producing 15.23 million tonnes of production with average yield of 673 kg/ha. India is the key player with 25% share in the global pulse basket from an area of about 32%, the annual production being 13.63 million tonnes in latest triennium. The important pulse producing states



(Figure 2) are Madhya Pradesh, Uttar Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh, which together account for 75% production. A look at the growth statistics shows that there was a positive growth in production of pulses in the country since independence. However, the source of growth varied with the periods. If area expansion was the major factor for growth during 1951-67, the yield improvement has been the key element in the post-All India Coordinated Pulses Improvement Programme (AICPIP) period (1967-2002). The past two decades have shown that the national pulse production has increased from 10.24 million tonnes in 1980-82 to 13.12 million tonnes in 1999-2002, registering a growth of 1.66% annually. However, the share of pulses in the total food grain production has reduced to 6.5% presently from 15.8% in 1951-55 (Figure 3).



**Table 3. Import and export of pulses in India**

Year	Import		Export	
	Quantity (000' tonnes)	Value Rs. crores)	Quantity (000' tonnes)	Value (Rs crore
1990-91	791.95	473.24	-	-
1991-92	312.61	255.27	-	-
1992-93	382.62	334.37	34.31	53.44
1993-94	628.18	567.01	43.60	73.59
1994-95	554.27	592.73	50.51	90.41
1995-96	490.75	685.57	61.36	131.91
1996-97	654.91	890.34	55.22	131.58
1997-98	1008.16	1194.64	168.05	360.89
1998-99	563.60	708.81	104.10	223.03
1999-2000	250.77	354.69	194.18	419.56
2000-2001	349.84	498.47	244.08	537.08
2001-2002	2177.13	3155.66	159.55	366.18

## Trade

The country is in gross deficit of pulses and thus requires meeting this shortfall through imports. During 2001-02, the country imported 21.77 lakh tonnes of pulses valued at Rs 3155.66 crore (Table 3). The most widely traded pulse crop is dry pea followed by dry beans, lentil and chickpea. Since, the majority of the pulses are consumed locally and do not enter the world market except in a small quantities (12% of the total production), any increase in demand from India generally leads to an increase in international prices; draining the precious foreign exchange and negative trade balance.

With rapid growth of the agriculture sector in the post-General Agreement on Trade and Tariff (GATT) era and the opening up of the markets for agricultural produce, there is a danger of cheap imports finding their way into the Indian market thus, making pulse production unsustainable and uneconomical. Expansion of pulses, for example chickpea in Australia and Canada, has been dramatic mainly because of the export opportunities available. In Canada, area and production of chickpea have increased from negligible in 1991 to more than 0.28 million ha with a production of 0.39 million tonnes at present, recording average productivity of 1368 kg per ha. This makes Canadian chickpeas quite competitive. Indian exports are mostly comprised of lentils to the Middle East countries.

## Major Constraints

In the post-Green Revolution period, the per capita availability of pulses has declined sharply in the country, mainly due to mismatch in population and production growth. In spite of having the largest area under chickpea, pigeonpea, lentil, dry beans and total pulses in the world, India's position in average production of these pulses has not been decent, i.e., 24<sup>th</sup> position in chickpea, 9<sup>th</sup> in pigeonpea, 23<sup>rd</sup> in lentil, 104<sup>th</sup> in dry beans, 52<sup>nd</sup> in dry pea and 98<sup>th</sup> in total pulses (FAO 2001). Similarly in Asia, the country's position in average production of these crops is not commensurate to the first position held up for production. Except chickpea and pigeonpea, the average production of other pulses in the country is significantly lower than the average yield in the world. For example, average production of lentil, dry pea and dry beans in India is 791, 1000 and 447 kg per ha as compared to global averages of 938, 1830 and 705 kg per ha, respectively. India's productivity is meager in most of the pulses as compared with highest yielding country and the average productivity of the five top most productive countries.

### Text Box 1 Production Constraints in Pulses

- Lack of high yielding varieties adapted to diverse growing condition
- Large area under rainfed cultivation (88%)
- Biotic and abiotic stresses (up to 30% losses)
- Poor plant stand
- Poor response to high input conditions and better management
- Moisture stress at terminal growth stage
- Inadequate seed replacement rate
- Emerging deficiencies of secondary and micro-nutrients
- Low risk bearing capacity
- Resource poor farmers
- Poor crop management
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The major constraints that limit the potential yield of pulses in the country are well known (Table Box 1). Besides socio-economic factors, these include biotic and abiotic stresses prevalent in the pulse-growing areas. Fusarium wilt coupled with root rot complex is probably the most widespread disease followed by Ascochyta blight mainly in the cool and humid climate of the north-west plain zone and botrytis grey mould in north-east plain zone causing substantial chickpea losses. While fusarium wilt, sterility mosaic, phytophthora blight and alternaria blight cause substantial pigeonpea losses, yellow mosaic, cercospora leaf spot and powdery mildew are considered as the most important diseases in both mungbean and uradbean. In lentils, diseases like rust, powdery mildew and wilt cause considerable damage. Powdery mildew and rust are the two most important and widely spread foliar diseases of dry pea throughout the country. There are some key insect pests, gram pod borer (*Helicoverpa armigera*) in chickpea and pigeonpea, pod fly in pigeonpea, whitefly, jassids and thrips in dry beans, aphids in lentil and bean fly in dry pea that cause severe damage to the respective crops. Weeds also cause substantial loss to pulses. Recently, nematodes have emerged as a potential threat in the successful cultivation of pulses in many areas.

The abiotic stresses include terminal drought, high temperatures during the reproductive stage, cold sensitivity during the vegetative and flowering stages and salinity/alkalinity throughout the crop period. These inflict major yield losses and instability in production. All these make pulse crops less productive with unstable performance. Consequently, pulses are perceived as marginal farmers' crops laden with high risk and poor yield. This perception discourages farmers to invest in requisite inputs vital for its successful cultivation. This is further confounded in the absence of favourable market intervention in the form of minimum support price and efficient procurement mechanism besides lack of liberal credit policy. On the technological front, pulses still need major breakthrough in yield levels through morpho-physiological changes in plant type and development of multiple disease resistant varieties coupled with tolerance to abiotic

stresses. The potential of already generated technologies demonstrated in farmers' fields has not been realized at the national level mainly because of non-availability of quality seeds along with critical inputs in time, limited irrigated areas, low priority given to pulses by the farmers and poor crop management. Moreover, pulses are generally grown by resource poor farmers on marginal and sub-marginal lands under rainfed conditions, which is often characterized by extremely diverse and unpredictable environmental factors. Inadequate transfer of technologies, poor storage, lack of processing and marketing facilities further discourage farmers to extend areas for pulse production.

### **Technological Advances**

Systematic and concerted research efforts over the years have resulted in increasing production technologies for pulse crops, which have brought about wider adaptability, yield stability, higher yield, and market specific characteristics like seed size and colour besides early maturity and tolerance to biotic and abiotic stresses. Focused programmes on breeding and refinement of production and protection technologies have shown a profound effect on crop productivity. About 480 varieties of various pulse crops have been released so far, out of which 360 were released after 1960. These varieties are not only high yielding but also withstand the onslaught of biotic stresses thus providing the much-needed stability in the production. As a result, there is a marked reduction in the periodicity, frequency and intensity of outbreaks of biotic stresses. In addition to resistance sources against key diseases and insect pests, substantial advances have also been made in recent years towards other components of integrated pest management such as cultural practices, bio-agents and bio-pesticides. By adopting these practices, it is now possible to control many of the pathogens hitherto unmanageable. The relative stability of pulse production as measured by low coefficient of variation also confirms the steady improvement in stability during the past decade. The coefficient of variation, which was 14.8% in 1951-60, has steadily declined to the present manageable level of about 7.32%.

One of the most important achievements of research efforts in pulses has been substantial reduction in duration of improved varieties. This has increased the per day productivity of pulses comparable to any rainfed crops including rainfed rice and wheat besides making them suitable for introduction in new niches and diversification of the existing cropping systems. Expansion of uradbean in rice fallows of coastal regions was possible due to development of short-duration and powdery mildew resistant varieties (LBG 17 and LBG 402). Development of extra-early varieties of uradbean/mungbean with synchronous maturity and resistance to yellow mosaic virus has helped their introduction and expansion in the Indo-Gangetic plain as catch crop during spring/summer season. Development of short-duration varieties of pigeonpea such as UPAS 120, Manak, AL 15, AL 201, Pusa 84, Pusa 992 and ICPL 151 has paved the way for area expansion under pigeonpea-wheat sequence in the irrigated areas of Punjab, Haryana, Delhi, north-western Rajasthan and Uttar Pradesh. Development of pigeonpea varieties suitable for planting in early September coupled with alternaria blight resistance has added new dimension to pigeonpea production in flood-prone area of north-east plains making maize-*rabi* pigeonpea sequence popular in Bihar. Similarly, identification of chickpea varieties suitable for late planting (KPG 59, Pusa 256, PBG 1 and Pusa 372) has led to diversification of rice-wheat system in the tail end of command areas of north India where irrigation is not enough to support good crop of wheat. A dramatic increase in chickpea area in southern and central India from 1.3 million ha in 1975 to 3.10 million ha in 1999-2000 has been possible due to development of high-yielding varieties like ICCV 2 capable to complete their duration before the onset of terminal drought. Other success story is the introduction of *rajmash* in the irrigated areas of eastern Uttar Pradesh, north Bihar, Vidharbha region of Maharashtra and Orissa as a *rabi* crop. This was possible mainly due to development of high-yielding varieties, such as Uday, Amber, HUR 15 and HUR 137 suitable for winter sowing, with matching agro-technology. Besides, production technologies for early pigeonpea, late chickpea, dwarf pea, *rabi rajmash*, *rabi* pigeonpea, spring/summer

mungbean and uradbean have been developed. The management practices have been refined to increase efficiency of production inputs.

Production technology of promising crop rotations involving pulse crops such as pigeonpea-wheat, rice-chickpea, rice-lentil and rice-uradbean/mungbean, mainly popular in Peninsular India have been worked. Systematic research on inter/mixed cropping with emphasis on genotypic compatibility and spatial arrangement has led to identification of efficient intercrops, such as, pigeonpea with soybean, groundnut, uradbean, mungbean and sorghum; chickpea with mustard, linseed, safflower and coriander; lentil with mustard and linseed; uradbean/mungbean with spring sugarcane and sunflower; and *rajmash* with potato. These intercrops, in a particular row ratio significantly increased total productivity and land use efficiency besides improving soil health.

## Strategies for Increasing Pulses Production

The country has experienced progressive decline in per capita availability of pulses from 69 g in 1961 to 37 g in 2004. With assured supply of cereals at an affordable price, the main focus of policy makers and planners now is on nutritional security. This can be only be achieved by adopting increasingly more productive technologies along with favourable developmental policies. To make the nation pulse sufficient, the productivity level of pulses has to increase substantially from the present level of 638 kg per ha to 800 kg per ha by 2007 with a minimum growth of 4.0% in production. 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 following approaches require immediate attention, which can have substantial bearing

<b>Text Box 2</b>	
<b>Strategies for increasing pulse production</b>	
➤	Genetic options
➤	Management options
➤	Developmental efforts

on the pulse production without further constraining natural resources:

- Improving productivity
- Bringing additional Area under Pulses

If there is any group of crops, that have the scope of improvement, it is pulses, where the past efforts have not been as concentrated or provided the rewarding results seen with wheat and rice. Different approaches like genetic, management and developmental options are available for improving productivity (Text Box 2).

### ***Genetic Options***

Efforts are needed to design varieties of pulses with appropriate growth habits and efficient source-sink relationships besides restructuring the plant as per the environmental requirements and cropping systems. Introgression of unexplored genes from the wild relatives could be rewarding for broadening the genetic base of important traits such as yield, yield attributes and resistance to biotic and abiotic stresses in pulses. The prospect is bright for further improvement in stability of resistance through vertical gene management and multiple resistances. Thus, immediate attention is needed on the following options:

#### ***Improved plant type***

It has amply been demonstrated in cereals particularly wheat and rice that physiologically more efficient plant types are essential for breaking the yield barrier and pulses are no exception to this. Pulses are grown under varying agro-ecological conditions and each set of conditions needs a specific plant type for higher productivity. Most of the pulses still have wild traits like indeterminate growth habit, pod shattering, pre-harvest sprouting and sensitivity to photoperiod and temperature regimes. It is presumed that the determinate types under good management would partition photosynthate to yield components with greater efficiency. Similarly, photo and thermo insensitive varieties will be able to have wide adaptability with minimum seasonal and regional effects on their phenology and yield potential besides a more synchronous

reproductive ontogeny and greater harvest index. The greatest physiological potential of genetic improvement in the productivity of the pulse crops lies not with increasing total biomass, but with increasing the proportion of biomass partitioned into seed i.e., higher harvest index (HI). For example, HI in late pigeonpea is very low ranging between 18-20%. Due to some unknown physiological factors, carbohydrates and nitrogenous products start accumulating in leaves and stems in pigeonpea, and as a result, major proportion of these products remain stored in non-transportable form of reserved carbon and nitrogen. Some enzymes are very useful for breaking down the large non-transportable carbohydrates into smaller units and thereby facilitating sugar translocation from leaves. The regulatory aspects of these enzymes and mechanism of carbohydrates transport are essential to understand source-sink relation for improving productivity.

Besides these physiological considerations, the plant type has to be restructured as per the environmental requirement and prevailing cropping systems. Breeding objectives need to be directed keeping in mind the impact of altered plant types on the yield of the component crops. Simulation models developed recently for some of the pulse crops offer the potential to interpret and predict the performance of individual genotypes in different environments, thus, offering a possible role in decision-making regarding suitability of the proposed plant type in the target environment and prevailing cropping systems.

#### ***Exploitation of hybrid vigour***

Due to partial outcrossing and spontaneously arisen genetic male sterility (GMS) system, pigeonpea has been considered for exploitation of hybrid vigour for the past two decades. Six GMS based hybrids viz., ICPH 8, PPH4, COH 1, COH 2, AKPH 4104 and AKPH 2022 were released in the past. These hybrids have shown definite yield advantage over traditional varieties. However, these hybrids could not become popular due to the need to manually rogue out the male fertile segregants within female rows after initiation of flowering. This leads to higher cost of production on account

of labour in seed production, and imperfect elimination of the fertile sibs reduces the quality of hybrid seed. An economically sound seed production technology is required so that quality hybrid seeds are supplied at affordable price. With the development of cytoplasmic male sterile and fertility restorer lines in pigeonpea, commercial exploitation of hybrid vigour appears to be a near possibility for a possible breakthrough in yield potential of pigeonpea. Recently, two stable cytoplasmic male sterile lines GT 288A and 67A were developed utilizing cytoplasm of wild species, *Cajanus scarabaeoides* and *C. sericeus*. Simultaneous conversion of CMS lines into suitable agronomic backgrounds and identification of fertility restorer lines resulted in the development of experimental hybrids. The first CMS based pigeonpea hybrid, GTH-1, has been released for cultivation in Gujarat as it gave 32% yield superiority (1627 kg/ha) as compared to the best check GT 101 (1228 kg/ha). Besides higher yield, it matures in 140 days and has large white seeds.

More efforts are needed, which are, directed towards diversification and stability of cytoplasmic male sterility, genetic enhancement of component lines (A and R lines) through insulation against key diseases and insect pests and identification of heterotic cross combinations. Appreciable heterosis reported in other pulse crops make them suitable for its exploitation. However, this requires an efficient male sterility system coupled with fertility restoration before invoking this option in other pulse crops.

### *Exploitation of untapped yield genes*

Wide hybridization in pulse crops has been attempted for broadening the genetic base of cultivated germplasm, creation of genetic variability for efficient plant types, introgression of genes for wider adaptability and minimizing the risk of epidemics. Important traits introduced from wild species into the cultivated varieties are resistance to cyst nematode and cold tolerance in chickpea, resistance to MYMV and bruchid in *Vigna* and male sterility in pigeonpea.

Wild species of chickpea are rich reservoir of not only resistant gene against various biotic

and abiotic stresses but also genes responsible for high yield, more seeds/pod, hybrid vigour, etc. Conventional crossing has been successful in producing inter-specific hybrids between *C. arietinum* and *C. reticulatum*. Incorporation of resistance to cyst nematode is an example of successful introgression from *C. reticulatum*. Similarly, transfer of cold tolerance from *C. reticulatum* and *C. echinospermum* has been achieved. Unfortunately, most of the desirable genes are in *C. bijugum*, *C. judaicum* and *C. pinnatifidum* and could not be exploited due to crossing barriers with the cultivated species. Recent success in inter-specific hybrid between *C. arietinum* and *C. echinospermum* and availability of new biotechnology tools for circumventing crossing barriers have further brightened the prospects of transferring useful traits from primary and tertiary gene pools in chickpea.

In pigeonpea, inter-specific crosses were made with the objective to broaden the genetic base of cultivated germplasm, incorporation of biotic and abiotic stresses and development of cytoplasmic genetic male sterile lines. Potential traits of wild *Cajanus* species useful for pigeonpea improvement have been identified. For instance, *C. scarabaeoides* possesses both physical and antibiosis types of resistance to pod borers while *C. sericeus* and *C. albicans* are rich in protein. *C. albicans* has tolerance to soil salinity. Resistance to phytophthora stem blight is available in *C. cajanifolius*. Several wild relatives were used in hybridization programme with *C. cajan* and sterile plants were isolated from the segregating populations. Male sterile plants were isolated from interspecific cross of *C. scarabaeoides*, and *C. sericeus* with cultivated species.

*Vigna* has six cultivated species namely mungbean (*V. radiata*), urdbean (*V. mungo*), cowpea (*V. unguiculata*), moth bean (*V. aconitifolia*), rice bean (*V. umbellata*) and adzuki bean (*V. angularis*) and six wild species, namely, *V. trilobata*, *V. grandis*, *V. dalzalliana*, *V. vexillata*, *V. radiata* var. *sublobata* and *V. mungo* var. *silvestris*. Inter-specific crosses between cultivated and wild species were attempted to transfer specific genes for resistance to diseases, insect pests and other edaphic stresses. Crosses between mungbean and

uradbean were attempted to combine desirable features such as durable resistance to MYMV and cercospora leaf spot, synchronous maturity, resistance to shattering and high methionine content of uradbean and more seeds per pod, erect growth habit and better quality traits of mungbean. Synchronous maturity and shattering resistance have been successfully transferred from urdbean to mungbean. A wide range of variation for plant types and other agronomic traits was observed in segregating generations of a cross between mungbean and uradbean (Pant Mung 2 x AMP 36) resulting in isolation of several superior progenies. For example, more seeds per pod of mungbean can be transferred to uradbean. Bruchid resistance, a novel characteristic not found in the parent species, can be recovered in the segregating generations of mungbean x urdbean cross. A high yielding variety of mungbean, Pant Mung 4 with improved plant type and resistance to several biotic and abiotic stresses, has been developed from a cross between mungbean and uradbean. However, interspecific hybridization was successful only when mungbean was used as female parent with uradbean and uradbean with rice bean. Improved techniques have increased the possibilities of success between *V. mungo* and *V. angularis*. Wild type *V. mungo* var. *silvestris* is valuable source of resistance against biotic and abiotic stresses. Some accessions of *V. radiata* var. *sublobata* have resistance to MYMV and non-preference to bruchids. Such crosses were attempted and segregants for profuse podding and MYMV resistance were isolated. Similar observations were also recorded in a cross between urdbean and *V. mungo* var. *silvestris*. Crosses between mungbean and rice bean were attempted to combine two mechanisms of resistance to MYMV in mungbean.

*Lens culinaris* Medic is the only cultivated species of genus *Lens* with two subspecies *macrosperma* with large seeds, yellow cotyledons and no pigmentation on flower and vegetative parts and *microsperma* with smaller seeds, orange and yellow cotyledons and more pigmentation. Based on the crossability studies, *L. orientalis* and *L. odemensis* were found to share common gene pool with the cultivated species and can easily be crossed with

cultivated species. Slight chromosomal rearrangements may cause partial sterility, but there are still ample opportunities of gene flow for utilization of these wild forms in lentil improvement programme. *Lens nigricans* can also be used in breeding programme through embryo rescue. *Lens ervoids* yielded partially fertile F1's through embryo rescue. In lathyrus, interspecific crosses involving *Lathyrus sativus* with *L. tingitanus* and *L. aphaca* have been tried for transferring disease resistance into cultivated species.

### *Transgenics in pulses*

Most of the pulses have been shown to be amenable to genetic transformation using recombinant DNA and tissue culture procedures. However, a highly reproducible transformation and regeneration system is prerequisite for the introduction of foreign gene into desired background. Effective protocols are available for regeneration *via* organogenesis and somatic embryogenesis in pigeonpea and chickpea. Successful efforts have been made to obtain multiple shoots through direct and indirect organogenesis. Several explants like, embryonic axes, cotyledonary node and apical shoot meristems have been tested. For development of transgenics, both *Agrobacterium* mediated and direct gene transfer methods have been used. So far, most of the transformation in pulse crops is limited to transfer of marker genes. Efforts are on to develop transgenic plants of chickpea and pigeonpea, which are resistant to gram pod borer (*Helicoverpa armigera*) using Bt crystal protein genes. At IIPR, transformed callus and plantlets of chickpea and pigeonpea possessing *npt II*, *bar* and *Cry 1Ab* genes have been obtained through *Agrobacterium* mediated transformation. Similarly, transformed plantlets have been obtained in pigeonpea using gene gun and *Agrobacterium* methods. Transformed chickpea plants possessing *Cry1Ab* gene have also been reported from IARI and ICRISAT. NCL and NBRI also conduct research in the same direction. Besides use of Bt genes, genes of plant origin like, lectins, protease and amylase inhibitors also hold great promise. Plant chitinases with antifungal activity against several fungal pathogens have been purified. The potential of chitinases in biocontrol has

stimulated interest to isolate genes encoding these enzymes and for cloning them into plants. NCL Pune has an elaborate programme on identification of novel plant genes conferring resistance against insect pests. Some of transgenic plants with genes for insect resistance are expected to be available commercially within the next 3-4 years.

### ***Pyramiding of resistance genes***

Characterization of the race structure of major fungal pathogens chiefly fusarium wilt, and development of gene deployment strategies to extend genetic resistance to it is immediately required to combat highly variable pathogens. Breeding for wilt resistance in chickpea and pigeonpea requires an understanding of the contemporary pathogen populations in the locations where resistance genes are to be deployed. *Fusarium oxysporum f.sp. ciceri* is well known for its pathogenic diversity in the country that can render a wilt-resistant cultivar resistant in one location and susceptible in another location. Based on the extensive research on the variability present in the *Fusarium oxysporum f.sp. ciceri* in India, four races namely, race 1, race 2, race 3 and race 4 are identified out of seven reported on the global basis. The other three races are 0, 5 and 6, which are confined to Spain and California (USA). Nine race specific recessive genes have been identified for fusarium wilt in chickpea. These genes are *foc-0*, *h1*, *h2*, *h3*, *a*, *b*, *c*, *foc-4*, *foc-5* and are independently inherited except for allelic pairs. Similarly, enough genetic variability and sufficient lines resistant to different races of *Fusarium udum* are available in pigeonpea but none of the lines can have resistance to most/all of the races. Traditional way of transferring one or more resistance genes to a single cultivar relies on field and green house screening against different races, which is very laborious and time consuming. With conventional approach, breeding lines with a single dominant resistance gene cannot be distinguished from breeding lines with multiple resistance genes. However, if DNA markers were available for each resistance gene, the identification of plants with multiple genes would become easy. In recent years, DNA markers have shown great promise in lessening the time and expense for pyramiding resistance genes.

So far 354 markers are reported in chickpea out of which three to four are reported to be closely linked with genes imparting resistance to race 1, race 4 and race 5 of Fusarium wilt. Besides mapping and identifying host plant resistance, efforts are being made to characterize pathogen populations making it feasible to deploy the relevant resistance genes to match the pathogen population. The ability to use marker-assisted selection to pyramid genes will make this technology an essential tool for pulse breeders in the present century.

### ***Multiple resistance***

Susceptibility of cultivars to biotic stresses adversely affects yield stability in pulse crops. In recent years, cultivars resistant to one or the other stress have been bred bringing stability to pulse production in the country. However, single gene based resistance proved to be ephemeral in nature due to susceptibility to other diseases and emergence of increasingly more virulent races/biotypes. Therefore, insulation of varieties against major biotic stresses is required to be taken up with the help of both conventional and molecular tools to meet the challenge posed by highly virulent and mobile pathogens. Stable resistance sources for many diseases and insect pests besides precise information on important aspects such as identification and characterization of races/biotypes, rate of emergence of new races/biotypes, genetic control, etc., are immediately sought for directed improvement in resistance breeding. In chickpea, varieties need to develop having multiple resistance against fusarium wilt, root rots, Ascochyta, and botrytis gray mould to succeed in farmers' fields. Similarly, pigeonpea varieties need to be insulated against wilt, phytophthora stem blight and sterility mosaic for stable performance. Uradbean and mungbean varieties are required to be resistant not only to mungbean yellow mosaic virus but also to cercospora leaf blight and powdery mildew. Besides rust disease, lentil and fieldpea varieties need to be resistant to wilt and powdery mildew, respectively.

### ***Development of nutrient responsive and nutrient use efficient genotypes***

Manipulation of the production environment with

fertilizer application has been the most preferred practice to meet plant requirements. However, the same may not be the most economical solution to all mineral deficiency and toxicity problems of the soils in future. Altering the plants to grow on soils with mineral deficiency without compromising on yield or quality has great potential. Lower input requirements, reduced production costs and less pollution could be some of the benefits expected to accrue with nutrient use efficient plants. Information about genetic aspects of plant mineral nutrition should be derived to augment research strategy for developing nutrient use efficient genotypes in pulse crops.

## **Management Options**

### ***Integrated nutrient management***

Pulses have shown varying degrees of response to fertilizers in different agro-climatic situations. While response to nitrogen is limited only to starter dose because of atmospheric nitrogen fixing ability, the pulses have shown significant response to phosphorus in terms of yield (Text Box 3). Foliar spray of 2% urea at flowering/pod filling stage has been turned out to be rewarding in terms of higher yield. Of late, deficiencies of the secondary and micro-nutrients such as sulphur, zinc, boron and iron are emerging and magnitude of response to such nutrients is increasing. Sulphur is one of the essential secondary nutrients required for proper plant growth. In recent years, introduction of high yielding varieties under intensive cropping systems coupled with use of sulphur-free fertilizers like urea and DAP and progressive decline in the use of organic manures/compost, has led to widespread deficiency of sulphur in soils. The recent statistics shows that out of 135 major pulse-growing districts, sulphur deficiency is

**Text Box 3**  
**Integrated nutrient management**

- Starter dose of 10-15 Kg N
- Application of P & K as per soil test
- Use of biofertilizer (Rh, PSB)
- Use of S and micronutrients
- Foliar spray of 2% urea
- Recycling of crop residue, FYM

pronounced in 87 districts. Recognizing this, a comprehensive research programme is initiated to determine response of different pulse crops to sulphur and find out an efficient and low cost source of sulphur. It has been observed that most of the pulse crops respond well to 20 kg of sulphur/ha and in some areas with light textured soils, the response is noticed up to 40 kg/ha. Gypsum, Pyrite or SSP has been proved to be low cost source of sulphur. Balanced and integrated nutrient management coupled with timely weed control need to be promoted.

### ***Enhancing biological nitrogen fixation***

Biofertilizers have an important role to play in improving the nutrient supply and their availability in integrated nutrient management in pulse crops. About 10-15% increase in yield is possible through inoculation of seed with efficient Rhizobium culture. Besides Rhizobium, several other free-living microorganisms are reported to facilitate nutrient uptake. Phosphate solubilizing bacteria helps increase the availability of phosphorus, which needs to be capitalized. Vascular Arbuscular mycorrhizae (VAM)- an obligatory fungus has been reported to increase availability of plant nutrients and water, both being the most precarious in rainfed agriculture. It is, therefore, imperative to develop appropriate technology to exploit these naturally occurring soil micro-organisms and generate in-depth information on their synergies besides quantification of benefits to soil fertility and nutrient uptake. Inoculation of seeds with appropriate Rhizobium culture can substantially enhance the nitrogen fixing ability of pulse crops.

### ***IPM module against gram pod borer***

Gram pod borer (*Helicoverpa armigera*) is the key pest of chickpea and pigeonpea causing heavy losses. IPM modules for management of this dreaded pest has been developed and field-tested. Use of sex pheromone trap at 3-5 traps/ha for monitoring the pest is recommended.

The economic threshold level (ETL) is 1-2 larva per metre row length. The integrated pest management strategy comprises timely sowing to exploit host avoidance phenomenon,

intercropping with mustard, barley and linseed in chickpea and sorghum in pigeonpea use of trap crops like *Vicia sativa* and African giant marigold, use of Nuclear Polyhedrosis Virus (NPV) @ 250 LE/ha or *Bacillus thuringiensis* (Bt) @ 1-1.5 kg/ha, and erection of perches @ 20-30/ha to attract insectivorous birds. Spraying with 5% Neem Seed Kernel Extract (NSKE) or Achook @ 1.25 l/ha or need based use of chemical control like 0.07% endosulfan or 0.004% fenvelarate at 15-20 days interval is recommended.

### ***Drought management***

Over 86% pulses are grown in rainfed area where drought of different intensities and duration are often experienced causing substantial loss in productivity. Under these conditions, water harvesting and its recycling, choice of suitable crops and varieties, planting techniques, seed bed preparation, plant population management, balanced nutrition, *in situ* moisture conservation, and use of mulches and water absorbing polymers help in combating droughts. Water harvesting which implies diversion of runoff to an appropriate site through land treatment and storing in surface reservoirs for subsequent use as protective/life saving irrigation has proved boon in many dry areas. Small farm ponds with 1-10 catchment areas have been found quite beneficial which need to be promoted.

### ***Developmental Options***

In pulses, we have yet to realize in farmers' fields the yield potential being expressed consistently in research stations and demonstration plots through the 'first generation' research efforts. Substantial but untapped yield potential locked up in already existing technologies can bring substantial improvements in pulse production by narrowing the gaps. An aggressive approach towards transferring the technologies generated at research stations coupled with developmental policies to ensure timely availability of critical inputs is warranted for bridging the yield gaps. In addition to the yield gaps, inter-regional and inter-seasonal disparities in yield realization also exist. While very large area (37%) under various pulse crops fall under low productivity with lower

than national average mainly in Andhra Pradesh, Karnataka, Orissa, Tamil Nadu and Rajasthan, there are states such as Bihar, Madhya Pradesh, Punjab, Uttar Pradesh and West Bengal harvesting more than the national average.

Improved production and protection technologies, including quality seeds, timely irrigation, farm operations, and effective control measures of biotic and abiotic stresses have the potential to double the pulses production. The present status of seed production in pulses indicates that indent for breeder seed is low because of poor seed replacement ratio (2-3%) as against the desired level of 10-15%. It is assessed that availability of quality seed in time can uplift about 20% production even with the available varieties. Therefore, a massive seed production programme is a must involving both public and private seed production agencies, NGOs and village panchayats. Mass production of quality biofertilizers and bio-agents needs to be taken up for wide distribution among pulse growers. In the low productivity regions, yield can substantially be raised by alleviating biophysical constraints like lack of water and unfavourable temperature through better management or by matching technologies to withstand the constraint without much reduction in yield. Even a modest gain of 100 kg per ha from 10 million ha, low productivity areas under pulses would have a far-reaching effect on pulse supply in the country.

### **Bringing Additional Area under Pulses (Horizontal Expansion)**

Pulses have tremendous scope for expansion in space and time. Early-maturing varieties of pulses can fit well in various cropping systems, thus, increasing not only the area under pulses but also sustaining the cereal-based cropping systems in the long run. Four options are readily available for bringing additional area under pulses:

- Inclusion of short duration varieties of pulses as catch crop in irrigated areas
- Introduction in new niches
- Substitution of existing low yielding crop in the prevailing systems and

**Table 4. Scope of area expansion under pulses through cropping system manipulation**

Crop	Intercropping with	Specific area	Potential area (m ha)
Mungbean	sugarcane (irrigated)	Western U.P., Central U.P., Eastern U.P., Bihar	0.50
	cotton and millets (rainfed uplands)	Maharashtra, A.P. and T.N.	0.50
	spring/summer sunflower (irrigated)	Western U.P., Haryana, Punjab	0.50
Pigeonpea	soybean, sorghum, cotton, millets and groundnut (rainfed upland)	A.P., Malwa Plateau of M.P., Vidarbha of Maharashtra, North Karnataka, T.N.	0.50
Chickpea	barley, mustard and safflower (rainfed upland)	South East Rajasthan, Punjab, Haryana, U.P., Bihar, Vidharbha of Maharashtra	0.50
<b>Total</b>			<b>2.50</b>

- Pulses as intercrop with wide space planted crops and relay crop.

The first option requires generation of high yielding varieties with early vigour, early and synchronous maturity, responsiveness to high input and resistance to key diseases and pests. The second option, which is most viable and practicable, rests on the development of short/extra-short duration high yielding varieties of various pulse crops along with matching agro-technology for growing them in non-traditional areas. Matching of crop phenology with the moisture availability coupled with insulation against key diseases and insect pests will be most crucial for successful introduction. The third option would require breaking yield barriers observed in the major pulse crops so as to make them more competitive and profitable in comparison to the cereal crops sought to be replaced from the prevailing cropping systems.

The last option requires that the breeding programmes should be oriented to minimize the intercrop competition and maximize complementarities with the companion crops. Further, the management practices should be refined to enhance input use efficiency in the system. Development of short duration varieties insulated against major biotic stresses with appropriate production technology has resulted into identification of several remunerative and more productive cropping systems. Pigeonpea-wheat, maize-post rainy pigeonpea, cultivation of short duration pigeonpea in peninsular India, cotton-chickpea, rice-chickpea/lentil sequential cropping, growing short duration pulses as catch crops in rice-wheat cropping system, uradbean in rice fallows, relay cropping of lentil/lathyrus, parallel cropping of rajmash-potato, sugarcane based intercropping are some examples of diversification through pulses. An estimated 2.5 million ha additional area can be brought under

**Table 5 New Niches for pulses production**

Crop	New niches	Potential area by 2020 (m ha)
Chickpea	U.P., Bihar, WB and Coastal Orissa	0.5
Pigeonpea (early)	North-west Rajasthan, Haryana, Punjab, U.P.	1.0
Pigeonpea ( <i>rabi</i> )	Bihar, Orissa, Southern Gujarat, M.P., W.B., eastern U.P.	0.3
Mung bean (spring/summer)	Punjab, Haryana, U.P., Bihar, W.B.	1.0
Urd bean ( <i>rabi</i> )	A.P., Karnataka, T.N.	1.0
Lentil	Eastern U.P., Bihar, Bundelkhand region	0.5
Lathyrus	Eastern U.P., north Bihar, Bundelkhand of U.P., W.B. and Chattisgarh	0.2
<i>Rajmash</i>	Central and eastern U.P., Bihar and Maharashtra	0.5
<b>Total</b>		<b>5.0</b>

different pulses through cropping system manipulation, crop diversification and multiple cropping systems (Table 4).

It can substantially increase the cropping intensity. In addition, there is a scope for introduction of pulses in new niches such as wasteland, reclaimed soils and rice-fallow land by efficient watershed management and as a replacement of less remunerative crops. It is estimated that about 5 million ha area can be brought under pulses by the end of 2020 by adopting various developmental activities (Table 5).

### Policy Support

Lack of assured market is one factor for the poor performance of pulses. It has been observed that market for pulses is thin and fragmented in comparison to cereals in many parts of the country. Due to serious problem of stored grain pests and lack of storage facilities, farmers are compelled to sell their produce to middlemen at low price. The minimum support price announced by the Government does not benefit farmers in absence of procurement mechanism. Moreover, all pulse crops are not

covered under the minimum support price (Text Box 4). Therefore, procurement policy for pulses needs to be strengthened immediately coupled with distribution of pulses through public distribution system and a reasonable buffer stock needs to be built up to meet the contingencies. Appropriate market intervention and promotion of post harvest technology are equally necessary to encourage farmers to invest more in pulse production.

In addition to the losses suffered by pulses during during harvest, transportation and threshing, they also encounter insect pest damage during storage, which is estimated to be around 0.21 million tonnes, costing 315 crore rupees to farmers. A mass awareness programme to educate farmers on scientific storage along with distribution of seed storage bins can check the post-harvest losses and increase the shelf life of pulses. According to various estimates, total post harvest losses are to the tune of 20-25% out of which milling losses alone contribute for 10%. To generate employment opportunities and to augment income of the farmers, the value-addition and agro-processing activities have to strengthen by distribution of efficient *Dal* mills and information on final products and by-products of pulses. This would help protect the resource-poor farmers from the hands of middlemen and market forces, as pulse farmers do not get even half of what consumer pays to buy dal from the market. Subsidy in the form of critical inputs as easy and cheap credits besides crop insurance are some of the policies, which can propel the farmers to grow pulses with minimum risk.

#### Text Box 4 Policy Issues

- Minimum support price
- Market Intervention
- Reasonable buffer stocks
- Pulse under PDS
- Credit facilities
- Crop Insurance
- Export