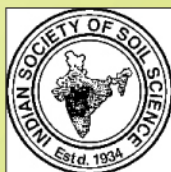


ISSS Bulletin No. 31

# Sustainable Pulse Production: *from Less for More*



Indian Society of Soil Science  
New Delhi  
2017

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**Sustainable Pulse Production:**  
*from Less for More*

*Edited by*  
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***Published on behalf of the Indian Society of Soil Science by:***

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## Preface

Pulses are an important component of Indian agriculture since time immemorial. They occupy a unique position in the world agriculture by virtue of being an rich source of protein (2 to 3 times higher than cereals), fibre, vitamins and minerals and their ability to fix atmospheric N<sub>2</sub> biologically in association with *Rhizobium* and contribute to soil carbon, require less water than other crops. However, during green revolution era, pulses were marginalized and pushed out from most productive environment of north India to harsh climate of central and south India. Pulses are raised to enhance the soil health for the succeeding crops but not cultivated in a healthy soil *per se*, which forced them to inhabit the poor soils where the physical, chemical and biological health is impaired. Coupled with this, pulses are generally grown in the rainfed situation where they suffer from either lack of water or sometimes from waterlogging, the latter being more sensitive for pulse production. With these factors, pulse production in the country could not keep a pace with population growth and consequently its availability decreased steadily from 64 g capita<sup>-1</sup> day<sup>-1</sup> in 1950-51 to 38 g capita<sup>-1</sup> day<sup>-1</sup> in 2014-15.

Realizing the importance of pulses for nutritional security, Government of India established the All India Coordinated Pulse Improvement Project (AICPIP) in 1966 and the national institute “Indian Institute of Pulses Research” in 1993 under which systematic and comprehensive research programmes on varietal development, agro-technologies and management of biotic and abiotic stresses were started in different agro-ecological regions. Though pulses did not witness genetic breakthrough as in case of cereals, a remarkable improvement and stability in productivity was achieved in recent past. Various agro-techniques such as raised bed planting, integrated nutrient management including biofertilizers, secondary and micronutrients, foliar nutrition, integrated weed management, irrigation schedule based on IW/CPE ratio and crop growth stages, micro-irrigation, integrated pest management and resource conservation have been developed for various agro-ecological zones.

To address these issues, the Indian Society of Soil Science (ISSS) organized a special symposium on “*Sustainable Pulse Production: from Less for More*” on 21 October 2016 as a part its 81<sup>st</sup> Annual Convention of the Indian Society of Soil Science at Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RVSKVV), Gwalior. A Committee constituted under the Chairman-



ship of Dr. S.K. Chaudhari, ADG (SWM), ICAR, New Delhi developed the detailed structure of the symposium. In a session of 2½ hour on the forenoon of 21 October 2016, the special symposium was held with five important topics namely, (i) Sustainable pulse production with less for more: An overview [*Speaker*: Dr. S.K. Chaudhari, ADG (SWM), ICAR, New Delhi]; (ii) Soil health: A missing link in sustainable pulse production [*Speaker*: Dr. A.K. Patra, Director, ICAR-Indian Institute of Soil Science, Bhopal]; (iii) Efficient water management: A key to sustainable pulse production [*Speaker*: Dr. S.K. Ambast, Director, ICAR-Indian Institute of Water Management, Bhubaneswar]; (iv) Technological advancements in pulse production (*Speaker*: Dr. S.K. Chaudhari, on behalf of Masood Ali, Former Director, ICAR-Indian Institute of Pulses Research, Kanpur); and (v) Government initiatives for enhancing pulses production in India [*Speaker*: Dr. B.B. Singh, Ex-ADG (O&P), New Delhi]. The session was chaired by Dr. S.K. Chaudhari, New Delhi and Dr. A.K. Patra, Bhopal acted as Convener. Grateful thanks are placed on record to all the speakers, Chairperson and Convener for successful organization of the symposium.

This bulletin is a complete treatise on sustainable pulse production from less for more with special emphasis on soil health and their management, efficient water management, technological advancements and Government initiatives for enhancing pulses production in India. Efforts made by all the authors in collating, synthesizing and presenting the information are gratefully acknowledged. It is hoped that this bulletin will act as the reference and base material for those engaged in research for sustainable pulse production in India.

5<sup>th</sup> December 2017  
New Delhi

**Dipak Ranjan Biswas**  
*Secretary*  
Indian Society of Soil Science

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## Sustainable Pulse Production with Less for More: An Overview

S.K. Chaudhari<sup>1</sup> and S.K. Jha<sup>2</sup>

### BACKGROUND

India accounts for about 35% of the global area and 27% of the global production of pulses. About 80% of global pigeonpea (*Cajanus cajan*), 65% of chickpea (*Cicer arietinum*), 37% of lentil (*Lens culinaris*) and more than 65% of mungbean (*Vigna radiata*) and urdbean (*Vigna mungo*) are produced in India. In the past decade, pulse production increased by 36.5% mostly contributed by chickpea, mungbean and urdbean. However, India needs to increase pulses production from 19 million tonnes (Mt) to anywhere between 25.39 and 36.9 Mt to meet its deficit. The production of pulses in the country during the last 3-4 years has been quite encouraging, increasing from 14.7 Mt in 2009-10 to 18.2 Mt in 2010-11 and highest ever 19.8 Mt in 2013-14 with an all-time high production achieved in chickpea (9.53 Mt) (Reddy 2015). However, during 2014-15, it has reduced by about 12.0% to 17.2 Mt owing mainly to weather aberrations. Maharashtra is the largest kharif pulses producer in the country followed by Karnataka, Rajasthan, Madhya Pradesh and Uttar Pradesh with a share of 24.9, 13.5, 13.2, 10.0 and 8.4% of total kharif pulse production, respectively and together accounting for about 70% of the country's total kharif pulse production. About 87% of the pulses cultivation in the country is rainfed in poor and marginal lands with minimum inputs and very little farm mechanization. The area under chickpea is shifted from north India to south and central India during the last decade. Area and production share of rabi pulses also increased compared to kharif pulses (Reddy 2013).

For sustaining and improvement of crop productivity as well as improvement of soil health, pulses need to be incorporated in rice based cropping systems in the different rice growing areas in the Peninsular India including the deltaic regions of important rivers viz., Krishna, Kaveri and Godavari, etc. (Mishra and Muthaiah 2003). The current domestic production of pulses in the country generally falls short of the requirement of about 22.5 Mt of processed dal and we are dependent upon imports to meet the domestic requirement (DARE 2016). In 2007-08, India imported pulses to the tune of 2.94 Mt, which increased to 4.54 Mt in 2014-15. The domestic requirement includes direct demand (60%) of pulse grains as whole/split grains, value added products (15%), seed (7%), milling losses (15%) and miscellaneous demands (3%). The shortfall in pulses production

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is mainly due to a slow growth in pulses productivity on account of poor spread of improved varieties and technologies, abrupt climatic changes, complex disease-pest syndromes, emergence of new biotypes and races of key pests and pathogens and declining total productivity and area under pulses cultivation.

### CONSUMPTION PATTERN

Pulses are consumed in a different ways including whole and split grains in the form of *dal*, flour (*besan*), and ingredient in sweets, snacks and fast foods and also as green vegetables. Protein content in different pulses varied from 26.5 to 57.0% in soybean (*Glycin max*), 20.9 to 29.2% in common bean (*Phaseolus vulgaris* L.), 15.8 to 32.1% in pea (*Pisum sativum*), 22 to 36% in fababean (*Vicia faba* L.), 19 to 32% in lentil, 16 to 28% in chickpea, 16 to 31% in cowpea (*Vigna unguiculata*), 21 to 31% in mungbean and 16 to 24% in pigeonpea (Burstin *et al.* 2007).

Among different pulses, chickpea has a vast variety of uses including 15% as a grain or *dal*, 15% in snacks and rest 60% in flour (*besan*). On the contrary mungbean, urdbean and lentil are used mostly (90%) as whole or split dal, while 10% of these crops goes to snacks preparation. In pigeonpea (*arhar*) entire production is used as split dal with little proportion going to green vegetable. Field pea [a type of pea of the species *Pisum sativum*, sometimes called *P. sativum* subsp. *arvense* (L.)], finds uses as whole or split dal (30%), snacks (10%) and flour (*besan* 60%). The minor pulses also find a variety of uses. For example, cowpea (*Lobia*) is used as a green vegetable as well as whole grains as *dal* while mothbean (*Moth*) (*Vigna aconitifolia*) is used entirely for snacks such as *namkeens*.

Consumption pattern of pulses also varies from state to state. For example, pigeonpea (*arhar*) is mostly consumed in Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, Orissa, Maharashtra, Tamil Nadu and Uttar Pradesh while chickpea, in Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Uttarakhand, Rajasthan and Jharkhand. Likewise, lentil (*masoor*) finds maximum use in Assam, Bihar, West Bengal and north-east states and urdbean is mostly consumed in southern states of the country besides north Indian states namely, Punjab, Uttarakhand, Himachal Pradesh, Delhi and Haryana. It is also interesting to note that the per capita consumption of pulses as a source of proteins has declined across the country. The per cent share of pulses in total protein uptake has decreased from 10.8 to 7.3% in rural households and 12.9 to 7.4% in urban households between 1988 and 2009.

### RESEARCH ACCOMPLISHMENTS

Shortfall in pulses has been attributed to a number of factors, the major being ever increasing population, geographical shift, abrupt climatic changes, complex disease-pest syndrome, socio-economic conditions of the farmers and less market opportunities (Singh and Pratap 2014). High influence of environmental factors and their interactions with genotype (G×E interaction) are the major production constraint in pulses which lead to a limited gain in terms of productivity in most of the pulses (Pratap *et al.* 2010). Yield

losses caused by various fungal, bacterial, viral and nematode diseases are enormous besides parasitic weed menace at various growth stages (Dita *et al.* 2006). Being rich in protein, several insect-pests also cause yield losses to food legumes both under field conditions and during storage (Clement *et al.* 1999).

Indian Council of Agricultural Research (ICAR) is engaged in the development of high yielding varieties/hybrids and package of practices for various pulse crops through Indian Institute of Pulse Research (IIPR), Kanpur in coordination with crop based Institutes, State Agricultural Universities (SAUs), State Departments of Agriculture and other related Institutes. There has been technological breakthrough in pulse crops in terms of notification of high yielding pest/disease tolerant varieties/hybrids that have certain degree of tolerance to common abiotic stresses such as fluctuation of temperature, soil/water salinity, soil alkalinity, soil acidity, *etc.* Early maturing, thermo-tolerant crop varieties with higher nutrient and water use efficiency for newer niches and cropping systems have also been developed and released for cultivation. A total of 280 high yielding varieties of different pulse crops including 61 of chickpea, 50 of mungbean, 35 of pigeonpea, 34 of urdbean, 27 of fieldpea, 23 of lentil, 18 of cowpea, 8 each of guar (*Cyamopsis tetragonoloba*) and rajmash (*Phaseolus vulgaris* L.) (frenchbean, also known as rajma or haricot bean or kidney bean); 7 each of horsegram (*Macrotyloma uniflorum*) (a miracle pulse, also known as Kulthi bean or Hurali or Madras gram), and mothbean and two varieties of lathyrus (*Lathyrus sativus*, *L. latifolius*, *L. japonicus*, commonly known as grass pea, peavines, vetchlings) have been notified for cultivation since 2001. Further, a large number of best management practices for pulses have been developed and validated, which include:

- Application of Pendimethaline (30 EC) @ 1.0 kg *a.i.* ha<sup>-1</sup> as pre-emergence and Imazethapyr @ 70-80 g *a.i.* ha<sup>-1</sup> as post-emergence application at 20-25 days after sowing (DAS) for weed management.
- Seed treatment with of Imidacloprid (17.8 SL) 5 mL kg<sup>-1</sup> seed followed by usual PGPR seed inoculation.
- Spray of Imidacloprid (17.8 SL) 0.3 mL L<sup>-1</sup> of water for the control of thrips.
- Life-saving irrigation for optimum productivity in Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra, Andhra Pradesh and Karnataka.
- Seed priming by soaking seeds for 6-8 h in water (Chhattisgarh, Bundelkhand region, Bihar, West Bengal, Odisha and Assam).
- Ridge planting of pigeonpea in high rainfall and low lying plain areas.
- Foliar spray of urea (2%) in rainfed areas at flowering/pod filling stage.
- Adoption of efficient and remunerative cropping systems *viz.*, rice-wheat-mungbean (Western UP, Haryana, Punjab), pigeonpea-wheat (Haryana, Punjab, North-West UP and North Rajasthan) and maize/sorghum /pearl millet-chickpea /lentil (Singh *et al.* 2009).

- Seed inoculation with efficient strains of *Rhizobium* and phosphate solubilizing bacteria (PSB) @ 15-20 g kg<sup>-1</sup> seed.
- Treating seed with Ammonium molybdate @ 1.0 g kg<sup>-1</sup> chickpea seed in central India.
- Raised bed planting for population management and ridge and furrow system to conserve and enhance water use efficiency in pigeonpea.
- Basal application of 100 kg DAP ha<sup>-1</sup> along with sulphur @ 20 kg and zinc @ 15 kg ha<sup>-1</sup> improves yield by 18-20%.
- Seed treatment with Thiram + carbendazim (2:1) @ 3 g kg<sup>-1</sup> of seed to ensure good plant stand.
- Use of borax @ 15 kg ha<sup>-1</sup> as basal in chickpea under rice based cropping systems of eastern India.
- *Trichoderma* + carboxin (4 + 1 g kg<sup>-1</sup> seed) for bio-control of soil borne diseases.
- Use of Pheromone traps (@ 4-5 traps ha<sup>-1</sup>) for control of pod borer in chickpea and pigeonpea.

#### IMPACT OF IMPROVED TECHNOLOGY OF PULSES

A number of varieties and production technology of pulses have proven their potential in the frontline demonstrations (FLDs) at the farmers' fields organized by the ICAR institutes, SAUs and KVKs. It has been demonstrated that adoption of improved varieties of pulses alone can increase the productivity of pulses by about 15% and the package of practices up to 34%.

#### KEY THRUST AREAS FOR RESEARCH ON PULSES

To meet the objective of increasing production of pulses, ICAR has identified following key thrust areas of research for different pulse crops for refinement of package of practices and facilitating technology dissemination.

- Development of short duration, photo-thermo-insensitive varieties of pulses for different agro-ecologies.
- Development of hybrids in pigeonpea with heterosis.
- Production of breeder seed of improved strains.
- Development of climate resilience in pulses for tolerance to high temperature and drought in winter.
- Development of efficient plant architecture in major pulse crops (chickpea, pigeonpea, urdbean, mungbean, lentil and field pea) for new niches.
- Developing intragenics/ cisgenics and transgenics against pod borer in chickpea and pigeonpea and MYMV in mungbean and urdbean.



- Pyramiding resistant gene(s) for various races of important diseases like wilt in chickpea and pigeonpea.
- Development of good agronomic practices (raised bed/ridge planting system, post-emergence weed management, input management and new cropping systems).
- Development and adoption of micro-irrigation techniques for enhancing water use efficiency.
- Development of bio-intensive integrated pest management modules.
- Forecasting and forewarning systems for optimizing results to ensure maximum returns.
- Development of resource conservation and utilization technologies (conservation tillage, residue and input management in conservation agriculture).
- Development of improved machines for planting, harvesting, threshing and processing.
- Increasing nutritional quality of pulses through bio-fortification and popularization as health food.
- Organizing frontline demonstrations in farmers' fields.

#### **STRATEGY TO INCREASE INDIGENOUS PRODUCTION OF PULSES FOR SELF-SUFFICIENCY**

Indian Council of Agricultural Research (ICAR) and Department of Agriculture Cooperation and Farmers Welfare (DAC&FW) have jointly submitted a comprehensive action plan to PMO in October, 2015, for attaining self-sufficiency in pulses. In order to ensure self-sufficiency in pulses, a road map to achieve 21 Mt pulses production in 2017-18 and 24 Mt in 2020-21 as against 17.2 Mt in 2014-15 has been proposed. The Central Government has been implementing National Food Security Mission (NFSM) for spreading new varieties of seeds and technologies of pulses among farmers. The allocation for NFSM in 2016-17 has been increased by Rs. 400 crores as compared to the previous year. In addition, a decision to take up a new sub-scheme under Rashtriya Krishi Vigyan Yojana (RKVY) to specially focus on rice fallow areas in eastern India, with a total allocation of Rs. 200 crores comprising of Central share of Rs. 130 crores has also been made by the DAC&FW.

The strategy to increase the productivity of pulses includes demonstrations of good agronomic practices and varieties on farmer's fields for reducing the yield gap, improving seed replacement rate (SRR), ensuring quality seed supply of newly released varieties with public-private partnership, maintenance of seed buffer of improved varieties, provision for life saving irrigation (micro-irrigation and water harvesting), ensuring availability of critical inputs like biofertilizers, sulphur (S), zinc (Zn), micronutrients, agrochemicals, bio-pesticides, *etc.* at state level and machines for essential agricultural operations like sowing, harvesting, inter-cultivation, threshing, processing, *etc.* through co-operatives or custom hiring. The details of these aspects have been given in the following sections.

### TECHNOLOGY DEMONSTRATIONS

Technology demonstrations of pulses have been taken up through KVKs under NFSM as a pilot project during *rabi* 2015-16. It is proposed to make the technology demonstrations through KVKs as a regular intervention to provide awareness about improved agricultural practices and help in seed availability of newer varieties.

### POPULARIZATION OF NEW VARIETIES THROUGH MINIKITS

In order to motivate the farmers to cultivate seeds of new varieties, minikits (small quantity of seed of newer varieties) available to the farmers' free of cost has proved to be an effective intervention. This intervention will help in quick spread of new varieties. This has proved to be a successful intervention under oilseeds scheme and would be considered for pulses also. A total of 59 high yielding varieties of different pulses have been notified during the last five years (2011-2015) as given below (Table 1).

**Table 1.** Different high yielding varieties of pulses notified during the last five years (2010-2015)

Crop	High yielding varieties of pulses notified during the last five years (2010-2015)
Chickpea (13)	Raj Vijay Kabuli gram 101, Raj Vijay gram 201; HK-4, PKV Harita, Raj Vijay Gram 203, L-555; GNG 1958, GNG 1969, NbeG 3, JG-12; Bidisha, Vallabh Kabuli Chana-1, Raj Vijay Gram 202
Mungbean (10)	IPM 02-14; Swati, MH-421, BM 2003-2; SML 832; MH 421; DGGV-2; BGS-9; CO 8, Shalimar Moong-2
Urdbean (10)	Co6 COBG 653, VBN (Bg) 7; Vishwas, VBN 6, UH-1, DU-1, TU 40; Pratap Urd-1; DBGV-5; Vallabh Urd-1
Pigeonpea (8)	TS-3R; Anand Grain Tur-2, BDN 711; Rajeshwari, Rudreshwar, PKV TARA; BRG-4; ICPH 2671
Field pea (7)	IPF 4-9, VL Matar 47; HFP 529, Gomati; IPFD 10-12; HFP 715; Shalimar Pea-1 (SKUA-P-8)
Lentil (6)	VL Masoor 514, LL931, VL Masoor 133; IPL-316; Raj Vijay Lentil 31; Shalimar Masoor-2
Horse gram (3)	Indira Kulthi-1; Gujarat Dantiwada Horsegram-1; CRIDAHARSHA;
Cowpea (2)	MFC-08-14; DCS 47-1

### ENHANCING BREEDER SEED PRODUCTION AND CREATING SEED HUBS

Availability of breeder seed is crucial for quality seed production. Against a total indent of 75870 q breeder seeds of different pulse crops placed by DAC&FW during the last six years (2009-10 to 2014-15), 82546 q breeder seeds of pulses were produced and supplied to different seed producing agencies for further multiplication and distribution so that quality seeds of improved varieties/hybrids could be made available to the farmers for cultivation and boost the productivity of pulses. Due to inadvertent risk of biotic and abiotic stresses, many times, seed chain (at 30% SRR) has been affected and so the availability of quality seed to the farmers. Therefore, there is a need to increase the amount of breeder seed by 10-15% over the quantity required annually as a contingency measure to bridge this gap. More number of centres needs to be strengthened for additional production of breeder seed. It has been planned to set up 150 seed hubs of

pulses in ICAR institutes, All India Coordinated Research Project (AICRP) Centres (mostly SAUs) and Krishi Vigyan Kendras (KVKs) and to incentivise pulses seed production by central and state seed agencies. The states should place more indents for breeder seed of pulses. In chickpea, the breeder seed production in the country was 7700 q against the indent of 7400 q during 2014-15; however, the total breeder seed requirement for 30% SRR happens to be about 10,500 q (Table 2).

**Table 2.** Requirement of breeder seed of different pulse crops for ensuring sufficient quality seed at 30% SRR

S. No.	Crop	Quality seed required (lakh q)	Breeder seed requirement (q)
1.	Chickpea	21.10	10500
2.	Pigeonpea	01.92	120
3.	Mungbean	01.79	227
4.	Urdbean	02.06	283
5.	Lentil	01.87	1331
6.	Fieldpea	01.88	1362
	Total	30.62	13823

### MEGA VARIETIES OF PULSES

The mega-varieties of chickpea are JAKI 9218, JG 11, GNG 1581, JG 13, JG 322, Vijay, JG 14, JG 6, Digvijay, JG 63. Among them, JG 11, JG 16, JG 322 and Vijay are more than 15 years old and need to be gradually replaced by new varieties in the next five years with continuous subsidy on them. States like Madhya Pradesh, Andhra Pradesh, Maharashtra, Rajasthan and Karnataka are the major indenter's; whereas Karnataka, Jharkhand and Uttar Pradesh are placing low indent. Likewise, in pigeonpea the mega varieties are ICPL 87119, ICP 8863, Bahar, UPAS 120 and NDA1 having the maximum seed indent and need to be supported by subsidy for few additional years before they are gradually phased out. Similarly, in mungbean, Samrat, SML 668, HUM 12, IPM 02-3 and Pant Mung 5; in urdbean Pant Urd 31, IPU 2-43, Shekhar 2, Uttara and TAU1; in lentil HUL 57, Pant L 8, DPL 62, Noori and Mallika and in fieldpea HUDP 15, KPMR 400, Vikas and Prakash are the most popular varieties covering a large area and need government support in the form of continued subsidy to sustain the seed requirement in next few years.

### PRODUCTION SUBSIDY FOR SEED GROWERS

The NFSM programme does not have any incentive for pulse seed growers unlike NMOOP which gives subsidy for oilseeds producers. It has been proposed to give subsidy for pulse seed growing agencies @ Rs. 2500 q<sup>-1</sup>. The subsidy will be given to central seed agencies like National Seed Corporation (NSC), Krishak Bharati Cooperative Limited (KRIBHCO), Indian Farmers Fertiliser Cooperative Limited (IFFCO), *etc.* directly and through state governments to state seed corporations and private seed companies.

### INCENTIVE FOR APPLYING CRITICAL INPUTS

One of the important reasons for low productivity of pulses in the country is growing them in marginal and poor soils with minimum inputs. Hence, promotion of use of micronutrients is necessary. Similarly, plant protection chemicals are essential in increasing the productivity of pulses. Currently incentive is being given under NFSM for integrated nutrient management (INM) and integrated pest management (IPM). However, this incentive is not sufficient and target only limited areas. It should be enhanced substantially.

### STRENGTHENING OF PRODUCTION UNITS OF BIOFERTILIZERS AND BIO-CONTROL AGENTS

About 40% of pulse growing regions have low to medium population of native *Rhizobium*. Appropriate measures are required for sustained pulse production by maintaining soil health with diversification, balanced fertilization and use of biofertilizers. Similarly, effective bio-agents for seed dressing like *Trichoderma* proved potential in controlling wilt and other root diseases. For ensuring availability of biofertilizers and bio-agents of good quality, strengthening of production units in selected State Agricultural Universities (SAUs) and ICAR Institutes would be an essential intervention.

### MECHANIZATION FOR PLANTING AND HARVESTING OPERATION

Increased mechanization for planting and harvesting is required to reduce peak season labour requirement. Ridge-furrow planters for planting of pigeonpea on ridges, BBF planters for *kharif* pulses, harvesters and threshers are essentially required for ease in operations at farm level. The allocation for mechanization under Sub-Mission on Agricultural Mechanization (SMAM) and NFSM should be enhanced.

### PROVISION FOR PROTECTIVE IRRIGATION THROUGH PRADHAN MANTRI KRISHI SINCHAI YOJANA (PMKSY)

Pulses are mostly grown in rainfed areas and their production is dependent upon amount, pattern and distribution of rainfall. The non-availability of water especially at critical stages of crops leads to severe reduction in productivity of pulses. Hence, it is necessary to make arrangement of life saving irrigations to protect the crops. Construction of water harvesting structures and installation of micro-irrigation system like sprinkler may be taken up in pulse growing areas on a large scale. Accordingly, the allocation of PMKSY should be increased significantly for these components especially for the pulse growing districts of the country.

### TRAINING AND AWARENESS CREATION

Training of the field functionaries, pulse seed growers and pulse farmers is essential for speedy dissemination of improved crop production practices of pulses. Integrated programme of ICAR/SAU/ CGIAR Institutes on capacity development of various stakeholders has also been proposed.

### **BRINGING ADDITIONAL AREA UNDER PULSES CULTIVATION**

To enhance overall production of pulses, there is an urgent need to bring 3-4 million hectare (Mha) additional area under pulses to increase domestic production. This can be achieved by increasing area under pulses in rice fallows, by intercropping them with sugarcane, cotton, millets, groundnut, sorghum and other crops and bringing pulses in short season spring/summer windows in northern states. Mungbean can be promoted in Punjab, Haryana, Western Uttar Pradesh and parts of Rajasthan during summer season after the harvest of wheat, potato and rapeseed and mustard. Likewise, lentil and chickpea should be promoted in rice fallows of Eastern Uttar Pradesh, Bihar, Jharkhand, Odisha, Chhattisgarh, West Bengal and mungbean/urdbean in rice fallows of Andhra Pradesh, Tamil Nadu, Odisha, Karnataka. There is an ample scope of increasing area under fieldpea cultivation in states like Punjab, Haryana, Uttar Pradesh and Bihar, and it is anticipated that with active policy and research support 50-60 thousand ha additional area can be brought under pulses cultivation.

### **PROCUREMENT OF PULSES**

As a tradition, government announces Minimum Support Price (MSP) for pulses too. It announced significant increase in MSP of pulses in 2015-16. However, whenever the price falls below MSP, very little procurement of pulses is done. As a result farmers are not encouraged to grow pulses. They prefer to grow rice and wheat which are procured on significant scale. There is no credible institutional arrangement for procurement of pulses and hardly any budget is earmarked, if the need arises, for procurement of these crops. There are issues relating to disposal of these crops after procurement. In order to provide remunerative prices for pulses to the farmers, proposal is there to implement two pronged strategies. The farmers who wish to withhold their produce from immediate sale after harvest will be given interest free loan up to 75% of value of produce and the government will also bear the charges for keeping farmers' stock of pulses in warehouses. This will help the farmers in not resorting to distress sale at time of harvest and also benefitting from market at appropriate time. The financial support will be given through banks and cooperative societies and administered through

### **NATIONAL BANK FOR AGRICULTURE AND RURAL DEVELOPMENT (NABARD)**

In addition, it is proposed to encourage states to take up procurement of pulses in case the price falls below MSP after harvest. The Centre assures to give fixed charges towards cost of procurement operation and losses if any, to the states without laying down any pre-condition except procurement at MSP when prices were below MSP in the harvesting season. As per preliminary estimates, it is proposed to give fixed charges @ 25% of MSP to the states for procurement of pulses.

This joint endeavour of ICAR and DAC&FW for enhancing indigenous production of pulses to attain self-sufficiency can become a reality, if proposed programmes are sustained for next five years.

### AUGMENTING PULSES PRODUCTION THROUGH SUMMER MUNGBEAN

Despite the fact that efforts have been made to acclimatize a number of high yielding varieties of pulses with matching agro-technologies and tolerance to biotic and abiotic stresses (associated with existing agro-ecologies and new niches), yet we have been falling short in expected production and productivity goals in pulses. Our renewed emphasis is on selective yet sustainable intensification of pulse-based cropping systems and development of modern efficient production/protection technologies. Mungbean, a fast growing and remunerative pulse crop with low water requirement in comparison to most of the cereal/oilseeds crops, could have the requisite yield potential in meeting the shortfall in total pulses production in the country as a whole. As the crop matures in around 60-65 days, agronomic strategy towards better management of crop through soil fertility consideration, timely planting, population maintenance, irrigation and crop protection practices play the key role for productivity enhancement during summer. The cultivation of mungbean during summer season gains wider acceptance with the availability of new varieties for additional income, improvement in soil fertility and efficient land utilization (Dodwadia and Sharma 2012).

There are certainly further scope/avenues for higher production in summer mungbean (with existing low coverage or land use) through amalgamation of improved technologies such as varietal interventions (Samrat, IPM 02-3, IPM 99-125, SML 134), compatible pre- and post-emergence herbicides/pesticides, precision management in crop cultivation complemented/supplemented with appropriate micro-irrigation based irrigation scheduling and suitable land configuration (raised bed/ridge planting especially during *khari*), replenishment of nutrients based on *Soil Health Cards* for optimum fertilization including application of Zn, S and Mo (in presence of adequate P and K) and use of suitable machines from planting (Fig. 1. IIPR No-Till Drill) to harvesting operations/value addition (ICAR News 2016b).



**Fig. 1.** IIPR No-Till drill (with labour requirements of around 40 man-h ha<sup>-1</sup>, field capacity 20 h ha<sup>-1</sup>, low cost of <1000 INR ha<sup>-1</sup> and low energy of operation of <80 MJ ha<sup>-1</sup>)

Sowing of the crop at optimum time plays a key role in obtaining the high seed yields (Rathore *et al.* 2010). Field experiments in North Plain Zones revealed that when summer mungbean is planted during last week of March after potato/garlic or winter vegetables, requires only two irrigations (due to higher residual soil moisture after march



harvested crop) in comparison to normal 3-4 irrigations for later planted crop after wheat/vegetables (with low residual soil moisture in April). A study conducted under a micro-irrigation management in summer pulses showed that a significant improvement in seed yield (31%) with water saving (11% less water use and 43.2% enhanced WUE) were recorded in summer mungbean with precision tillage carried out by laser leveller (ICAR News 2016). Sprinkler irrigation was advantageous for enhancing the irrigation efficiency even for two months duration of mungbean crop (with 20% less water use and 24% higher WUE) over flood or normal irrigation at podding and seed setting stages. It was attributed to consistent supply of water maintaining plant water balance and rhizosperic soil moisture content. Sprinkler irrigation could play a safe proposition for precision/regulated irrigation scheduling in respect of its frequency/time/ quantum. The beneficial effect of blanket flood irrigation was not pertinent under field condition in terms of plant stand, biomass and grain yield which was more likely in the absence of a laser leveller. A popular mungbean variety Samrat suffers in hot summer months due to blanket irrigation owing to irregular *in-situ* depressions/ponding zones developed in field especially in the absence of a laser leveller.

Large plot demonstrations laid to study the effect of overhead sprinkler irrigation + improved agro-techniques (paired row, narrow row spacing with sprinkler irrigation), convincingly showed the beneficial role of sprinkler irrigations in the late afternoon/evening hours in summer mungbean (Fig. 2 and 3). Although there was similar yield under sprinkler *vis-à-vis* flood irrigation at critical stages (two irrigation at branch and pod), yet there is significant water economy through micro-irrigation (35-50%). In addition, farmers' practice of planting at uniform 30 cm row spacing reduced seed yield to the extent of 16-20% over 22.5 cm row spacing. Variation in performance of different varieties also exists (10% additional yield was realized under cv. 'Samrat' at 1.23 t ha<sup>-1</sup> over cv. 'IPM 205-7' at 1.12 t ha<sup>-1</sup> when mungbean was sown during last week of march).

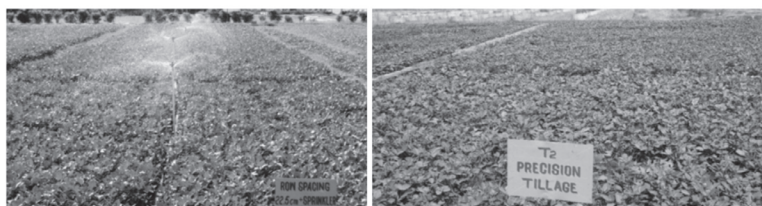


Fig. 2. Irrigation scheduling aided with overhead sprinklers and laser leveller (precision tillage)

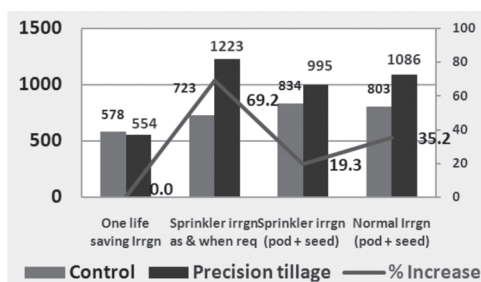


Fig. 3. Interacting influence of tillage and irrigation on mungbean yield (kg ha<sup>-1</sup>)



In variety  $\times$  row spacing evaluation trial under late planting condition (after wheat), significantly higher grain yield was obtained at 15 cm  $\times$  10 cm (1.56 t ha<sup>-1</sup>) when mungbean was planted during 2<sup>nd</sup> week of April over either 22.5 cm  $\times$  10 cm or 30 cm  $\times$  10 cm (Table 3). Although varieties differ in their performance in yield, yet 22.5 cm  $\times$  10 cm was found to be optimum and economically superior (as with low seed rate) under existing condition irrespective of varieties and sowing dates.

**Table 3.** Biomass and grain yield (t ha<sup>-1</sup>) of summer mungbean under different sowing dates and row spacing

Row-row spacing	Sowing date			
	March 4 <sup>th</sup> week		April 2 <sup>nd</sup> week	
	Total biomass	Grain yield	Total biomass	Grain yield
15 cm	3.42	1.28	7.06	1.56
22.5 cm	3.25	1.22	5.58	1.24
30 cm	2.78	1.05	4.45	1.04
CD ( $P=0.05$ )	0.19	0.13	1.23	0.45

Therefore, diversification and intensification of rice-wheat cropping system in Northern India through introducing pulses has long been neglected by farmers as a profitable and viable enterprise. This is possible with development of infrastructure facility such as irrigation water availability renders these feasible and economically viable now than ever before. Over several trials conducted on on-farm situations, it has been amply demonstrated that such possibilities do exist and wherever feasible/ economically viable, low input requiring pulses could be popularized as a soil building crop. In the existing studies made at on-farm (Fatehpur and Kanpur Dehat of Uttar Pradesh), farmers' have sown mungbean cv. 'SAMRAT' just after harvest of winter wheat with only 2-3 irrigations as per need. There are two situations where the crop is either planted at 30 cm row spacing in line or broadcasted in the entire field after plough followed by a plank. Comparison made for both these situations revealed the most yield reduction in the latter due to inadequate plant stand/improper maintenance of plant population later and little/inadequate plant protection (also in the former case). The seed yield of summer mungbean realized was up to 750 kg ha<sup>-1</sup> for a period of 60-65 days without any second picking (due to synchronous maturity as an additional attribute of the plant types). However, higher gross return to the extent of INR 33000 within a short period of 2 months motivated farmers to take up spring/summer mungbean cultivation especially where supplementary irrigation can be managed. Farmers also realized higher rice yield due to improved soil fertility (as mungbean being buried over in the field). As a result of better return, the farmers have started cultivating summer mungbean after wheat/garlic or even after potato. As the water requirement of the crop is less in comparison to other cereals and oilseeds, this can be profitably grown and adopted under water scarcity areas and rainfed/dryland areas (through supplementary irrigation with water harvested by farm pond, micro-water storage tanks).

In conclusion, within the technology framework, substantial productivity enhancement through the existing varieties of pulses could be possible with short duration varieties that fit well in different (inter-) cropping systems so as to augment vertical expansion

of pulses in the country. Mungbean for example through development of new plant types, photo-thermo-insensitive cultivars and matching agrotechnology could help in expanding the areas of pulses further (in the non-traditional areas of the country), thereby both up- and out-scaling productivity (over seasons and locations) and overall production scenario in the country.

### WATER MANAGEMENT IN PIGEONPEA

Studies made on drip-fertigation (a form of micro-irrigation) where both water and fertilizer are applied precisely at the root zone during peak crop water demand ensuring direct benefit to plants. This supplementary irrigation especially during long dry spell after rainy months could possibly alleviate moisture stress in the growing crop. Further, restrictions imposed as a result of climatic aberrations in terms of deficiency in rainfall and its diminished frequency/distribution especially at flower/pod development can also be alleviated with supplementary irrigation aided with micro-irrigation. In an experiment carried out during 2010-12 involving precision irrigation through drip-fertigation schedules revealed a potential seed yield of 3708 kg ha<sup>-1</sup> was realized, under drip-fertigation at branching only. Even a single irrigation (2 cm through 5 splits) through drip-fertigation with half of N+K fertilizer to pigeonpea at branching (3419 kg ha<sup>-1</sup>) produced significantly higher (19.6%) seed yields over rainfed crop. In addition, drip-fertigation at both stages also out-yielded significantly over improved practice (furrow irrigation) during second year (9.4%). Yield attributes such as pods/plant, 100-seed weight and harvest index showed similar trend with that of seed yield. Lower water use, greater profile soil moisture content and water use efficiency (65.1 kg ha-cm<sup>-1</sup>), higher plant NPK uptake with improved soil nutrient availability and greater net return (INR 9700 ha<sup>-1</sup>) were evident with drip-fertigation at both the stages (Table 4). Water saving measures through micro-irrigation could possibly be extended to large areas enabling efficient management of precious water through community sharing of irrigation infrastructures through village cooperatives and welfare schemes.

**Table 4.** Effect of drip-fertigation on yield, economics, WUE and soil organic carbon under long duration pigeonpea

Drip-Fertigation	Grain yield (kg ha <sup>-1</sup> )	Net return (₹ 000 ha <sup>-1</sup> )	WUE (kg ha-cm <sup>-1</sup> )	Agronomic efficiency (kg grain/kg NPK)	SOC (%)	
					0-15 cm	15-30 cm
Rainfed	2858	66.40	58.2	10.6	0.27	0.18
Drip <sup>Br</sup>	3419	74.91	66.9	16.9	0.31	0.23
Drip <sup>pod</sup>	3092	64.36	60.1	13.2	0.28	0.19
Drip <sup>Br+pod</sup>	3468	76.05	65.1	17.4	0.32	0.25
Irrigation <sup>Br+pod</sup>	3262	74.49	60.2	15.0	0.29	0.22
CD ( <i>P</i> =0.05)	225	7.01	4.4	2.6	0.21*	0.17*

In other trials involving micro-irrigation (sprinklers), the results obtained were similar. Initial studies were conducted on sprinkler irrigation in closely planted short statured legumes like chickpea and mungbean revealed that three sprinkler irrigations of 60 mm

each at sowing, branching and pod formation stages were found sufficient for chickpea with a water saving of 44.0%. Sprinkler irrigation in mungbean increased yield by 39.7% over surface irrigation and resulted in water saving of 49.8%.

#### **SUSTAINING SOYBEAN SYSTEM IN CENTRAL INDIA WITH PULSES -AN EFFICIENT WATER MANAGEMENT THROUGH BROAD BED FURROWS (BBFs) INTERCROPPING, *etc.***

On intercropping with pulses/cereals/oilseeds in terms of total system productivity for both *kharif* + rabi (soybean+intercrop - lentil), significantly higher total productivities and net returns were recorded with soybean+pigeonpea - lentil followed by soybean+urdbean - lentil in Central India. Similarly, BBF proved its superiority over flat planting both during *kharif* and *rabi*. Because of scanty rainfall and its uneven distribution, supplementary irrigation once to lentil could be useful.

Soybean is the most important rainy season crop of Central India. Most Indian farmers begin cultivating soybean, which is a rainfed crop, during June following arrival of the monsoon rains. The crop is preferred mainly in the states of Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka. The crop has occupied its dominance in Central India over the years especially in Madhya Pradesh because of more or less favourable growing conditions compatible with climate and soil condition. Thus, the crop is grown in the country in an area of around 11.63 Mha during 2015-16 with anticipation of at least 10% reduction in its area during 2016-17 due to economic considerations and competing crops especially pulses (pigeonpea and other *kharif* crops). The reasons are many. Many farmers in Madhya Pradesh who plants soybean during *kharif* have decided to switch to other crops as soybean is no longer remunerative mostly due to lower prices and higher cost of production. Still many others prefer to grow the crop despite the loss. Besides biotic stresses (*e.g.*, the yellow vein mosaics and sucking pests), the crop also suffers more due to abiotic stresses as a result of ponding of water under heavy soil condition.

Despite the fact that the soybean has a access to best marketing practices, the crop losses its shine as its production and productivity have gone down over the years resulting in rare possibility of covering its cost of cultivation. On the other hand, deficiency in rainfall and its diminished frequency/distribution pose further restriction in soybean and its cropping systems as these are grown mainly under rainfed conditions. Moreover, scanty rainfall not only limits crop growth and development, but also puts a hold in realizing potential productivity of crops/genotypes. In addition, introduction of soybean as a commercial crop in India had led to development of dominant cropping systems namely, soybean-wheat in Vertisol and associated soils that further led to stress on both soil and environment (due to the post-rainy crops, mostly wheat, which is grown under frequent irrigation condition).

Thus, there is an urgent need to manage the natural resources of soybean growing regions, particularly rainfall, to control soil erosion and to improve rainfall-use efficiency by switching to improved land configuration and appropriate soil cover. The rainwater stored by improved agronomic approaches can suitably be recycled for crop growth and

development thereby enhancing the scope for another crop during *rabi* season. For example, low water requiring pulses like chickpea and lentil can very well be integrated with (after) soybean under rainfed agro-ecologies. Hence, there is an urgent need to integrate various soybean-based cropping systems for better productivity and farm income. The role of an efficient intercropping system compatible with soybean can't be overlooked. Short duration pigeonpea, urdbean and some compatible cereals are found to be most promising and remunerative if selection of suitable varieties are made and necessary crop environment is altered through modifying existing sowing windows. Therefore, the current series of investigations were undertaken to fulfill the twin objectives of (i) enhancing crop productivity and sustainability in soybean based intercropping system (*kharif*), and (ii) enhancing system productivity of soybean-lentil system under rainfed agro-ecology of Central India (*kharif* + *rabi*).

Keeping in view, the proven advantages of intercropping, extensive studies were made during 2014-16 at ICAR-Indian Institute of Pulses Research, Regional Centre, Bhopal to screen the crop/varieties for their performance and adoption in soybean system. While assessing and refining the most remunerative inter-cropping system, two most compatible crops (short duration pigeonpea and urdbean) were zeroed for sustainable bio-intensification of soybean system. The pigeonpea was found to be most promising. The strategies adopted are specific and time bound and so was the cropping scheme devised (ICAR News 2016a).

#### STRATEGIES FOR BIO-INTENSIFICATION OF SOYBEAN SYSTEM IN CENTRAL INDIA

- Sowing of short duration pigeonpea with soybean by mid-June or July (possible with 1<sup>st</sup> few pre-monsoon shower of rain).
- Switching to more appropriate pigeonpea variety (TJT 501, TT 401, JKM 189 and other short duration varieties).
- Managing crop optimally under rainfed condition (with restricted crop growth and dry matter) on broad bed furrows (BBFs).
- Relatively narrow spacing for pigeonpea (by maintaining a row spacing of 50-70 cm).
- Planting of *rabi* pulses say lentil by 1<sup>st</sup> week of December under residual moisture.
- Provision of one supplementary irrigation, if possible, during *rabi* for realization of higher yield.

#### TECHNOLOGICAL INTERVENTIONS

Five intercrops *viz.*, short duration pigeonpea 'TJT 501', maize 'RASI 4242', sorghum 'MGSH 55', urdbean 'IPU 2-43' and sesame or *til* 'Western' were taken along with soybean 'RSV 2001-4' in 2:2 replacement series both in flat bed and broad bed furrow (BBF) land configurations. These crops were followed by lentil 'IPL 316' during *rabi* with or without supplementary irrigation. The study showed that soybean was found to be highly compatible with short duration pigeonpea. The slow growth of pigeonpea during initial period facilitated soybean growth as a parallel cropping. After maturity of

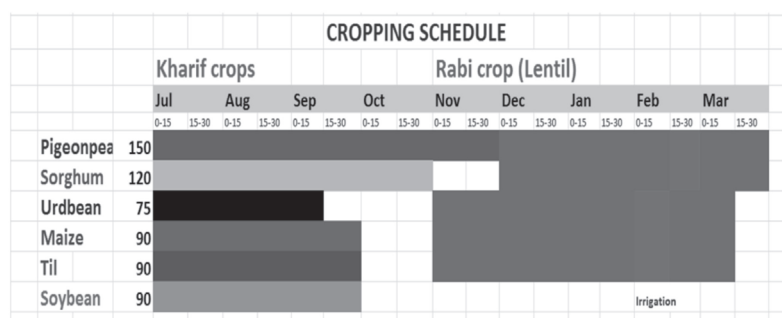
soybean (around 3 months from sowing), pigeonpea occupied the total space (Fig. 4 and 5) and in fact, performed as a pure or monocrop and gave higher soybean equivalent yield (SEY, 3556 kg ha<sup>-1</sup>) in comparison to other intercropping situation (SEY, 544-707 kg ha<sup>-1</sup>).

Under the situation, BBF had distinct advantage for both *kharif* and *rabi* crops as significant enhancement in crop productivity to the tune of 19.2, 16.6, 18.5 and 16.7% in soybean alone, lentil alone, total productivity during *kharif* and *rabi*, respectively was recorded under BBF over flat planting. Thus, significantly higher system productivity realized under BBF over flat planting (both during *kharif* and *rabi*) was in fact attributed to enhanced yields in most of the intercrops under it (Table 5).

When comparison was made on total system productivity for both *kharif* + *rabi* (soybean+intercrop - lentil), significantly higher total soybean productivity were recorded with soybean+pigeonpea - lentil (SEY, 4691 ha<sup>-1</sup>) followed by soybean+urdbean - lentil (SEY, 2425 kg ha<sup>-1</sup>) under heavy soil condition of India's Central Zone (Table 5). Nevertheless, as both pigeonpea and sorghum were harvested late in the season (end of November) thereby delayed lentil sowing which affected both the *rabi* crop (of lentil) and total productivity adversely. Yet, because of very high productivity of pigeonpea, it compensated fully the loss in lentil yield due to delayed sowing. As a result, net return per hectare has gone up to INR 97, 238 and BCR (net return over cultivation cost) to 4.26 (the highest, and doubled over other systems), thereby making the system the most productive (promising) and remunerative (Table 5, Fig. 6, 7). Significantly higher productivity was also realized under BBF over flat planting at the site.



**Fig. 4.** Performance of soybean + pigeonpea (2:2 replacement series), pigeonpea and lentil after soybean in Central India



**Fig. 5.** Cropping scheme inclusive of *kharif* crops (soybean+intercrop) and *rabi* crop (lentil) with crop duration in days

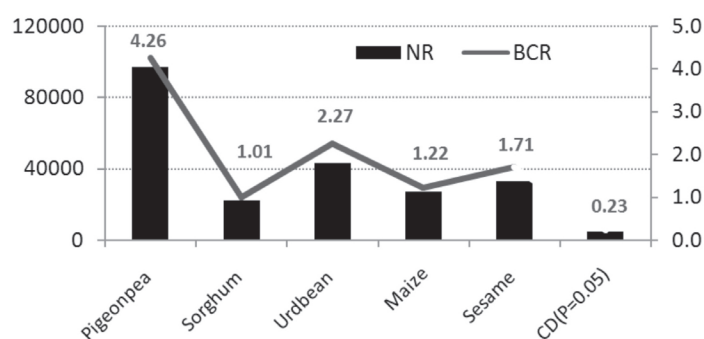
Source: ICAR News (2016b)

**Table 5.** Comparison of land configuration and intercropping in soybean+intercrop (2:2) - lentil system

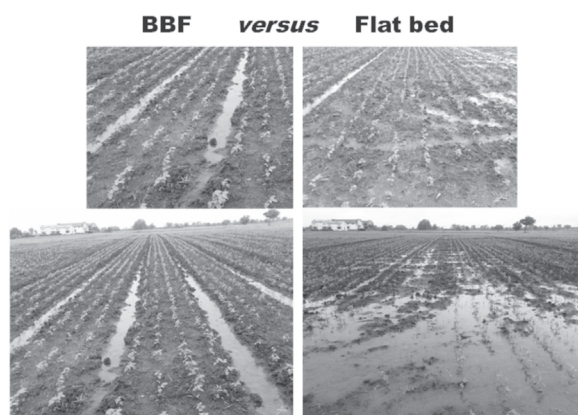
Land configuration/ Cropping system	Soybean yield* (kg ha <sup>-1</sup> )	Intercrop yield during <i>kharif</i> (SEY, kg ha <sup>-1</sup> )	Lentil yield (kg ha <sup>-1</sup> )	Total system productivity (SEY, kg ha <sup>-1</sup> yr <sup>-1</sup> )	Net return (INR ha <sup>-1</sup> yr <sup>-1</sup> )
<i>Land configurations</i>					
Flat	421	1110	693	2363	39567
BBF	502	1312	808	2785	49857
CD ( <i>P</i> =0.05)	68	96.4	63.5	108	2776
<i>Intercropping system</i>					
Soybean+pigeonpea-lentil	432	3556	584	4691	97238
Soybean+sorghum-lentil	465	565	604	1756	22599
Soybean+urdbean-lentil	481	684	1049	2425	43128
Soybean+maize-lentil	483	544	765	1945	27390
Soybean+sesame-lentil	445	707	750	2053	33207
CD ( <i>P</i> =0.05)	NS	274	82.5	192	4921
CD ( <i>P</i> =0.05) for Interaction	NS	388	117	272	6960

\*Soybean area is 50% of total area; SEY: Soybean equivalent yield (kg ha<sup>-1</sup>)

Source: ICAR News (2016b)

**Fig. 6.** Economics of soybean+pigeonpea - lentil system in Central India (INR ha<sup>-1</sup> yr<sup>-1</sup>)

Source: ICAR News (2016)

**Fig. 7.** A typical advantage of BBF (possible by BBF Planter) over flat bed (both for drainage of excess of water and conservation of soil moisture)



In addition to the pertinent effect of BBF, and soybean+pigeonpea system, supplementary irrigation once to lentil could also enhance its productivity over the rainfed crop. As a result, significantly higher (27.4%) lentil yield (and its soybean equivalent yield) was obtained following irrigation due to scanty rainfall received during monsoon season although total productivity of soybean-lentil system was not influenced by irrigation. The study thus, confirmed the sustainability of soybean system with pulses.

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## Soil Health, the Missing Link for Sustainable Pulse Production in India

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### INTRODUCTION

Pulses constitute the major source of protein for majority of population in India that is predominantly vegetarian in dietary habits. The Government of India has fixed a target of food grains production as 270.10 Mt for the year 2016-17 with a target of 20.75 Mt for pulses which is an optimistic target. While, declining crop response ratio to fertilizers is a major worry to the policy makers, in the past decades, the ratio, measured from the grain productivity to fertilizer consumption, has declined phenomenally in several crops including pulses. A ratio of 15 during the first plan period (1974-79) has declined to 6 kg grain per kg NPK during the end of the 6<sup>th</sup> plan (2007-12). This is the reflection of deteriorating soil health in the production systems, particularly pulse production environments. However, there is marginal increase in the response ratio in the past couple of years. In many areas, yields have started declining because of deceleration in total factor productivity, decline in organic matter content in soil and emergence of multi-nutrient deficiencies (Ali and Gupta 2012). The other constraints in raising productivity of pulses include cultivation in marginal soils, rainfed conditions and inadequate nutrition (Thomas *et al.* 2013). Negligible growth rate of pulse area and production as compared to cereals has been documented by Narayan and Kumar (2015), growth rate of area -0.09, -0.60 and 1.62, and production 1.52, 0.59 and 3.35 during 1980s, 1990s and 2000s decades, respectively. Both extremes of rainfall either excess or deficit, favour pulse productivity, since their cultivation is primarily confined to rainfed areas making the production critically dependent on the rainfall where nutrient management is a real challenge.

### PULSE CROPS AS DRYLAND SAVIORS

Almost a dozen pulse crops are grown across the country with about a 24% share in the total global pulses production. The maximum area of pulses is contributed by chickpea (35%) followed by pigeonpea (16%). Although, chickpea, a *rabi* season crop in the central and north Indian states is grown by 22 states and two Union Territories of Dadra and Nagar Haveli and Delhi and pigeonpea by 24 states and three Union Territories of Andaman and Nicobar Island, Dadra and Nagar Haveli and Delhi (Singh 2013). In the recent past,

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chickpea is cultivated in the southern states during *kharif* season with ICRISAT strains. The short duration cultivars developed through ICRISAT-ICAR-NARS partnerships have played a key role in expanding area and productivity of chickpea in southern India. In India, about 93% of sorghum, 94% of pearl millet and 87% of pulses are cultivated in drylands (Singh *et al.* 2007; Somasundaram *et al.* 2014). More than 90% of lentil area is distributed in Madhya Pradesh and Uttar Pradesh contributing to more than 70% of country's production. Pigeonpea is mainly grown in Maharashtra, Karnataka and Andhra Pradesh states (>60% area in India) with 60% of production (1.4 Mt). Madhya Pradesh has the highest area (38%) under chickpea, followed by Maharashtra (16%), Karnataka (12%), Rajasthan (11%), Andhra Pradesh (8%) and Uttar Pradesh (8%). Andhra Pradesh leads in the total pulse productivity (Gowda *et al.* 2013). Farmers consider pulse crops as "soil health enhancers" and are primarily cultivated to enhance the health of the soil in terms of physical, chemical and biological health. This factor seriously impairs pulse production in the country. Although pulses help to enhance soil health (Ganeshamurthy *et al.* 2006), their production is dwindling due to the missing soil health link.

#### NUTRITIONAL REQUIREMENTS *VIS-À-VIS* NATIONAL FOOD SECURITY SITUATION

India with a total geographical area of 329 Mha is blessed with extremely diverse climatic and edaphic conditions. About 57% of the total land area is under agriculture as against the world average of 11.5%. Significant land use changes have occurred, where the net sown area increased from 119 Mha 1950-51 to about 140 Mha by 1970-71 except some minor variations. Also the net irrigated area in India increased from about 21 Mha in 1950-51 to 48 Mha by 1990-91, which in the last 18 years increased only by about 10 Mha. India's population during the last three and half decades (1972 to 2007) increased many folds. Production of most of the food items increased more than double which contributed in improving per capita availability of all food commodities except pulses (Table 1) and the ratio of cereals to pulses is declining alarmingly (State of Indian Agriculture 2009). Using 2004-05 as the base year, the total demand for rice, wheat, coarse cereals and pulses has been projected for the years 2016-17 and 2021-22 in table 2 (Kumar 2009). Non-availability of sulphur-based phosphatic fertilizer for balanced nutrition (94.3% respondents) was identified as a major constraint for pigeonpea production in Uttar Pradesh (Singh *et al.* 2007). The per capita production of pulses in India has declined (Srinivasarao *et al.* 2015) considerably. To be efficient, the basic requirement of a soybean farmer is for a system that provides adequate and effective means of surface drainage as well as assured root-zone recharge during the *kharif* season, besides adherence to the best management practices (BMPs) for crop, soil, water and nutrients (Ramesh *et al.* 2017).

#### SOIL HEALTH: A PANACEA FOR SUSTAINABLE PULSE PRODUCTION

##### Physical health

Soil structure, texture, bulk density, porosity and aggregate stability are recognized as the major soil physical health parameters. While structure pertains to aggregation and

**Table 1.** Per capita production of various food items (kg)

Year	Cereals	Pulses	Ratio of pulse to cereals
1971-1975	164	19	0.12
1976-1980	172	18	0.10
1981-1985	179	17	0.09
1986-1990	182	16	0.09
1991-1995	192	15	0.08
1996-2000	191	14	0.07
2001-2005	177	12	0.07
2005-2006	176	12	0.07
2006-2007	180	13	0.07

Source: State of Indian Agriculture (2009)

**Table 2.** Total demand for food grains as household food (2004-2005 to 2021-22)

Commodity	Food grains (Mt) in 2004-2005	Food grains projection (Mt) in	
		2016-2017	2021-2022
Rice	79.5	92.0	97.4
wheat	57.7	71.9	73.5
Coarse cereals	13.4	14.5	15.1
Pulses	9.8	14.3	16.1

Source: Kumar (2009)

the optimum pore space, texture indicates the proportion of sand, silt and clay. The physical health manipulates the soil fertility through hydrological processes like water movement in the soil, bulk density, porosity, water retention, root penetration and water-logging, *etc.* Aggregate stability is considered as a good indicator of soil health. In rainfed pulse production ecosystems and dry land ecosystems, water and wind erosion are serious processes impairing the physical soil health. Research conducted elsewhere in the world has developed few indices for soil physical health since a quantitative assessment is rather difficult (Kumar *et al.* 2014), to mention a few, soil productivity index of Neill (1979) and physical rating index of Gupta (1986). However, the former has included pH and EC too for computation. The other physical constraints *viz.*, shallow depth, soil hardening, slow and high permeability, sub-surface compacted layer and surface crusting (Painuli and Yadav 1998) too in many pulse growing areas degrade soil physical health. Water-logging is a serious deterrent in the former under rainfed Vertisols where major chunk of pulses are cultivated. Major water-logging affected areas in India are Bihar, Maharashtra, Madhya Pradesh and Uttar Pradesh, contributing to nearly 58% of the total area and 65% of national pigeonpea production (ICRISAT 2009). In rainfed Alfisols, Entisols and Aridisols, soil crust formation by the beating action of precipitation reduces infiltration and enhanced rainfall run-off besides hindrance to germination of rainfed pulse crops (Indoria *et al.* 2016). These soils are extremely prone to rainwater induced erosion (Fig. 1). Deep black cotton soils in the states of Madhya Pradesh, Maharashtra, Gujarat, Andhra Pradesh, and Tamil Nadu get inundated during *kharif* season, thereby causing serious damage to pigeonpea, urdbean and mungbean. Shallow and coarse textured soils in north and western



**Fig. 1.** Rain induced soil erosion in Vertisol in soybean crop at Madhya Pradesh

states have low water retention capacity and require irrigation for supporting a good *rabi* pulse crop.

### Chemical Health

Soil chemical health is identified with the chemical indicators *viz.*, total C and N, mineral nutrients, organic matter and cation exchange capacity (CEC), *etc.* (Cardoso *et al.* 2013). These attributes are correlated with the capacity to provide nutrients for plants. Pulses are raised under poor and marginal soils where the nutrient content is too low to support a good crop of pulse. Eighty per cent area and production is contributed by six major pulses producing states *viz.*, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka and Andhra Pradesh occupied 18.27 Mha contributing 11.67 Mt (Narayan and Kumar 2015). Alfisols and Vertisols of peninsular India and Aridisols of extremely dry climates are the principal soil orders in dry areas where many varieties of pulses are cultivated in India, although Entisols and Inceptisols also occur. About 30% of dryland area is covered by Alfisols and associated soils while 35% by Vertisols and associated soils having vertic properties and 10% by Entisols of the alluvial soil regions (Virmani *et al.* 1991). Although several soil and agro-climatic factors affect runoff in these soils, surface runoff carries away nutrient-rich fine topsoil, causing soil degradation (Wani *et al.* 2003). On the Vertisols of the comparatively high and dependable rainfall areas leguminous crops *viz.*, groundnut, safflower, soybeans, pigeonpea, green gram, black gram, and chickpea are extensively grown on these soils (Kanwar 1982). Apart from soil and nutrient losses, poor nutrient management is leading to multi-nutrient deficiency of essential nutrients, which is posing a threat to rainfed agriculture. Due to increased rainfall intensities, land degradation is likely to increase in future. The gap between nutrient supply and demand is likely to widen further by 2030 to 50 Mt of NPK. With phosphate and potash raw materials reserves depleting worldwide, the availability of chemical fertilizers may become increasingly difficult. Biomass recycling and legumes in the crop rotation are to be encouraged in order to sustain soil fertility in rainfed areas (CRIDA 2011). Another major problem is salinity and alkalinity of soils which is high both in semi-arid tropics and in the Indo-Gangetic plains (Gowda *et al.* 2013) affecting pulse production. The Vertisols, Inceptisols and Entisols located in Ambajogai *tahsil* of Beed district were low in available

N and P and high in available K. While, the exchangeable Ca and available S were in sufficient quantity, the exchangeable Mg ranged from low to high Dhamak *et al.* (2014).

### Biological Health

Pulse crops are generally cultivated to enrich the soil for the subsequent crop in the rotation and not for the pulse itself and are cultivated as a bonus/catch/relay crop in the rotation. Inclusion of leguminous plant and its incorporation in the yearly cropping sequence improved good build-up of soil organic carbon (Ramesh and Chandrasekharan 2004) due to the development of beneficial soil organisms for safeguarding the soil biological health. Leaf litter in pigeonpea crop is a good source of organic manure (Ramesh *et al.* 2005), and leaf litter of pulses too (Fig. 2). Although, application of FYM is, by and large, a regular practice in the soybean crop to maintain/improve soil health in Madhya Pradesh (Vinaygam *et al.* 2006), in the recent findings suggest that farmers seldom apply organic manures hardly once in a span of four years. About 40% of the pulse-growing regions have low to-medium population of native *Rhizobium* (Ali and Gupta 2012). Hence, improving the soil fertility was one of the thrust areas of pulses policy (Sharma 2013).



Fig. 2. Pigeonpea leaf litter

### RAPID SOIL TESTING

Soil health encompasses three components *viz.*, physical, chemical and biological health interactive attributes (Bandyopadhyay *et al.* 2009). The ICAR-Indian Institute of Soil Science, Bhopal has developed a mini laboratory ‘Mridaparikshak’ that can estimate 15 soil parameters *viz.*, pH, EC, organic carbon, available nitrogen (N), phosphorus (P), potassium (K), sulphur (S), zinc (Zn), iron (Fe), manganese (Mn), boron (B), copper (Cu), gypsum requirement, lime requirement, and calcareousness. This is a digital mobile quantitative soil test mini-lab to provide soil testing service at farmers’ doorstep. It is compatible with soil health card. ‘Mridaparikshak’ comes with smart soil-pro, an instrument for determining soil parameters and displaying of fertilizer nutrient recommendations (Fig. 3).



**Fig. 3.** Mridhaparikshak developed by ICAR-IISS, Bhopal

In addition, this mini-lab is supplied with sieves, electronic weighing balance, shaker (with two plates), hot plate, *etc.* Further, the results of 'Mridhaparikshak' can be disseminated quickly to farmers *via* SMS. The soil test reports can also be saved in the mini-lab. The quantity of chemical solutions provided along with 'Mridhaparikshak' is for analyzing 100 samples and the solutions can be subsequently refilled.

### SOIL HEALTH ISSUES AND CROP PRODUCTIVITY

#### Rainfed ecology

Rainfed agriculture has emerged as an opportunity in raising pulse growth. Food production is tied up with amount and distribution of rainfall. Pulses have been cultivated since time immemorial in rainfed conditions which are characterized by poor soil fertility and moisture stress environments (Sundaram 2010) show remarkable variability and diversity in terms of varieties and quantity of production (Inbasekar 2014). Nearly half of the net cultivated area remains dependent on rainfall even now. Rainfed agriculture supports nearly 40% of India's estimated population of 1210 million in 2011 (Table 3). India ranks first among the rainfed countries in the world in terms of rainfed area, but ranks among the lowest in rainfed yields (Abrol 2011). Pulses being cultivated in rainfed situation (which are prone for nutrient erosion) and are raised especially on scarce soil moisture during winter season. In India, about 80% of the total pulse production confined to Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh and Karnataka. Chickpea is the major pulse crop cultivated during winter season in the Vertisols of central and northern India (Patil *et al.* 2016). A luxuriant pigeonpea crop on ridge and furrows in Kawardha, Chhattisgarh is shown in fig. 4, while a luxuriant chickpea crop is shown in fig. 5.

#### Biological Nitrogen Fixation in Legumes

Pulse crops are considered as soil health enhancers and help in the maintenance of sustainability of cropping systems across the length and breadth of the country. Introduction of pulses in cereal based crop rotations in the Indo-Gangetic plains (IGP) such as



**Table 3.** Share of rainfed area in total area under crops

Crop	Area (Mha)	% under rainfed	Area under rainfed (Mha)
Total crops	191.55	68	130.48
Pulses	22.09	77	17.01
Red gram	3.38	96	3.24
Bengal Gram	7.89	67	5.29

Source: Indian Agricultural Statistics (2010)

**Fig. 4.** A luxuriant pigeonpea crop on ridge and furrows, Kawardha, Chhattisgarh**Fig. 5.** A luxuriant chickpea crop in the field

rice-wheat have ensured their sustainability through dual benefits of N economy and improved soil health. A consolidation of studies on biological N fixation in pulses has estimated an amount 30 to 147 kg ha<sup>-1</sup> N fixation by pulse crops in the soils saving fertilizer N cost (Table 4).

### IMBALANCED NUTRIENT APPLICATION

Nutrient imbalance is one of the major abiotic constraints limiting productivity of pulses (Thiyagarajan *et al.* 2003) and is gradually deteriorating soil health. The in-built mechanism of biological N<sub>2</sub> fixation enables pulse crops to meet 80-90% of their N requirements, hence a small dose of 15-25 kg N ha<sup>-1</sup> is recommended as starter dose to



**Table 4.** Range of estimated amount of N fixed in soil by pulse crops

Crop	Range of estimated amount of N fixed in soil (kg ha <sup>-1</sup> )
Chickpea	41-134
Pigeonpea	31-97
Mungbean and urdbean	30-74
Lentil	60-147
Field pea	30-125

Source: Paroda (2000)

**Table 5.** Consumption ratio of fertilizer nutrients in India over time

Year	N : P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O
1951-52	7.9 : 0.9 : 1
1961-62	8.9 : 2.2 : 1
1971-72	6.0 : 1.9 : 1
1981-82	6.0 : 1.9 : 1
1991-92	5.9 : 2.4 : 1
2001-02	6.8 : 2.6 : 1
2007-08	5.5 : 2.1 : 1
2008-09	4.6 : 2.0 : 1
2009-10	4.3 : 2.0 : 1
2010-11	4.7 : 2.3 : 1
2011-12	6.7 : 3.1 : 1
2012-13	8.2 : 3.2 : 1
2013-14	8.0 : 2.7 : 1
2014-15 (P)	6.7 : 2.4 : 1

(P): Provisional

Source: FAI (2016)

meet out the requirement of most of the pulse crops. But in practice, in few soybean growing areas, only N is applied as a fertilizer dose in the form of urea. A study on pulse cultivation in Madhya Pradesh by Maji and Sulaiman (1995) has indicated that the fertilizer use was very low with chickpea receiving the highest priority and pigeonpea the least. Although the recommended dose in Madhya Pradesh was 15-25 kg of N and 20-50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> through superphosphate, the actual application on an average, was found to be 2.8 kg in pigeonpea, 6.4 kg in lentil, 8.1 kg in blackgram and 12.0 kg in chickpea. For the growth and development of root nodules, P is absolutely necessary and application of 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> has been recommended. Only three per cent of the total consumption of fertilizers in India is received by pulses (Prasad 2012).

As evident from the fertilizer consumption data (FAI 2016), the ratio of N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O at the All India level is presently at abysmally distorted level of 9.5: 2.7: 1, as compared to the ideal level of 4:2:1 for non-legumes and 2:4:1 for legumes for medium level of soil fertility (Table 5). The imbalanced has led to depletion of native P and K from soil when excess N fertilizer is added.

### NUTRIENT MINING

In order to maintain the soil fertility under intensive cropping systems it is mandatory to replenish the nutrients extracted by the crops raised. If the extraction exceeds replenishment nutrient mining occurs. Such deficits on a continued basis causes decline in soil fertility and invite further imbalances in crop nutrition. An estimated 29.4 Mha of Indian soils are experiencing decline in fertility which is likely to increase in future (Table 6). Balance of K, S and micronutrients is negative for soil (Tandon 2004). Efficiency of fertilizer N seldom exceeds 40%, and that of P and micronutrients, it is only 20 and 2%, respectively, even with the best management practices. For K, the efficiency is about 50%.

**Table 6.** Balance sheets (Mt) for NPK in India

Nutrient	Gross balance sheet			Net* balance sheet		
	Addition	Removal	Balance	Addition	Removal	Balance
N	10.9	9.6	1.3	5.5	7.7	-2.2
P <sub>2</sub> O <sub>5</sub>	4.2	3.7	0.5	1.5	3.0	-1.5
K <sub>2</sub> O	1.4	11.6	-10.2	1.0	7.0	-6.0
Total	16.5	24.9	-8.4	8.0	17.7	-9.7

\* The net values were arrived at by adjusting nutrient use efficiency figures *i.e.* 50, 35 and 70% for N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O, respectively

Source: Tandon (2004)

### GAP BETWEEN NUTRIENT DEMAND AND SUPPLY

There exists a wide gap between pulse nutrient demand and supply. Farmers seldom apply P-fertilizer which resulted in skewed nutrient ratio in the soil that led to the development of multi-nutrient deficiencies. The following table shows the average uptake of primary and secondary nutrients for the production of one tonne of main produce (Table 7).

### NUTRIENT MANAGEMENT IN PULSES

Blanket fertilizer recommendations have been prescribed for all pulse crops state wise for enhancing pulse productivity and are generally advocated by different State

**Table 7.** Uptake of nutrients by crops

Crop	Total uptake (kg t <sup>-1</sup> of main produce)					
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	S	Ca	Mg
Chickpea	60.7	9.2	39.2	8.7	18.7	7.3
Pigeonpea	70.8	15.3	16.0	7.5	19.2	12.5
Lentil	57.0	14.9	21.6	3.0	7.5	2.0
Soybean	70.7	30.9	57.7	6.7	14.0	7.6
Green gram	106.0	48.1	73.2	12.0	71.0	43.0
Black gram	78.9	14.4	65.6	5.6	-	-
Rice	20.0	11.0	30.0	3.0	7.0	3.0
Wheat	25.0	9.0	33.0	4.7	5.3	4.7

Source: FAI statistics (2012-13)

Governments and these recommendations were made almost 2-3 decades back which are outdated in the present context of release of new high yielding varieties and hybrids. These are based on crop responses over large areas without taking into account the spatial and temporal variability of soil in terms of plant nutrient supplying capacity. Although, in principle, these recommendations are to be updated periodically, in practice, these continue for decades. As a result of same dose over years without taking into account the crop varieties/hybrids, yield losses occur leading to poor nutrient use efficiency and environmental pollution. The blanket recommendations neither have flexibility to factor in farmer resource endowment nor provide readjustment space for guidance of marginal and small farm holders having limited resources. Due to less complexity in arriving at plant nutrient application, these recommendations find advocacy with Line Departments (Dey 2016a). However, only 40% of total pulse area is fertilized (Table 8).

**Table 8.** Usage of fertilizer by pulses (2006-07)

Crop	Gross cropped area (000 ha)	Per cent area treated with fertilizers	Consumption per ha of							
			Gross cropped area (kg)				Area treated with fertilizer (kg)			
Gram	4195	51.9	23.0	21.6	3.2	47.8	44.4	41.7	6.1	92.1
Mungbean	936	23.3	11.6	8.7	0.7	21.0	49.8	37.5	2.8	90.1
Lentil	235	36.9	32.2	25.5	8.1	65.8	87.2	69.0	22.0	178.2
Total pulses	14311	40.6	19.5	17.5	2.5	39.6	48.1	43.2	6.3	97.6
Total food grains	107707	72.0	71.8	28.3	9.9	110.0	99.6	39.3	13.7	152.6

*Source:* Fertiliser Statistics (2014-15)

### STCR-BASED FERTILIZER RECOMMENDATIONS IN PULSES

Liebig's law of minimum states that the growth of plants is limited by the plant nutrient element present in the smallest amount, all others being in adequate quantities. From this, it follows that a given amount of a soil nutrient is sufficient for any one yield of a given percentage nutrient composition (Dey 2015). The targeted yield approach of Ramamoorthy and co-workers established the theoretical basis and experimental proof for applicability of Liebig's law of the minimum for N, P and K too. Among the various methods of fertilizer recommendations, the method based on yield targeting is unique in the sense that this method combines the soil test based fertilizer dose and the level of yield the farmer can hope to achieve with good agronomic practices. The differentiation of significant multiple regression equations provide a basis for soil test-fertilizer requirement calibration for maximum yield as well as maximum profit per hectare besides, maximum profit per rupee investment on fertilizer. The resultant fertilizer adjustment equations have been tested in follow up and frontline demonstrations conducted in various parts of the country. In these trials, soil test based rates of fertilizer application helped to obtain higher response ratio and benefit: cost ratios over a wide range of agro-ecological regions (Dey and Srivastava 2013).

Pulses generally respond very well to starter dose of N (20 kg ha<sup>-1</sup>) for enhancing plant uptake when roots are tiny and thereby promoting early vigour. Placing P and K in

the root zone as per soil test crop response (STCR) approach of yield targeting based on soil test values will help in realising yield based on resource endowment of farmers. This approach provides the choice to farming community about setting a realistic yield target based on available resources (Dey and Santhi 2014). This method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve if good crop husbandry is followed in raising the crop.

An example of fertilizer prescription equation for Uttarakhand developed by STCR centre at GBPUA&T, Pantnagar for pigeonpea cv. UPAS-120 to recommend nutrients through locally available organic sources and inorganic sources for a specific yield target is given below:

$$FN = 5.66 T - 0.28 SN - 0.21 ON$$

$$FP_2O_5 = 16.81 T - 7.92 SP - 2.26 OP$$

$$FK_2O = 9.56 T - 0.47 SK - 0.31 OK$$

where, FN, FP and FK are fertilizer doses, T is the yield target, SN, SP and SK are initial soil test values and ON, OP and OK are concentration of N, P and K of manure.

### FERTILIZER PRESCRIPTION EQUATIONS

Various centres of All India Coordinated Research Project (AICRP) on STCR have developed fertilizer prescription equations (Table 9) for pulse crops with the sole source of nutrients through NPK.

Fertilizer prescription equation under integrated plant nutrient supply system are also developed wherein fertilizer nutrient doses are adjusted not only to that contributed from soil but also from various organic sources like FYM, green manure, compost crop residues and biofertilizers like *Azospirillum* and *Phosphobacteria*. Various centres of AICRP on STCR developed STCR-IPNS fertilizer equations for pulse crops (Table 10).

**Table 9.** STCR based equations for pulses

State	Fertilizer prescription equations developed for crop/variety
Andhra Pradesh/ Telangana	Pigeonpea (LRG-30), chickpea (Annegiri)
Maharashtra	Green gram (S-8), chickpea (Vishal),
Himachal Pradesh	Lentil, chickpea for mid-hills wet temperate zone; rajmash for mid-hills sub-humid zone
Delhi and adjoining region	Cowpea (Pusa Sukomal)
Bihar	Green gram, pigeonpea, pea, gram, lentil, rajmash and black gram
Tamil Nadu	Black gram (ADT 3)
Rajasthan	Mothbean (RMO-40)
Madhya Pradesh	Arhar (JA-3, ICPL-No.148 and Asha), urdbean (T-9) and gram (JP-74, JG-62, JG-315 & JG-322)
Uttarakhand	Chickpea (Pusa 262), pigeonpea (UPAS-120) and cowpea (Pant Lobia 2)
Puducherry	Black gram (Vamban 3)
Gujarat	Pigeonpea (AGT 1)
Uttar Pradesh	Chickpea (Pusa-364)

**Table 10.** STCR–IPNS equations for pulses crops

State	STCR-IPNS fertilizer prescription equations developed for crop/variety
Assam	Green gram (Pratap) for summer season
Karnataka	Dryland red gram
Chhattisgarh	Chickpea (JG130) for Raipur and adjoining regions
Delhi and adjoining region	Cowpea (Pusa Sukomal)
Uttarakhand	Chickpea (Pusa 262), pigeonpea (UPAS-120) and cowpea (Pant Lobia 2)
Bihar	Lentil, pigeonpea, black gram, fababean ( <i>Bakla</i> )
West Bengal	Chick pea (Pusa-364)
Madhya Pradesh	Lentil (JL-1)
Odisha	Cowpea (Utkal Manika), black gram (B-388), green gram (OBGG-52)
Puducherry	Black gram (Vamban 3)
Gujarat	Pigeonpea (AGT-1)

### BENEFITS OF SOIL TEST BASED TARGETED YIELD APPROACH

Front line demonstrations (FLD) conducted at farmers' field clearly brought out the superiority of STCR-IPNS fertilizer recommendations for various crops over blanket recommendation and farmer's practice in terms of yields with higher BCR/net returns (Dey 2016a). The same was conformed from the FLDs conducted in Assam, Bihar, Chhattisgarh, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Odisha, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh and West Bengal and that even farmers with very little knowledge of modern agriculture could achieve yield target by practicing STCR technology within  $\pm 10\%$  variations of the target set (Dey 2015). Benefits of STCR-IPNS recommendations as reflected by FLDs on gram under arid conditions (Dey 2016b) revealed an enhancement in B: C ratio from 1.47 (under farmers' practice) to 3.34 (Table 11).

### LAND MANAGEMENT FOR *KHARIF* PULSES

Land configuration and land management is the vital issue in rainfed pluses. Pulse crops require a clod free seedbed for proper germination and establishment of seedlings.

**Table 11.** Benefits of STCR recommendations as reflected by front line demonstrations on gram under arid condition

Particulars	Farmers' practice (FP)	General recommendation dose (GRD)	STCR	STCR-IPNS*
Average yield (q ha <sup>-1</sup> )	9.33	13.03	16.51	19.28
Average fertilizer used (N+P <sub>2</sub> O <sub>5</sub> +K <sub>2</sub> O+S)	10.8+27.6+0+0	20+40+0+0	20+29+20+36.8	20+16.2+15+26.5
% Change over FP		+39.7	+76.96	+106.65
Yield response (kg kg <sup>-1</sup> of nutrient)	24.30	21.72	15.60	24.81
B:C Ratio	1.47	2.32	3.16	3.34

\*5 t FYM ha<sup>-1</sup>

The seedbed is prepared by a deep ploughing or disking, followed by 2-3 cross harrowing and levelling. In drylands, a deep summer ploughing is necessary for moisture conservation. In case of hard pan in the soil, sub-soiling is done. Thorough levelling is essential for quick drainage and also to avoid waterlogging. Broad-bed and furrow (BBF) system or ridge and furrow planting is preferred to overcome waterlogging (Fig. 6). The BBF system involves preparation of a broad bed of 90 cm, furrow of 45 cm and sowing of crop at a row spacing of 30 cm. The BBF technology has many advantages including *in-situ* conservation of rainwater in furrows, better drainage of excess water and proper aeration in the seedbed and root zone. This is particularly important for rainfed pulses, particularly under Vertisols. If a farmer can't afford broad bed furrow former (cost Rs. 45,000), a simple technique has been devised wherein 15-20 days after sowing of pulses, after every 10 rows a deep furrow can be opened with the help of the country plough to facilitate the drainage of excess water from the fields and the technology has got wide adoption among the farming community of Madhya Pradesh. In NICRA villages in Madhya Pradesh, farmers who adopted broad bed furrow planting method in soybean with BBF planter avoided damage to the crop due to excess rainfall in *kharif* 2013 season and realized about 40% yield advantage compared to flatbed sowing (Prasad *et al.* 2014).



Fig. 6. Broad bed furrow making for pulse cultivation in a Vertisol

#### MICRONUTRIENT STATUS OF PULSE SOILS AND THEIR MANAGEMENT

As early in 1976, even before the delineation of areas with micronutrient deficiency, Sharma and Gonsinkar (1976) has found a two-fold increase in nodulation in *Rhizobium* inoculated pulses when Fe, Mo were supplied along with Co. Later, Dey and Ghosh (1980) confirmed the beneficial effect of Mo on nodulation in soybean. Application of Mo @ 1.0 kg ha<sup>-1</sup> could accelerate the uptake of all primary nutrients N, P and K including S (Dwivedi *et al.* 1996) in leguminous crops. Subsequently, Ramesh *et al.* (2001) has found the enhancement in nodulation as well as yield of soybean when 250 mg of ammonium molybdate was added with 500 mg of ferrous sulphate kg<sup>-1</sup> of *Rhizobium* inoculated seeds. Ali and Gupta (2012) have indicated that deficiency of micronutrients, especially S and Zn is widespread among pulse-growing regions. Out of 137 pulse-growing districts, 87 districts show 20–60% S deficiency. About 50% pulse growing districts having Zn deficiency. These nutrients are important for increasing pulse production in the country. The recent delineation of Zn deficient soil areas in India by Shukla *et al.* (2015a) has indicated

that about one-third of the country's vast area was acute deficient in Zn. Zinc deficiency once observed more in cereal belts has extended to pulse growing areas too. There was a decline in Zn deficiency in the northern parts of the country but on the reverse in western and southern parts of the country. Low deficiency of Zn areas once reported, have developed temporal intensification due to crop intensification as well as imbalanced use of macronutrients, Zn demanding of new cultivars, and continuous removal of readily-available soil Zn pools. However, soil mining of Zn by agricultural crops should not be a concern except in those rare cases of extremely low total soil Zn content.

The AICRP on Micro, Secondary and Pollutant Elements (AICRP-MSPE) have observed the micronutrient deficiencies in pulse crops frequently (Shukla *et al.* 2012). Due to widespread deficiencies of Fe in several parts of the country, Fe response was noticed in pulses grown in Uttarakhand, although, Fe is not a serious concern for pulse crops in the soils of Uttarakhand state (Table 12). The response to Zn was to the tune of 16.1, 20.2-38.3 and 8.3-34.8 for groundnut, soybean and lentil, respectively.

Boron is a unique non-metal micronutrient required for normal growth and development of plants which is more often gets leached down the soil profile with excess moisture. Its bioavailability in soils is affected by several factors including parent material, texture, nature of clay minerals, pH, liming, organic matter content, sources of irrigation, interrelationship with other elements, and environmental conditions like moderate to heavy rainfall, dry weather and high light intensity (Moraghan and Mascagni 1991). Besides, response to B was 28.1-37.7 and 1.0-22.0% for soybean and lentil, respectively. The Fe deficiency in the state ranged from 0-5% with an average of 1.4%. There are only three districts where Fe deficiency varies from 4-5% while available Fe status in all other districts is sufficient to meet the crop requirements (Shukla *et al.* 2015a).

Green gram has shown greater response (52%) to applied iron in the soils in Nagarjuna Sagar and Sri Rama Sagar projects (Table 13) of the Telangana state (Raj *et al.* 2009). Application of S, Zn, B and Mo in groundnut and green gram at Nalgonda and

**Table 12.** Available zinc and iron status (DTPA-extractable) in soils of different districts of Uttarakhand

District	DTPA-Zn (mg kg <sup>-1</sup> )	DTPA-Fe (mg kg <sup>-1</sup> )
Almora	0.39 - 14.18	6.45 - 82.88
Bageshwar	0.57 - 23.90	1.47 - 53.81
Chamoli	0.21 - 25.86	7.46 - 283.62
Champawat	0.29 - 25.52	7.94 - 193.66
Dehradun	0.29 - 19.28	2.83 - 62.80
Haridwar	0.17 - 12.14	1.70 - 124.70
Nainital	0.30 - 16.43	3.69 - 160.21
PauriGarhwal	0.28 - 22.09	3.73 - 688.39
Pithoragarh	0.14 - 17.86	3.48 - 53.58
Rudraprayag	0.11 - 17.18	0.47 - 106.14
Tehri Garhwal	0.21 - 18.14	3.74 - 79.32
U.S. Nagar	0.03 - 12.70	2.65 - 110.28
Uttarakashi	0.15 - 17.11	6.75 - 128.99
Uttarakhand	0.03 - 25.86	0.47 - 688.39

Source: Shukla *et al.* (2015a)



**Table 13.** Total micronutrients (mg kg<sup>-1</sup>) contents at different depths in soils of Telangana

Depth	Zn	Cu	Fe	Mn
0-15	16.27	11.80	4500	160
15-30	24.80	13.29	8693	231
30-45	48.00	26.93	4867	536

**Table 14.** Effect of zinc, boron and sulphur on green gram at Karimnagar district, Telangana state

Treatment	Yield with NPK (t ha <sup>-1</sup> )	Yield response (%)
Control	1.36	
5 kg Zn ha <sup>-1</sup>	1.42	4.4
5 kg Zn ha <sup>-1</sup> + 1 kg B ha <sup>-1</sup>	1.62	19.11
5 kg Zn ha <sup>-1</sup> + 40 kg S ha <sup>-1</sup>	1.64	20.58
5 kg Zn ha <sup>-1</sup> + 1 kg B ha <sup>-1</sup> + 40 kg S ha <sup>-1</sup>	1.68	23.52
5 kg Zn ha <sup>-1</sup> + 1 kg B ha <sup>-1</sup> + 40 kg S ha <sup>-1</sup> + Mo	1.72	26.4

Karimnagar districts (Table 14) showed significant response over NPK alone. In green gram, the response to Zn, Zn+B, Zn+S, Zn+B+S and Zn+B+S+Mo was 4.4, 19.11, 20.58, 23.52 and 26.4 per cent over NPK, respectively. The response increased by four folds when S was added along with Zn. Application of B over Zn+S enhanced the green gram yield by 4.5% while application of Mo along with Zn+B+S improved the green gram yield by 3% but it was non-significant (Shukla *et al.* 2015c).

The Fe status in soils of Haryana state has been a cause of concern for the stakeholders since last decade. The Fe deficiency is frequently noticed in pulses and the deficiency of Fe is aggravated under excess of carbonate and bicarbonate ions, ionic imbalances, higher pH and low water potential. On average, 22% soils (Table 15) are deficient in available Fe in Haryana state (Shukla *et al.* 2015c).

#### NUTRIENT-BIOTIC STRESS INTERACTION IN PULSES

Many pulse crops are prone to biotic stresses like insect, disease and nematode attack. As a major pulse crop of the country, most of the cultivated chickpea varieties suffer heavy losses due to attack by insect pests and diseases in the central and north Indian belt during rabi season remain unabated. Insects such as *Helicoverpa* (pod borer) and leaf miner cause substantial economic losses in standing chickpea crops, whereas seed beetles and bruchids inflict huge storage losses. Dry root rot, *Fusarium* wilt, and collar rot are some of the important diseases prevalent. Heavy incidence of *Fusarium* wilt and dry root rot was reported by many farmers in few southern states (Pande *et al.* 2012). Nutrition

**Table 15.** Response of gram to application of micronutrients in Haryana

Crops	No. of experiments	Range	Mean response (t ha <sup>-1</sup> )
Zinc	5	0.02 - 0.18	0.13
Iron	3	0.09 - 0.22	0.19

Source: Shukla *et al.* (2015c)

of pulses has a substantial impact on the predisposition of plants to be attacked or affected by pests and diseases. By affecting the growth pattern, the anatomy and morphology and particularly the chemical composition, the nutrition of plants may contribute either to an increase or decrease of the resistance and/or tolerance to pests and diseases. These pulse crops remain susceptible to pest and disease attack as adequate nutrition is lacking in these crops particularly potassium nutrition. Perrenoud (1990) after reviewing the literature concluded that the use of potassium decreased the incidence of fungal diseases in 70% of the cases besides a reduction in bacteria, insect, mite and virus attack in plants. In India, farmers seldom apply K to pulse crops. The K:N uptake ratio is lowest for pulses (0.22 to 0.70) in India (Kinekar 2011). Farmers seldom use K-fertilizers in oilseed and pulse crops under rainfed farming and also there is no regional recommendation for K application for groundnut in Gujarat and for soybean in Maharashtra (Naidu *et al.* 2011).

#### EFFICIENT PULSE GENOTYPES

ICAR-Indian Institute of Soil Science, Bhopal through the AICRP-MSPE has evaluated 20 cultivars of pigeonpea and gram screened by Hyderabad, Anand, Ludhiana, Pantnagar, Pusa and project coordinating unit Bhopal to identify micronutrient efficient as well as inefficient cultivars by assessing micronutrient uptake efficiency and micronutrient yield efficiency index (Shukla *et al.* 2012). The efficient cultivars could better utilize soil micronutrient under deficient condition and do not respond application of micronutrient fertilizers, whereas inefficient cultivars respond well to external application of micronutrient fertilizers but poor in utilizing native micronutrients from soil. The genetically micronutrient inefficient cultivars are virtually agronomically efficient for enhancing micronutrient content in seeds. Thus, the efficient cultivars may be utilized by breeders for QTL identification responsible for efficiency and developing high yielding micronutrient enriched cultivars (genetic biofortification) while the inefficient cultivars may be used for agronomic biofortification to dense the grains of highly responsive cultivars with micronutrients. The list of efficient and inefficient cultivars of different crops with their yield and micronutrient concentration in grain identified for further physiological study is presented in table 16.

#### ORGANIC PULSE PRODUCTION

Soil health maintenance essentially hovers around the organic matter management and the recent thrust in organic pulse production is gaining momentum in the international scenario. ICAR-Network Project on Organic Farming initiated in the year 2004 is concen-

**Table 16.** Yield and micronutrient concentration of genetically efficient cultivars of pigeonpea with and without Zn application

Efficient	Yield (t ha <sup>-1</sup> )		Concentration (mg kg <sup>-1</sup> )	
	No Zn	With Zn	No Zn	With Zn
ICPL 87119	1.84	1.99	27.8	41.8
T 15-15	1.46	1.55	32.3	44.6
Virsa Arhar 1	1.53	1.76	32.8	38.7

trating on pulse based cropping systems too. The experiments in the project have been designed mainly to evaluate the relative performance of location specific, important cropping systems under organic and conventional farming, and assess agronomic efficiency of different organic inputs especially organic manures and bio-agents. Location specific pulse based cropping systems which are under evaluation involve chickpea, lentil, green gram and soybean. For example ICAR-Indian Institute of Soil Science, Bhopal has developed organic package of practices for soybean and soybean based cropping systems (Fig. 7 and 8). As per the data available from the National Centre for Organic Farming, Ghaziabad, it is stated that a total of 34345 Mt of organic pulses have been produced in the country of which half of the production is totally organic (12023 ha) and the rest from under conversion areas (17617 ha). A case study made in Rajasthan state in the year 2004-05 is presented in the table 17 wherein organic pulse based cropping systems are in vogue in few districts.



**Fig. 7.** Organic soybean at ICAR-IISS, Bhopal



**Fig. 8.** Organic soybean-chickpea cropping system at ICAR-IISS, Bhopal

**Table. 17.** Organic farming status in Rajasthan (2004-05)

S.No.	District	Cropping pattern	No of farmers	Organic area (ha)
1	Dungarpur	Pulses-cereals, Cereals-cereals	105	52.0
2	Tonk	Moong-wheat, Bajra-mustard, Til-wheat	132	590.0
3	Nagour	Guar-cumin, Guar-wheat, Moongbean-mustard	54	63.0
4	Bhilwara	Urdbean/moongbean-wheat	30	12
5	Jhunjhunu	Pulses-wheat	14	11.2

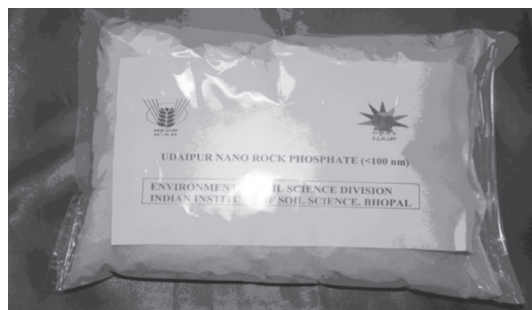
*Source:* Bhattacharyya and Chakraborty (2005)

### INTERCROPPING OF PULSES

Pulse crops are intercropped as a means of enhancing “soil health” as well as transferring the fixed atmospheric nitrogen to their counterparts in the cropping systems throughout the world, in general, and under dryland production systems, in particular. Legume is a natural mini-nitrogen manufacturing factory and can play a vital role in increasing indigenous N production besides help in solubilizing insoluble P in soil. Intercropping of short duration pulses like black gram and/or green gram with red gram showed balanced competitive abilities and proved more efficient in the system (Sarkar and Shit 1993). The carryover of N derived from legume grown, either in crop sequence or in intercropping system for succeeding crops improves soil health considerably *i.e.* 75 kg in Indian clover, 75 kg in cluster bean, 35-60 kg in fodder cowpea, 68 kg in chickpea, 55 kg in black gram, and 36-42 kg ha<sup>-1</sup> in pigeonpea (Ghosh *et al.* 2005). Plant population and spatial arrangement in intercropping have important effect on the balance of competition between the component crops and their productivity (Meena *et al.* 2008) and intercropping of oilseed and pulse crops is one of the ways to increase their production because intercropping is more advantageous than sole cropping of either of these crops (Padhi and Panigrahi 2006) and also soil health. Finger millet + pigeonpea in 4:2 row ratio produced higher finger millet equivalent yield over broadcast sown finger millet and the soil fertility status was highest after pigeonpea cultivation on contours (Dass and Sudhishri 2010). The fixed N<sub>2</sub> is recycled when legume crop residues decompose for the benefit of non-legume crops grown with or after grain legumes (Lupwayi *et al.* 2011). Because of the contribution of fixed N from the cowpea, corn performed better through intercropping in Hawaii (Ahmad *et al.* 2015). Intercropping of cereals and oilseeds with red gram increased land use efficiency over pure cropping of red gram under rainfed conditions on upland Oxisols of Bihar plateau. The utilization of intercropped pulses as green manure offered the opportunity of a quickly available nitrogen source for the maize crop when intercropped (Hodtke *et al.* 2016).

### NANOTECHNOLOGY IN PULSE PRODUCTION

Nanotechnology is regarded as one of the key technologies of the 21<sup>st</sup> century in safeguarding soil health through a reduction in fertilizer usage in pulse production, particularly P sources. This technology promises to improve fertilizer management practices through the enhancement of management and conservation of inputs to crops. Nano-formulations represent an efficient means for targeted distribution of fertilizers in a controlled fashion with high site specificity, thus reducing collateral damage (Jampilek and Králová 2015). Indian-origin researchers in the US have shown that spray of Zn nanoparticles can substitute N and P fertilizers to increase mungbean growth without causing pollution and deterioration of soil health. Researchers at the University of Delaware have found the unique behavior of hydroxyapatite nanoparticles (HANPs) that show promise as a P-nano-fertilizer and could be used to help slow down the release of P in soils (*Nanowerk News* 2015), *a boon to pulse production*. A urea-modified hydroxyapatite nanoparticle-encapsulated *Glyricidia sepium* nano-composite showing a slow and sustained temporal release of N to maximize the N use efficiency has been demonstrated by



**Fig. 9.** Nano-rock phosphate from Udaipur rock phosphate developed by ICAR-IISS, Bhopal

Kottegoda *et al.* (2011). The ICAR-IISS has been working on nano-rock phosphate to satisfy the P requirement of pulses in the country (Fig. 9).

### CONCLUSIONS

Pulse crops are predominantly raised under low to marginal fertility conditions with inadequate fertilizer nutrient applications and are considered only as bonus crops. The mind-set of the farmers needs to be changed with demonstrations in farmers' fields of balanced fertilizer applications and their phenomenal impact on yields. Drainage and moisture management are the keys to pulse production, the technology of BBF need to be promoted under rainfed environments of Vertisols. The latest addition of liquid biofertilizer inoculation with efficient culture has been accepted in parts of the country along with drip irrigation is a promising steps to enhance biological N-fixation. This need to be extended in all pulse growing regions in the country and demonstrated. Screening of P-efficient genotypes and their release and popularisation could help to avoid P build-up in soils. A comprehensive pulse management program could help to bridge the gap between demand and supply in pulses.

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## Efficient Water Management: A Key to Sustainable Pulse Production

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Pulses are an important part of Indian diet as a prime source of protein for approximately 31% of the vegetarian population and India is the largest producer, consumer and importer of pulses in the world and ranks first in area with a share of 32% followed by Niger (7%) and Myanmar (5%). In production too, India ranks first with a contribution of 23% to world's pulses production followed by Canada (8%) and China (7%). Notwithstanding to this achievement, productivity is very low (648 kg ha<sup>-1</sup>) as compared to other countries such as France (4219 kg ha<sup>-1</sup>), Canada (1936 kg ha<sup>-1</sup>) and USA (1882 kg ha<sup>-1</sup>). About 84% of the pulses cultivated in the country are under rainfed (DAC 2014) and in diverse rainfed agro-ecologies (rainfall of < 500 mm to > 1000 mm and soil types viz., Entisols, Inceptisols, Vertisols, Aridisols, Alfisols, Oxisols. Only one-third of chickpea area has access to irrigation whereas pigeonpea is predominantly (96%) grown under rainfed conditions. For meeting the domestic demand, the country is importing 3.5 to 5.0 Mt of pulses every year. By 2050, the domestic requirements may rise to 26.5 Mt.

Among the pulse crops, chickpea has a share of 43%, while pigeonpea 16% to the total pulse production. These two crops along with black gram and green gram contribute about 80% of total pulse production in the country.

### CORE PRODUCTION ZONES OF PIGEONPEA AND CHICKPEA

Based on the acreage, the pulse growing districts have been divided into 3 groups viz., 0.1 - 0.4 lakh ha, 0.4 - 0.8 lakh ha and more than 0.8 lakh ha. Pigeonpea is cultivated in 68 districts with 10,000 ha area which account for about 3/4<sup>th</sup> pigeonpea area of the country. A map prepared by plotting pigeonpea productivity at district level over area indicated that (Fig. 1). Mahabubnagar district of Telangana and Gulbarga district of Karnataka have more than 0.8 lakh ha area but the productivity is less than 0.6 t ha<sup>-1</sup>. Chickpea is being cultivated in 127 districts with a sown area of at least 10,000 ha and are referred as major districts for Chickpea (Fig. 2) accounting for about 90% chickpea area of the country. A map plotting chickpea productivity at district level over area indicated that the districts viz., Hanumangarh, Bikaner and Churu of Rajasthan, Banda of Uttar Pradesh, Sagar, Satna and Ujjain of Madhya Pradesh, Ahmednagar and Osmanabad of Maharashtra and Bijapur and Gulbarga of Karnataka have more than 0.8 lakh ha area with

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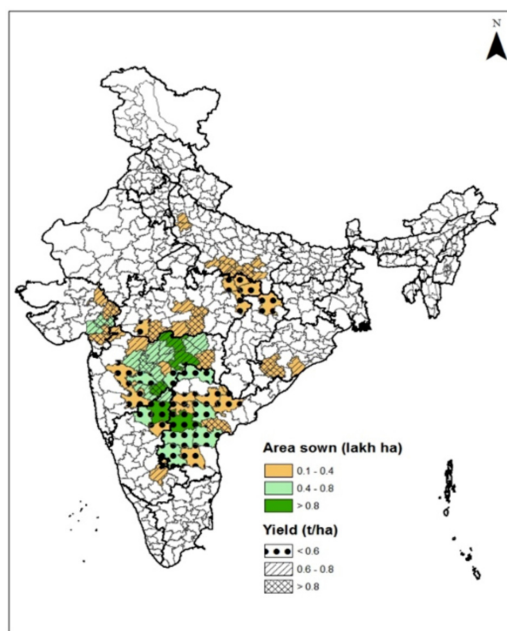


Fig. 1. Production zones of pigeonpea

Source: Ravindra Chary *et al.* (2016)

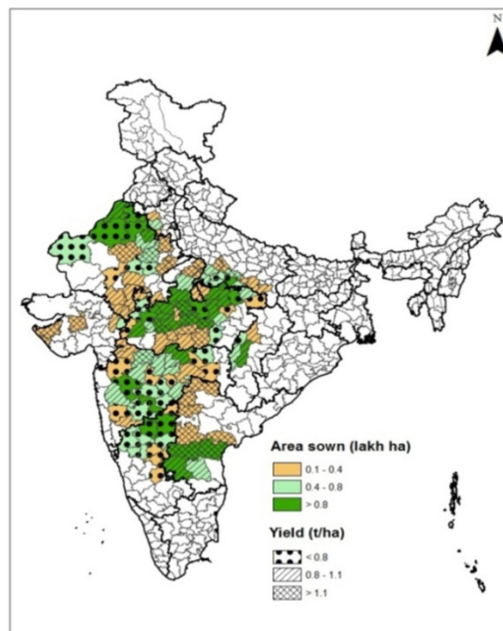


Fig. 2. Production zones of chickpea

a productivity less than  $0.8 \text{ t ha}^{-1}$ . Impact on production could be phenomenal if the yield levels are enhanced in these districts through efficient irrigation and rainwater (*in-situ* and *ex-situ*) management technologies (Ravindra Chary *et al.* 2016).

Though, impressive gains were achieved in some of the rainfed crops in recent times, the gap between attainable and farmers' yields still remains as high as 62% (Fig. 3; AICRPDA 2011a) in pulse crops which is a major cause of concern.

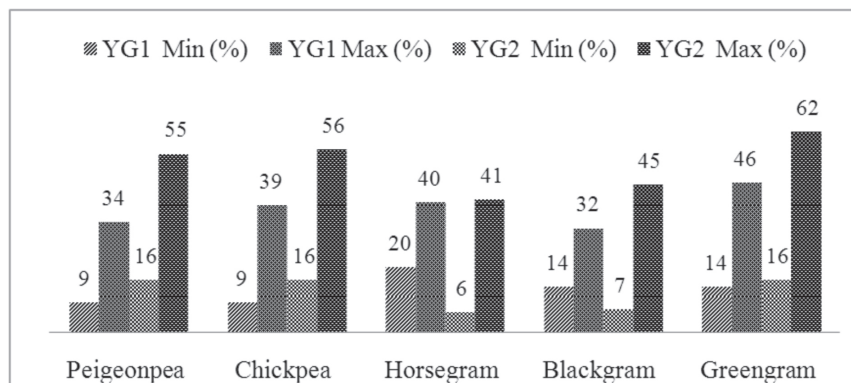


Fig. 3. Yield gap in different pulses under rainfed conditions. YG (yield gap) 1 = potential experimental yield – attainable yield; YG2 = attainable yield - yield with farmers' practice

Source: Ravindra Chary *et al.* (2013)

### KEY CHALLENGES RELATED TO WATER/SOIL MOISTURE AVAILABILITY IN PRODUCTION OF RAINFED PULSE CROPS

Although many pulses are short duration crops, moisture stress at critical stages drastically affects crop productivity. The uncertain drought/moisture stress is a major contributing factor to low productivity, which is estimated at 0.2, 0.6 and 1.0 t ha<sup>-1</sup> against a potential of 1.0, 1.9 and 3.0 t ha<sup>-1</sup> under arid, semi-arid and sub-humid regions, respectively.

The high intensity rainfall events during the crop growing season, particularly in black soil areas, and the associated waterlogging impairs pulse production. The soils of long and medium duration pigeonpea in northern and central India respectively, usually sown with the onset of rainy season remain saturated with excess moisture during most of their vegetative period. Similar conditions are enforced for other *kharif* pulses like black gram/green gram in northern and central India and horsegram in north-west Himalaya and Karnataka experience by the monsoon. The pulse crops are affected due to climate change/variability which directly or indirectly affecting temperature, precipitation, changes in soil moisture and the distribution and frequency of infestation by pests and diseases. The predicted changes in temperature and rainfall and consequent availability of water to crops and extreme weather events are all likely to affect substantially and the potential of pulse production (Ali *et al.* 2009). The delayed onset of monsoon too impacts acreage, production and productivity too. Further, the climate shifts also observed among the 8 core pigeonpea growing districts and among 17 core chickpea growing districts (Raju *et al.* 2013), would have negative effects on yields due to less rainfall and associated weather aberrations including seasonal drought.

Irrigation water management under assured water supply and rainwater management (*in-situ* and *ex-situ*) in pulse crops in diverse agro-ecologies through All India Coordinated Research Project on Irrigation Water Management (AICRP-IWM) and All India Coordinated Project for Dryland Agriculture (AICRP-DA) are enumerated hereunder.

### ENHANCING PRODUCTION OF PULSE CROPS IN IRRIGATED AREAS

#### Irrigation scheduling in pulse crops under surface irrigation

Traditionally, surface irrigation methods are adopted during critical growth stages of pulse crops under traditional and/or modified land configuration systems. The most appropriate irrigation method was screened according to soil type, land configuration and nature of crop so that irrigation scheduling for pulse crops can be optimized for various regions. Some of the results from AICRP-IWM centres on irrigation scheduling in pulse crops (AICRP-IWM 2016) are discussed hereunder.

Although, pulse crops are cultivated under rainfed conditions, need one or two irrigations during deficit rainfall situation (Prasad 2012), for *e.g.* pulses grown during spring or summer season respond to irrigation during flowering and pod formation, when there is a dry-spell, besides adequate drainage during excess rains (Sharma *et al.* 2005). At critical growth stages, first irrigation should be given 20 days after sowing (DAS) and



thereafter at 10 days interval. The delay in first irrigation at 30 DAS could not reverse impairment in the growth and yield even if irrigations are revived at shorter intervals. Further, furrow irrigation with raised-bed systems improved the irrigation water-use efficiency under permanent raised-bed seeding where tillage was done on top of the beds. Furrow irrigated seeding system in north-west India resulted in higher yield with significant water savings (16-20%) for a wide spectrum of legumes compared to traditional farmers' practice (Lumpkin and Sayre 2009).

In pigeonpea, mulching with sugarcane trash @ 8 t ha<sup>-1</sup> controlled weed growth conserved of soil moisture through moderation of soil temperature and increased yield (Gajera *et al.* 1998). In Vertisols of Powarkheda (Madhya Pradesh), two irrigations scheduled at flowering and seed development stages produced 15.3 q ha<sup>-1</sup> seed yield. Further, the assessment of drainage practices in clay soils of Tawa command area during 2007 showed that ridge-furrow system produced a pigeonpea seed yield of 24.0 q ha<sup>-1</sup>. Irrigation scheduling at -0.03 MPa soil water suction at 30 cm depth produced significantly higher seed yield of pigeonpea (cv. Ravi 20) at Gayeshpur.

In Vertisols of Belvatgi (Karnataka), irrigation at IW/CPE 1.0 consuming 24.7 cm total water produced 58.6 q ha<sup>-1</sup> seed yield of frenchbean with a water use efficiency (WUE) of 290 kg ha-cm<sup>-1</sup>. Further, in the Malaprabha command area, the irrigation scheduled at IW/CPE 1.0 (6 cm depth) produced 58.1 q ha<sup>-1</sup> frenchbean yield.

In clay loam soils of Bilaspur, blackgram irrigated at critical growth stages produced higher seed yields than rainfed crop with 13.69 - 16.60 kg ha-cm<sup>-1</sup> water expense efficiency. Irrigation scheduling at IW/CPE 0.75 (irrigation depth of 3 cm during the first 25 days and thereafter 4 cm) for cv T-9 was optimum during summer season in sandy loam soils of Chalakudy (Kerala) for yield and WUE.

In moderately well drained soils on medium land, irrigation scheduled at 30% depletion of available soil moisture (DASM) recorded a rajmash seed yield of 86.2 q ha<sup>-1</sup> and WUE of 37.68 kg ha-cm<sup>-1</sup>, respectively compared to 50 and 60% depletion of ASM. Irrigation at 30% DASM also had the lowest water requirement (24.14 cm) and higher WUE of 35.67 kg ha-cm<sup>-1</sup>. At Faizabad, in silt loam soils, rajmash with paired row sowing on raised bed system produced 8.40 q ha<sup>-1</sup> seed yield which was significantly higher than seed yield obtained with flat and ridge system. On the other hand, at Jammu, depth of irrigation (4, 5 and 6 cm) had no significant influence on seed yield of rajmash grown on same soil type. But frequency of irrigation, *i.e.* 15 days interval showed 15.4 q ha<sup>-1</sup> seed yield, significantly higher than those with stressed irrigation at 20 days interval and at par with frequent irrigation at 10 days interval. In sub-tropical plains of Jammu, maximum seed yield of 798 kg ha<sup>-1</sup> of rajmash was obtained with irrigation scheduled at 15 days interval (requiring only two supplemental irrigations) over irrigation intervals of 10 days and 20 days, which registered yield of 679 and 607 kg ha<sup>-1</sup>, respectively. A five cm depth of irrigation gave higher seed yield (790 kg ha<sup>-1</sup>) over four and six cm depths. In Vertisols of Powarkheda, scheduling four irrigations at 20 + 40 + 60 + 80 DAS produced 8.40 q ha<sup>-1</sup> seed yield of rajmash which was significantly superior over one, two and three irrigations. At Chiplima, it was observed that rajmash grown with paddy straw mulch



registered highest yield of 7.90 q ha<sup>-1</sup> (20.9% increase over no mulch) when irrigation was scheduled at 50% DASM.

Under south Gujarat condition, higher seed yield of cluster bean (1632 kg ha<sup>-1</sup>), water saving (25%), WUE (4.53 kg ha-mm<sup>-1</sup>), net returns (Rs.58516 ha<sup>-1</sup>) and B:C (3.77) was obtained with irrigation at 0.6 IW/CPE. In south Gujarat heavy rainfall zone (AES-III), for cluster bean (GG 2) grown during summer season, six irrigations (60 mm depth) were recommended *i.e.*, first irrigation just after sowing, second at 7 to 10 DAS and remaining 4 irrigations at fortnightly interval.

In sandy clay loam soils of Panthnagar (Uttarakhand), the pod yield of pea (cv. Arkele) increased with an increase in the amount of water applied with sprinkler irrigation up to IW/CPE 1.0 (7.01 t ha<sup>-1</sup>). The green pod yield under flood irrigation method was at par with IW/CPE 1.0, however, flood irrigation required 40.0 mm more irrigation water. WUE was maximum (156 kg ha-mm<sup>-1</sup>) in case of IW/CPE 0.6 with sprinkler irrigation, where only one irrigation was applied. Under flood irrigation, pod maturity was less uniform (uniformity is a desirable feature in case of vegetable pea crop) as compared to sprinkler irrigation.

At Chiplima, water requirement was calculated for cowpea, sesame and green gram crops grown on loamy soils. Irrigation at 30% DASM produced highest seed yield of 38.6, 4.90 and 5.90 q ha<sup>-1</sup> in cowpea, sesame and green gram, respectively. Lowest yield was obtained with irrigation schedule of 60% DASM. Water requirement was highest at 30% DASM in cowpea but at 50% DASM in both green gram and sesame. WUE varied from 94.94 to 124.43 kg ha-cm<sup>-1</sup> in cowpea, 15.58 to 16.03 in sesame and 16.63 to 19.12 in green gram. At Pantnagar, maximum seed yield of cowpea (1408 kg ha<sup>-1</sup>) was obtained under 60 cm water table where 6 irrigations were given based on 100 mm CPE by flood method followed by 1356 kg ha<sup>-1</sup> under same treatment receiving same number of irrigations by sprinkler method. Further, under different water table and number of irrigations, the maximum cowpea seed yield (1408.2 kg ha<sup>-1</sup>) was obtained under 60 cm water table where 6 irrigations given based on 100 mm CPE by flood method which was followed by sprinkler method (yield 1356 kg ha<sup>-1</sup>) receiving same number of irrigations. Significantly higher soybean equivalent yield (1663.0 kg ha<sup>-1</sup>) and maximum water use efficiency (29.75 kg ha-cm<sup>-1</sup>) were recorded with soybean+pigeonpea (4:2) intercropping system. Soybean equivalent yield and water use efficiency were not significantly influenced by irrigation schedule (rainfed and irrigation at 60% DASM).

At Prabhani, significantly higher chickpea seed (2973 and 1225 kg ha<sup>-1</sup>) and straw (2840 and 1375 kg ha<sup>-1</sup>) yields were obtained with three sprinkler irrigations at grand growth+flowering+pod formation stages, however it was on par with two sprinkler irrigations at flowering + pod formation stages in respect of seed (2860 and 1078 kg ha<sup>-1</sup>) and (2690 and 1348 kg ha<sup>-1</sup>) straw yield during 2014-15 and 2015-16, respectively.

### **Irrigation water management in pulse crops under pressurized irrigation**

Pressurized irrigation techniques such as drip and sprinkler irrigations are used to determine optimum irrigation schedules and to save water while enhancing crop produc-

tivity of pulse crops. The experimental results at AICRP-IWM centres on pressurized irrigation scheduling of pulse crops (AICRPIWM 2016) are presented briefly below.

At Morena, seed yield and straw yield of pigeonpea and water productivity was maximum under sub-surface irrigation with porous pipe/inline drippers as compared to drip and border strip irrigation. At Prabhani, significantly higher chickpea seed (2973 and 1225 kg ha<sup>-1</sup>) and straw (2840 and 1375 kg ha<sup>-1</sup>) yields were obtained with three sprinkler irrigations at grand growth+flowering+pod formation stages than rest of the irrigation treatments, however it was comparable with two sprinkler irrigations at flowering + pod formation stages in respect of grain (2860 and 1078 kg ha<sup>-1</sup>) and (2690 and 1348 kg ha<sup>-1</sup>) straw during 2014-15 and 2015-16, respectively.

In sandy loam soils of Gayeshpur, irrigation scheduled at IW/CPE 0.5 produced significantly superior seed yield (1.5 t ha<sup>-1</sup>) of chickpea (cv. GNG-663) over sprinkler irrigation. Although flooding increased the yield water requirement was 2.5 times higher than sprinkler irrigation. Depth of irrigation through sprinkler (6 cm) produced 1.44 t ha<sup>-1</sup> Chickpea seed yield, significantly superior to those either four or five cm depths. At Sriganganagar, irrigation to chickpea at IW/CPE 0.6 gave significantly higher seed yield (2.11 t ha<sup>-1</sup>) as compared to IW/CPE 0.5. Yield of chickpea also increased significantly with every increase in the depth of irrigation water with highest seed yield (2.30 t ha<sup>-1</sup>) recorded with 60 mm depth. Total water use (270.5 mm) was highest in case of flood irrigation with 239.7 mm water used with sprinkler irrigation at IW/CPE 0.6. In sandy loam soils of Sriganganagar, in fallow-chickpea sequence, the maximum water use efficiency (9.80 kg ha-mm<sup>-1</sup>) was recorded under IW/CPE 0.6 and minimum recorded with flood irrigation (8.90 kg ha-mm<sup>-1</sup>). Yield of chickpea increased significantly with each increase in the depth of irrigation water through sprinkler. Highest seed yield (2.78 t ha<sup>-1</sup>) was recorded with 60 mm depth which was statistically superior to 40 mm and 50 mm depths.

At Navasari, during *rabi* seasons of 2011 to 2014, assessment of drip irrigation in pigeonpea with and without mulch indicated that the interaction effect of drip at 0.6 Pan evaporation fraction (PEF) with black plastic mulch and irrigation had significant effect on seed yield (1774 kg ha<sup>-1</sup>) and WUE (3.85 kg ha-mm<sup>-1</sup>) with 32% water saving. Therefore, in South Gujarat heavy rainfall zone (AES III), for growing of pigeonpea (GT-102) during *rabi* season, paired row sowing (60×20:120 cm) with drip irrigation at 0.6 PEF and mulching with black plastic (50 µ and 56% coverage) was suggested for higher net returns and saving of water over surface method of irrigation.

At Pantnagar, in sandy clay loam soil, pea crop irrigated with IW/CPE 1.0 through sprinkler produced 7.24 t ha<sup>-1</sup> pod yield with a net return of Rs. 72365 and B:C ratio of 3.01. In another experiment, when vegetable pea was grown in sandy loam soil, green pod yield was maximum (7.82 t ha<sup>-1</sup>) under sprinkler irrigation at IW/CPE 1.0, followed by surface irrigation at vegetative and flowering stages. At Morena, pea grown on sandy loam soil showed that micro-tube irrigation produced 13.0 q ha<sup>-1</sup> seed yield as compared to 12.2 q ha<sup>-1</sup> under drippers and 11.2 q ha<sup>-1</sup> under border strip method of irrigation. At Pantnagar, mean pod yield of vegetable pea increased (72.4 q ha<sup>-1</sup>) with increase in

amount of water applied in sprinkler irrigated treatments up to IW:CPE 1.0, followed by that with IW:CPE 0.8 (5.85 t ha<sup>-1</sup>) in sandy clay loam soil. But the amount of water required was same (75 mm) for both the treatments. Irrigation at IW:CPE 1.0 through sprinkler, recorded the maximum net return (Rs.72365 ha<sup>-1</sup>) and B:C ratio (3.01), however this did not vary significantly over 2 irrigations applied at vegetative and flowering stages as flood (Rs. 69795 ha<sup>-1</sup> and 2.91). But one major drawback observed with flood irrigation was non-uniform pod maturity, which was not desirable from harvesting point of view. Pod discolouration was also observed in flood irrigated crop. Thus sprinkler irrigation (depth 30 mm) at IW:CPE 1.0 may be advocated for higher yield, WUE and economic returns from vegetable pea (cv. Arkel).

At Madurai, during 2013-15, in a study to optimize the irrigation schedule for pigeonpea under conventional dibbling and transplanting condition involving different irrigation regimes of 40, 60 and 80% PE, the surface irrigation with soil application of fertilizer was maintained as a control. Seedlings were raised in portrays and planted at 28 days, at a lateral spacing of 1.5 m and plant spacing of 75 × 18 cm (drip) and 45 × 30 cm (surface). The study revealed that the conventional sowing under drip irrigation and irrigated at 60% PE level with drip fertigation of 100 recommended dose of fertilizer has produced maximum yield of 1520 kg ha<sup>-1</sup> and net income of Rs. 41862 ha<sup>-1</sup> and B:C ratio of 2.11. However, water saving when compared to conventional irrigation of surface irrigation was only 21%. When pigeonpea was transplanted under drip irrigation and irrigated at 60% PE with 100% fertigation of recommended dose of fertilizer recorded seed yield of 1515 kg ha<sup>-1</sup> with a B:C ratio of 2.00, net income of Rs. 39727 ha<sup>-1</sup>, water saving of 39% and WUE of 3.65 kg ha<sup>-1</sup> mm.

In sandy loam soils of Gayeshpur, in rice-broad bean cropping system, irrigation applied at 30 CPE and higher dose of phosphorus (90 kg ha<sup>-1</sup>) recorded maximum seed yield 51.1 and 57.0 q ha<sup>-1</sup>, respectively. Broad bean can be grown up to last week of December as contingent crop after *kharif* rice, if planting of *kharif* rice was much delayed in planting as well as harvesting. In such cases, quite a substantial yield of broad bean could be obtained to compensate *kharif* rice loss. Broad bean, after *kharif* rice, is being considered as profitable crop under lowland ecosystem replacing summer rice.

### **Irrigation water management in pulses under intercropping systems**

In silty loam soils of Faizabad, rice-pigeonpea (late maturing) system with irrigation schedule of 5 cm irrigation at 2 Days after disappearance (DAD) produced 34.0 q ha<sup>-1</sup> rice equivalent yield, which was significantly superior to irrigation scheduled 5 cm water at 11 DAD under rainfed conditions. At Pusa, intercropping of wheat+rajmash (2:2) with two irrigation applied at crown root initiation (CRI)+flowering resulted in higher wheat equivalent yield (46.6 q ha<sup>-1</sup>) and WUE 269.6 kg ha-cm<sup>-1</sup>.

## **B. ENHANCING PRODUCTION OF PULSE CROPS IN RAINFED AREAS**

The production of pulse crops in rainfed areas is a function of both spatial and temporal availability of soil moisture within the field during the crop growth period. Improving soil surface conditions to increase infiltration and water holding capacity are

two basic requirements in rainfed areas (Ravindra Chary *et al.* 2013). The strategies for enhancing production of pulse crops through *in-situ* and *ex situ* rainwater management are presented below.

#### ***BUILDING IN-SITU MOISTURE RESERVES TO TIDE OVER THE RECURRING DROUGHT SPELLS***

Levelling of the soil and bunding is the simplest and most important operation required to effectively utilize the rainwater under scarce and erratic rainfall situations. Graded bunds are suggested in higher rainfall areas with less permeable black soils. Bunding was beneficial in increasing the yields of green gram, mothbean, lentil and pigeonpea by 194, 20, 8 and 58%, respectively compared to no bunding (AICRPDA 2003).

Cultivation across the slope is the most viable option for efficient *in-situ* moisture conservation and increases soil moisture content by 22-75% and enhances the productivity of green gram (623%), pigeonpea (75%) and soybean+pigeonpea (up to 50%) (Taley 2012). Contour cultivation boosts it further by building up temporary water storage capacity in furrows across the slope. Contour cultivation is, however, difficult to achieve on small and narrow fields. Under such situations, cultivation across the slope is a viable alternative for efficient *in-situ* moisture conservation. Taley (2012) reported that the soil moisture content increased by 22-75% due to contour cultivation and enhanced the productivity of green gram (62.5%), pigeonpea (75%) and soybean + pigeonpea (46-50%). Further, due to cultivation of chickpea across the slope, there was an increase in soil moisture content (16-36%), chickpea yield and rainwater use efficiency (RWUE) in deep black soils. Similarly, contour cultivation with opening of contour furrows at 20 m HI and formation of square basins (20 m × 20 m) enhanced yield of chickpea by 50 and 66.6%, respectively.

Off-season tillage has been found to be useful in increasing rainwater infiltration and minimizing water evaporation through 'mulching' effect. Deep ploughing plays an important role in stabilizing the productivity of rainfed pulses through *in-situ* soil moisture conservation (AICRPDA 2003). Summer tillage with two-bottom mouldboard plough utilizing residual moisture or pre-monsoon showers is recommended to make the land ready for planting in eastern Uttar Pradesh. This practice helps in greater retention of rainwater (36% higher than conventional method) and enhances the yield of pigeonpea by 86% compared to farmers' practice (Venkateswarlu *et al.* 2009). In another experiment at Arjia (Bhilwara district, Rajasthan), *in-situ* moisture conservation system involving summer deep ploughing with raised bed of 40 cm width gave highest black gram yield (1243 kg ha<sup>-1</sup>), rainwater use efficiency and lowest runoff and soil loss compared to farmers' practice of flat bed (AICRPDA 2011b). It is evident from several experiments that the effects of deep tillage could last for 2 to 5 years depending upon the soil texture and rainfall.

The adoption of reduced tillage is expanding during recent years. With the integration of herbicides, the number of tillage operations can be reduced and conservation tillage

systems such as reduced/low tillage system could be adopted. In sandy soils of at SK Nagar (Gujarat), among different tillage treatments, low tillage + inter-cultivation twice + herbicide use gave higher seed yield of cluster bean and RWUE than intensive tillage systems (AICRPDA 2011b). However, reduced tillage was not effective in increasing the lentil yields in Inceptisols of Varanasi and Faizabad, mostly due to heavy weed infestation.

In Alfisols, the problem of crusting and sealing is encountered during early stages of crop growth resulting in uneven germination and plant stand. Under stress conditions, shallow tillage as an additional inter-cultivation has been found to be effective in breaking up the crust, improve infiltration, and reduce moisture losses through evaporation by creating dust mulch.

With the integration of herbicides, the number of tillage operations can be reduced and conservation tillage systems such as reduced/low tillage system could be adopted. At SK Nagar, Gujarat, low tillage + inter-cultivation twice + herbicide use gave higher seed yield of cluster bean and higher RWUE than intensive tillage systems (AICRPDA 2011b). Promotion of zero tillage systems in high rainfall zones may help in relay of *rabi* pulses in rice, particularly eastern and north-eastern regions.

Mulching is useful for achieving higher rainfall infiltration, reduced soil erosion, structural stability and minimize soil moisture losses through evaporation. Different materials such as crop residues, green manure, sand, polyethylene and pebbles can be used as mulch. Soil water content under sand mulch at any point of time in a year could be 85-98% compared to no mulch. The practice of sand mulching in sodic Vertisols of northern Karnataka enables double cropping of groundnut or green gram in *kharif* followed by sorghum or chickpea in *rabi*. This practice gives a yield advantage of 300% in chickpea and 366% in green gram. The cost of sand application can be recovered within 2 years of cropping. A uniform layer of pebbles on soil surface will prevent transfer of heat from the surrounding air to the soil, reducing evaporation losses. It also helps to control runoff water effectively. Large scale demonstrations conducted on an area of 500 ha in Bagalkot taluk of Karnataka clearly indicated the yield advantage of 200% in green gram (Guled *et al.* 2003).

Compartmental bunding, dividing the field into parcels of 4.5 m × 4.5 m and 3 × 3 m on lands having slopes of 2 and 3%, respectively, is yet another *in-situ* moisture conservation practice in medium to deep Vertisols in post-monsoon predominant cropping areas like northern Karnataka. In Inceptisols and Vertisols at Bijapur, the seed yield of chickpea with compartmental bunding gave yield advantage of 50% and additional net returns of Rs. 2850 ha<sup>-1</sup> as compared to flat sowing. The impact of the practice was more pronounced during sub-optimal rainfall years. In eastern Uttar Pradesh, ridge-furrow planting of pigeonpea (on ridge) and rice (in furrows) both in uplands and medium lands helped in runoff modulation, crop diversification, risk reduction and disruption of pest cycle. This system produced a rice equivalent yield of 8866 kg ha<sup>-1</sup> and 47% higher income as against 3500 kg ha<sup>-1</sup> of rice with farmers' practice of sole rice under flat planting (Venkateswarlu *et al.* 2009). Pawar *et al.* (2008) reported that opening of ridges and furrows, 60 cm apart across the slope in Vertisols gave significantly higher pigeonpea yield and was found more economical compared to tied ridges and compartment bunding.



Graded border strips increased yield of pulse crops significantly (Guled *et al.* 2003) which are recommended in medium deep to deep black soils with permeability of less than 8 mm per hour in areas of medium to heavy rainfall.

Conservation furrows are the opening of furrows parallel to rainfed crop rows across the land slope, with a country plough, 3 to 4 weeks after the germination of the main crop. During runoff causing rainfall events, the rainwater gets concentrated within these furrows, infiltrates into the soil (root zone) and is available to the crop for meeting the evapo-transpiration demand for a longer duration compared to no furrow. Opening of conservation furrow at 35 DAS in between two rows of pigeonpea in finger millet / groundnut+pigeonpea intercropping system (8:2) in Alfisols of Bengaluru and southern Karnataka and pigeonpea in Alfisols of Ananthapuramu and scarce rainfall zone of Andhra Pradesh gave higher yield and income (AICRPDA-NICRA 2016).

Set furrow cultivation is another effective micro-site improvement process which conserves rainwater effectively and offers excellent drought proofing. In this technique, crop rows are set permanently by opening deep furrows of 25 to 30 cm at wider distance and all the inputs (crop residues, manures and fertilizers) are applied in the set furrows before sowing. In Vertisols of Bijapur, set furrow with residue incorporation + *Glyricidia* in pigeonpea + groundnut intercropping (2:4) resulted in efficient *in-situ* moisture conservation and gave higher pigeonpea equivalent yield (1864 kg ha<sup>-1</sup>) and net returns (Rs. 71931 ha<sup>-1</sup>) than farmers' practice (1479 kg ha<sup>-1</sup>) (AICRPDA 2015).

Broad bed furrow system was found useful in Vertisols of low to medium rainfall (<1000 mm) regions (AICRPDA 2003). The raised and sunken bed system is advocated for Vertisols of high rainfall (>1000 mm) regions. In Inceptisols of Bastar plateau region (Chhattisgarh), half feet raised/sunken bed improved seed yield of cowpea by 35% compared to flatbed method (AICRPDA 2015). In Inceptisols of Kandi region of Punjab, ridge planting of green gram and black gram gave 33 and 12% higher seed yields compared to flat planting, respectively (AICRPDA-NICRA 2016).

### **Recycling of harvested run off**

It may not be possible to conserve all the rainwater *in situ*, in spite of adopting different soil and water conservation measures. The soil topographic features and climatic factors prevailing in most rainfed areas are highly conducive to generation of runoff. This inevitable runoff may be collected in small and medium water harvesting structures such as farm ponds and the stored rainwater can be recycled as supplemental/ life-saving irrigation to the crop to cope with dry spells. Rainwater harvesting is a centuries old strategy, but neglected in many areas because of availability of modern irrigation technology (Singh 1998). Rainwater harvesting for recession cropping is unique and has some location specificities including socio economic considerations that must be considered first before going in for their imposition in new areas. Extensive studies on rainwater harvesting in dugout ponds in Alfisols and Vertisols regions indicated that appropriate pond size varies from 200 to 3000 m<sup>3</sup>. In Alfisols of scarcity zone of Andhra Pradesh, a farm pond size of 10 m × 10 m with 2.5 m depth, side slopes of 1.5:1 with a storage



capacity of 250 m<sup>3</sup> lined with soil + cement mixture (6:1 ratio) was found for a catchment area of 5 ha. Several studies revealed that yield of pulse crops can be increased with protective/supplemental/ pre-sowing irrigation from stored rainwater during prolonged periods of dry spells *i.e.* 39% in chickpea; 66% in pigeonpea; 50% with pre-sowing irrigation in chickpea (AICRPDA 2010) and in Inceptisols of Ballawal Saunkhri (Punjab), one supplemental irrigation during prolonged dry spell at 20 DAS gave the yield of 3600 kg ha<sup>-1</sup>; in Vertisols of Parbhani, supplemental irrigation (5 cm) from harvested rainwater with sprinklers increased pigeonpea seed yield by 78% (AICRPDA-NICRA 2016) and in Vertisols of Akola, two protective irrigations of 50 mm depth, from harvested rainwater in farm ponds, through sprinklers to chickpea gave 43% higher seed yield compared to one protective irrigation after sowing .

Studies at AICRPDA centres revealed that yield of pulse crops could be enhanced through supplemental irrigation from stored rainwater during prolonged dry spells (Table 1).

**Table 1.** Response of pulses to supplemental irrigation

AICRPDA center (AESR*)	Climate (MARF** mm)	Soil type	Crop	Yield (kg ha <sup>-1</sup> )		Increase in yield (%)	Source
				Irrigated	Control		
Akola (6.3)	Semiarid hot moist (824)	Vertisols	Pigeonpea	1000	600	66.6	Taley (2012)
Rewa (10.3)	Sub humid hot dry (1088)	Vertisols	Chickpea	1905	1270	50	AICRPDA (2010)
Agra (4.1)	Semiarid hot dry (665)	Inceptisols	Lentil	1353	1119	20.9	AICRPDA (2011b)

\*Agro-ecological sub region, \*\*Mean annual rainfall

Source: Ravindra Chary *et al.* (2016)

### Managing excess moisture conditions

Traditionally, pulses are sown on flat seedbeds under rainfed conditions. In eastern Uttar Pradesh, Bihar, West Bengal, Odisha and parts of central India, pigeonpea crop often suffers due to water stagnation during rainy season which ultimately reduces productivity. With promotion of rice cultivation, compartmental bunding also increased, which led to poor drainage and thus a challenge to successful cultivation of *kharif* pulses in these areas (Ali *et al.* 2012). Raised land configurations such as broadbed and furrow, raised and sunken beds etc. not only help in efficient conservation of rainwater but also drain out excess water during high rainfall events, particularly in black soils, thereby enhance the productivity of pulses.

### Pulses based cropping systems matching growing seasons

The potential areas suitable for mono cropping, intercropping and double-cropping of pulse crops fitting into length of effective crop-growing season is presented in table 2.

**Table 2.** Potential cropping systems and drought vulnerability based on rainfall and soil types

Rainfall (mm)	Major soil orders	Growing season (weeks)	Suitable cropping system
350-650	Alfisols, shallow Vertisols, Aridisols and Entisols	15	Single rainy season
350-650	Deep Aridisols and Inceptisols	20	Either rainy or post-rainy season crop
350-650	Deep Vertisols	20	Post-rainy season crop
650-800	Alfisols, Vertisols, Inceptisols	20-30	Intercropping
800-1100	Deep Vertisols, Alfisols and Entisols	30	Double cropping
>1100	Deep Alfisols, Oxisols <i>etc.</i>	30+	Double cropping

*Source:* CRIDA (1997)

### Pulses as contingency crops to cope with delayed onset of monsoon

In rainfed areas, as a general rule, early sowing of crops with the onset of monsoon is the best-bet practice that gives higher realizable yield. Major crops affected due to monsoon delays and with a narrow sowing window cannot be sown beyond the sowing window (moisture availability period). Under such circumstances, pulse crops/ short duration varieties could be ideal option for optimal use of the left over growing period. Several varieties of *kharif* pulses were identified with yield and economic advantage under diverse rainfed agro-ecologies to cope with delayed onset of monsoon (Srinivasarao *et al.* 2016; AICRPDA-NICRA 2016).

### CONCLUSIONS

Water management either through efficient irrigation techniques or *in-situ* and *ex-situ* rainwater management is the key for achieving higher production and bridging the present yield gap in pulse crops. Further, agro-ecology specific rainwater management practices in rainfed pulse crops and efficient surface irrigation methods and pressurized irrigation in irrigated pulse crops could contribute to sustainable pulse production.

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## Technological Advancements in Pulse Production

Masood Ali

Unlike cereals (rice, maize and wheat), pulses did not witness genetic breakthrough. Nevertheless, a remarkable improvement and stability in productivity was achieved. With advanced screening facilities and techniques, donors for major diseases were identified and used in breeding programme to develop disease resistant/tolerant varieties with high yield. Short duration varieties were developed to fit in different environments and cropping systems. Quality improvement for seed size, colour and lustre as desired by consumers/traders were brought in. With identification of new varieties, some of the pulses were introduced in new niches (rice fallows-urdbean, mungbean) and non-traditional seasons (frenchbean, pigeonpea). Genetic resources have been enhanced and are utilized for searching genes for abiotic and biotic stresses. Efforts are on way to mine genes for various stresses, gene pyramiding for pathogenic variability and transgenic for gram pod borer. New cropping systems (crop rotation and intercropping) have been developed for different regions which are more productive and efficient and facilitated area expansion under pulses. Agro-techniques such as raised bed planting, integrated nutrient management including biofertilizers, secondary (S) and micronutrients (Zn, B and Mo), foliar nutrition, integrated weed management (cultural + herbicides), irrigation schedule based on IW/CPE ratio and crop growth stages, micro-irrigation, integrated pest management and resource conservation have been developed, refined and standardized for various agro-ecological zones. Technology for pulse production in rice fallows and agronomy of non-traditional pulses in new niches have been developed.

In India, pulses are grown since ancient time. They provide nutritious food/feed, conserve natural resources and maintain ecological harmony for sustainable agricultural production. Their ability to thrive well even in fragile environments (harsh climate, marginal soils) and perform better than other crops made them a panacea of dryland agriculture. In Indian agriculture, the value of pulses is far more important on account of food habits (vegetarianism), chronic protein-energy malnutrition (low availability and poor access to protein rich food) and low-input agriculture (> 55% rainfed areas, resource-poor farmers).

In India, over a dozen pulse crops such as chickpea (*Cicer arietinum* L.), pigeonpea (*Cajanus cajan* (L.) Millspaugh), urdbean (*Vigna mungo* (L.) Hepper), mungbean (*Vigna radiate* (L.) Wilczek), lentil (*Lens culinaris* Medikus), peas (*Pisum sativum* L.), lathyrus (*Lathyrus sativus* L.), cowpea (*Vigna unguiculata* L.), horsegram (*Macrotylum uniflorum*

Lam), mothbean (*Vigna aconitifolium* (L.) Jacq), frenchbean (*Phaseolus vulgaris* L.), etc. are grown across the country. Chickpea has highest area (8.89 Mha) followed by pigeonpea (3.88 Mha), urdbean, mungbean, lentil and peas (Table 1).

**Table 1.** Area and production of pulses in India (2012-15)

Crops	Area		Production	
	Mha	% Share	M t	% Share
Chickpea	8.89	37.0	8.56	47.0
Pigeonpea	3.88	16.2	2.99	16.4
Urdbean	3.14	13.1	1.87	10.2
Mungbean	3.04	12.7	1.42	7.8
Lentil	1.41	5.8	1.06	5.8
Fieldpea	0.89	3.7	0.88	4.8
Others	2.73	11.5	1.43	7.9
All Pulses	24.00	100	18.21	100

Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka and Andhra Pradesh are major pulse growing states (Table 2). During triennium 2012-15, the area, production and productivity of pulses was 24.0 Mha, 18.2 Mt and 758 kg ha<sup>-1</sup>, respectively. However, the domestic production is quite low compared to its requirements (25 Mt) and thus 4-5 Mt pulses are imported annually.

**Table 2.** Major pulse growing states of India (2012-15)

States	Area (Mt)	% Share
Andhra Pradesh	1.55	6.45
Chhattishgarh	0.89	3.70
Gujarat	0.69	2.87
Karnataka	2.36	9.83
Madhya Pradesh	5.40	22.50
Maharashtra	3.54	14.75
Rajasthan	3.60	15.00
Uttar Pradesh	2.34	9.75
Others	3.63	15.12
All India	24.23	

Unlike cereals (rice, wheat and maize), yield gain in pulses since 1950-51 till date has been only very marginal. Up to 1970-75, the yield was almost stagnant (468 kg ha<sup>-1</sup> during 1950-55 compared to 476 kg ha<sup>-1</sup> during 1970-75) due to lack of improved varieties and traditional crop management practices. After the establishment of All India Coordinated Pulse Improvement Project (AICPIP) in 1966, a new era of varietal development and improved agro-technology began. Refinement and standardization of agronomic practices under AICPIP was complemented by research output of other all India coordinated projects (Dryland Agriculture, Cropping Systems/ Farming Systems, Weed Management, Water Management, Soil Test Crop response, Micro- and Secondary Nutrients).



Improved agro-technologies along with new varieties (high yielding, short duration and disease resistant) led to significant improvement in productivity during 1990-95 (21.4%) over 1970-75 which further increased to 55.5% during 2010-15.

### HISTORICAL PERSPECTIVE

- Prior to establishment of AICPIP in 1966, research on pulses was limited and confined to only dryland research stations and under non-plan schemes on legumes in a few States. Evaluation of elite land races/varieties and working out their optimum sowing time and plant population, and identifying most productive cereal + pulse crop mixtures were the major activities. Realizing the importance of pulses for nutritional security, Govt. of India established AICPIP in 1966 under which systematic and comprehensive research programmes on varietal development, agro-technologies and management of biotic and abiotic stresses were started in different agro-ecological regions.
- During 1970s, available varieties of different pulse crops were evaluated for their performance on different planting dates and plant population, and their agronomic optima was worked out for various agro-ecological regions. The optimum planting time, seed rate, plant population, requirements of major plant nutrients including bio-fertilizers were worked out. A few short duration varieties of pigeonpea like 'Pusa Ageti' and 'UPAS 120' and summer mungbean (Type 44 and Pusa Baisakhi) were developed during this period. New cropping systems such as pigeonpea- wheat and rice-wheat-mungbean were developed after working out agronomic requirements of the new varieties.
- During 1980s, new plant types of different pulse crops like peas (dwarf, leafless) and chickpea (erect, tall), *etc.* were evolved. Development of new varieties in a few crops, led to their introduction in new niches/seasons such as frenchbean (cv. PDR 14) for winter planting, pigeonpea (cv. Bahar) for post-rainy season in north-east plains and urdbean (cv. LBG 17) for rice fallows in peninsular India. The agronomy of new crops and their varieties were standardized. Most efficient and compatible intercrops with pulses and their row ratios were worked out for different regions. Studies on foliar nutrition, pre-emergence herbicides and water absorbing polymer (Jal-Shakti) were initiated. Seed inoculation with efficient rhizobium culture was advocated. Irrigation at branching and pod development stages was recommended in chickpea and fieldpea.
- During 1990s, many short duration and high yielding varieties of mungbean, urdbean, pigeonpea, chickpea and lentil were developed. Chickpea varieties for late planting (December) were also developed. In varietal development, major emphasis was laid on genetic enhancement and multiple disease resistance. Agronomy of these new varieties was standardized. Genotypic compatibility and fertilizer requirements in cropping systems mode were intensified. Major research focus was placed on integrated nutrient management; crop-weed competition, weed suppressing ability of pulses and integrated weed management.

- At present, major research focus is on gene mining for tolerance to abiotic stresses and genetic gain, gene pyramiding for different races of pathogens, restructuring plant types for climatologically vulnerable regions, transgenic, hybrid technology, input-use efficiency, drought management, micro-irrigation, resource conservation technologies, PGPR and climate smart practices.

### RECENT ADVANCEMENTS (MILESTONES)

#### Improved varieties

Intensive breeding efforts led to development of new varieties with short duration, disease resistance, large seed, photo-thermo insensitivity and amenable for late planting besides higher yield which facilitated crop diversification, intensification and introduction in new niches and cropping systems. Over 500 new varieties with numerous economic traits and farmers' preference have been released for different agro-ecological regions since inception of AICPIP.

Highlights of new varieties are enumerated below.

**New Plant types:** In 1988, a dwarf-leafless (leaflets converting into tendrils) variety of fieldpea (Aparna) was developed. This dwarf variety responded well to high plant population, irrigation and nitrogen, and thus significant increase in productivity (Ali 1988). Later on, many dwarf and semi-dwarf varieties (Sapna, Utra, Malviya Matar 15, KPMR 400, KPMR 522, Vikash, Prakash, Pant P 74) were developed. In chickpea, a tall-erect variety (BG 261) with basal branching and bold seeds was developed in 1984. This variety was found ideal for intercropping with mustard cv 'Varuna' in 6:2 row ratio (Ali 1992). Now, more emphasis is laid on tall- erect plant types in chickpea, lentil and mungbean to facilitate mechanical harvesting. In short duration pigeonpea, a few varieties with determinate growth habit (ICPL 87, ICPL 151, ICPL 85010) were developed to facilitate synchronous maturity and timely harvesting but it could not click due to heavy infestation of pests.

**Short duration:** The traditional long duration varieties often experienced terminal drought resulting in partial or complete failure of crop, encountered more pest infestation and favoured mono-cropping. Therefore, efforts were made to develop short duration varieties in all pulse crops with matching phenology for different agro-ecological regions. The advent of short duration varieties of pigeonpea during 1975-76 such as 'Pusa Ageti', 'UPAS 120', etc. led to the introduction of pigeonpea in the irrigated area of north-west plains under pigeonpea - wheat double cropping system (Ramanujam 1971). Later on, many short duration (130-160 days) varieties such as ICPL 151, Pusa 33, Pusa 855, Manak, Al 15, Al 201 and Pusa 992 were developed (Ali and Kumar 2009). Mid May to mid-June was found to be the optimum time of planting for success of pigeonpea-wheat rotation.

In chickpea, first short duration (110 days) variety (ICCV 2) was developed in 1991. Subsequently, many short duration (90-110 days) varieties such as ICCV 10, JG 11, JG 74, BGD 72, ICCV 37, SAKI 9516, JAKI 9218, Vijay etc. were developed which

revolutionized chickpea cultivation in central and south India. In mungbean, development of short duration and photo-thermo insensitive variety possessing synchronous maturity (Pusa Baisakhi) in 1974, led to its cultivation as a catch crop during mid-March to mid-June after harvest of *rabi* crops such as potato, mustard, sugarcane and wheat. Later on, many short duration (60-65 days) varieties such as PDM 54, PDM 11, Pusa 9531, Pusa Vishal, SML 668, HUM 12, Pant Mung 5 *etc.* were developed which played a catalytic role in spread of spring/summer mungbean and crop intensification in north India. Similarly, development of short duration (70-75 days) varieties of urdbean such as Basant Bahar, PU 19, PDU 1, UG 218, KU 300, WBU 109 *etc.* led to its cultivation in spring season. Agronomy of spring/summer mungbean and urdbean was comprehensively worked under AICPIP. Intercropping of mungbean and urdbean with spring sugarcane has been found quite promising.

**Disease resistance:** Pulse crops suffer heavily due to several fungal, viral and bacterial diseases which brings instability in their productivity. The most common diseases are *Fusarium* wilt (chickpea, lentil and pigeonpea), rust (lentil, peas), MYMV (mungbean, urdbean, cowpea), BGM and Ascochyta blight (chickpea), Phytophthora stem blight and sterility mosaic (pigeonpea) and powdery mildew (peas, urdbean, mungbean). Therefore, breeding for disease resistant varieties remained a core programme under varietal improvement. Since more than one major disease occurs in many crops, emphasis is now placed on multiple disease resistance as well as introgression of genes for different races/pathotypes of diseases. Some of the important varieties possessing resistance to major diseases in different crops are given in table 3.

**Large seeds:** The myth about negative linkage between large seeded varieties and higher yield was dispelled with release of bold seeded (20-25 g 100seeds<sup>-1</sup>) desi varieties of chickpea such as Pusa 256, Phule G 5, Pusa 391, K850, BGD 72, Pusa 362, Samrat, GG 2 *etc.* which became very popular. Similarly, in kabuli chickpea, extra-large seeded (> 55 g 100seeds<sup>-1</sup>) varieties such as PG 0517, PKV Kabulli 4 and MNK 1 released in 2010 have become very popular in central and south India as they earn premium price in the international market. Similarly, the first bold seeded variety of lentil (Malika) was released in 1986 and thereafter, several large seeded (>2.5 g 100seeds<sup>-1</sup>) varieties such as Priya, Sheri, Noori, JL 3, VL 507, IPL 406 *etc.* have been developed which fetch premium price in market and also meet export requirements.

**Hybrids:** Among pulses, pigeonpea and lathyrus are often cross pollinated crops. This phenomenon (heterosis) has been exploited in pigeonpea. ICRISAT and ICAR joined hands in early nineties which led to identification of first GMS based hybrid ICPH 8 in 1991. Thereafter, a few more hybrids, PPH 4, CoPH 1, CoPH 2, AKPH 4101 and AKPH 2022 were developed but they could not become popular due to inherent difficulties in seed production. To overcome this problem, aggressive efforts were made to search for cytoplasmic genic male sterility (CMS) and as a result of this, the first CMS based hybrid GTH 1 was released for cultivation in Gujarat state in 2004. However, due to variation in flowering in parental lines and mixtures, this hybrid could not be successful. A few medium duration hybrids (ICPH- 2607, -2740, -3762) developed by ICRISAT have been released in the states of Madhya Pradesh, Odisha and Telengana during 2010-15.

**Table 3.** Disease resistant/tolerant varieties of pulse crops

Crop	Disease	Resistant/tolerant varieties
Chickpea	<i>Fusarium</i> wilt	Avrodhi, Bharti, DCP 92-3, GG 1, HC 1, ICC 32, JG 11, JG 16, JG 315, JG 74, Kranti, KWR 108, Phule G 12, Vaibhav, Vardan, JG 322, GNG 1581, GNG 663
	<i>Ascochyta</i> blight (AB)	PBG 1, Gaurav, PBG 5, GNG1581, Samrat, HC 5
	Wilt+AB	GNG 1581, BGM 417
Pigeonpea	<i>Fusarium</i> wilt	Maruthi, Asha, BSMR 736, BSMR 853, ST 1, Birsa Arhar, JKM 7, BDN 708, Vipula, Rajeev Lochan, BDN 711
	Sterility mosaic (SMD)	Bahar, Hy 3C, Sharad, Pusa 9, Varendra Arhar 1, BSMR 853, GT 100, Amar, MA 6, BDN 708, BDN 711, IPA 203
	<i>Alternaria</i> blight	Sharad, Pusa 9, NDA 3
	Wilt+SMD	GT 100, BDN 708, BDN 711, BSMR 853, Rajeev Lochan, MA 6, Vipula, GJP 1
Mungbean	MYMV	ML 267, PDM 11, PDM 54, MUM 2, Narendra Mung 1, ML 613, Pant Mung 4, Pusa Vishal, HUM 1, Meha, COGG 912, HUM 16, IPM 02-14
	Powdery mildew (PM)	TARM 2, Pusa 9072, TARM 1, TARM 18, Pairymung TJM 3
	MYMV+PM	Pusa 105, ADT 3, LGG 407, LGG 450
Urdbean	MYMV	Pant U 35, Narendra Urd 1, Birsa Urd 1, TU 94-2, KU 301, Azad Urd 1, Uttra, KU 96-3, Pant U 31, WBU 109, NUL 7, IPU 07-3
	Powdery mildew (PM)	LBG 17, LBG 402, AKU 4, WBG 26, TU 40
	MYMV+PM	LBG 20, NUL 7, IPU 02-43
Lentil	Rust	Sapna, Lens 4076, Priya, Sheri, Pant L 6, IPL 406
	<i>Fusarium</i> Wilt	Sekhar2, Sekhar 3. HM 1, LL 931, JL 3, VI 507
	Rust+Wilt	Narendra Masur 1, Pant L 4, Priya
Fieldpea	Powdery mildew (PM)	Aparna, Pant P 5, JP 885, Sikha, DDR 27, Uttara, Ambika, KPMR 522, HFP 715
	Rust	Malviya Matar 15, Prakash, Aman, Pant P 74
	PM+ Rust	Malviya Matar 15, Prakash, Pant P 74, HFP 529

**Non-traditional crops/varieties:** The development of *Alternaria* resistant variety ‘Sharad’ and ‘Pusa 9’ of pigeonpea opened a new era for its pre-rabi season cultivation in Bihar and eastern Uttar Pradesh. The productivity of pre-rabi pigeonpea was 3430 kg ha<sup>-1</sup> as compared to 2410 kg of wheat and 1290 kg ha<sup>-1</sup> of chickpea. First fortnight of September planting was found optimum (Roy Sharma *et al.* 1980). Consequently, the maize-pigeonpea crop rotation was preferred by the farmers. Later, the agronomy of pre-rabi pigeonpea was also worked out. Similarly, non-traditional crop for northern plains like frenchbean was introduced in the frost-free irrigated plains of north India due to development of variety PDR-14 (Udai) in year 1987. Its agronomic requirements like sowing date, nitrogen requirement, intercropping with potato *etc.* were intensively worked out at IIPR Kanpur during late 1980s (Ali and Kushwaha 1987).

Urdbean was traditionally grown in coastal peninsula on limited scale during *rabi* season after rive harvest under *para* cropping system. But the development of powdery

mildew resistant variety ‘LBG 17’ during late 1980s revolutionized its cultivation in rice fallows in coastal Andhra Pradesh and Tamil Nadu (Satyanarayana *et al.* 1988)

**Varieties with specific traits:** In chickpea, a large no. of varieties having drought tolerance (RSG 888, Phule G 5, Vijay), lodging resistance (DCP 92-3), salinity tolerance (Karnal Chana 1), heat tolerance (JG 14) and amenable for late planting (Udai, Pusa 372, Pant G 186, Rajas, Pusa 547) have been developed. In fieldpea, varieties with shining green seeds (HFP 9907 B, HFP 9926) and suitable for late planting (DDR 23) have been released.

**Transgenics:** Gram pod borer is the key pest of chickpea and pigeonpea for which host-plant resistance is not available in the germplasm. The integrated pest development technology developed for its management does not provide desirable control. Therefore, efforts are under way to develop Bt transgenic against *Helicoverpa armigera*. Transformation protocols have already been developed. Several transgenic events using insecticidal genes (Cry 1 Ab, Cry 1 Ac, Cry 1 Abc) with high mortality rate of larvae under insect bio-assay are under testing at IIPR, ICRISAT and other institutes (Singh 2013).

#### AGRO-TECHNIQUES

**Planting techniques:** Traditionally, pulses are sown on flat seed beds after land preparation. In eastern region (Uttar Pradesh, Bihar, Jharkhand, West Bengal, Orissa and parts of central India, *kharif* planted pulses often suffer due to water stagnation during rainy season which ultimately reduces productivity. During 1994-95, ridge planting of pigeonpea was conceptualized and evaluated under AICPIP/AICRP which showed very encouraging results in maintenance of optimal plant populations and consequently higher productivity due to proper drainage (Table 4). Ridges were made at 60-75 cm distance leaving 30 cm wide furrows for drainage of rain water. Two to three rows of short duration legumes such as mungbean/urdbean can be successfully planted on ridges. This system helps in reducing quantity of irrigation water, and also minimizes incidence of *Phytophthora* blight in pigeonpea.

**Table 4.** Effect of planting techniques on grain yield of pigeonpea in NWPZ (AICPIP)

Planting technique	Grain yield (t ha <sup>-1</sup> )		
	Ludhiana	Hisar	Pantnagar
Flat sowing	1.69	0.71	1.34
Raised bed sowing (2.7 m wide)	NT	1.18	2.08
Ridge sowing	1.40	0.96	1.95
Flat sowing and making furrows 50 DAS	2.05	1.02	1.53
CD ( <i>P</i> =0.05)	0.10	0.09	0.15

**Cropping system:** Development of short duration and disease resistant varieties of different pulses paved way for design and development of new cropping systems both in rainfed and irrigated areas. Some of the examples are pigeonpea-wheat in N-W plains, maize– pre-rabi pigeonpea/frenchbean in N-E plains, rice–wheat–mungbean, maize-po-

**Table 5.** Promising Intercrops for different states

Promising intercrops	States
Soybean + Pigeonpea	Madhya Pradesh, Maharashtra
Groundnut + Pigeonpea	Gujarat
Pearl millet/Sorghum + Pigeonpea	Andhra Pradesh, Karnataka, Gujarat, Maharashtra
Sorghum/Pearl millet + Urdbean/ Mungbean/Cowpea	Uttar Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Karnataka
Sugarcane=Urdbean/Mungbean	Uttar Pradesh, Punjab, Haryana
Chickpea + Mustard	Punjab, Haryana, Uttar Pradesh, Bihar
Chickpea + Linseed	Uttar Pradesh, Madhya Pradesh, Maharashtra
Chickpea + Safflower	Maharashtra, Karnataka
Cotton + Urdbean/Mungbean	Punjab, Haryana, Madhya Pradesh, Gujarat, Andhra Pradesh, Maharashtra

tato/mustard–mungbean/urdbean in northern plains and rice-urdbean in coastal peninsula. Some of the promising intercrops identified for different states are given in table 5.

Studies on system of planting under intercropping systems showed that paired row planting is better than uniform row planting when component crops include both tall and shot species. This allows normal plant population of main crop and thus total productivity and LER are higher. Apart from crop species, genotypes play an important role in improving productivity under intercrops. Chickpea genotype ‘KWR 108’ was found more compatible than ‘BG 256’ and ‘KPG 59’ for intercropping with linseed cv. ‘Neelam’ under row ratio of 6:2. Similarly, lentil variety ‘L4076’ was found more compatible than ‘DPL 62’ in lentil + linseed intercropping. Mungbean varieties ‘PDM 11’ and ‘PDM 84-143’ and urdbean variety ‘DPU 88-31’ were most compatible for intercropping with spring planted sugarcane (Ali 1992; IIPR 2009).

**Integrated nutrient management:** The initial studies showed that most of the pulse crops respond to 15-20 kg N ha<sup>-1</sup> and 20-40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> as basal application. Response to applied K was either absent or negligible. However, in recent years, most of the pulses responded well to 20-40 kg K<sub>2</sub>O ha<sup>-1</sup>. Generally, a basal application of 15-20 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O ha<sup>-1</sup> is recommended. However, P and K recommendation are made on the basis of soil test value. In short duration pulses like urdbean, mungbean and cowpea, the fertilizer recommendation is 75% of that made for chickpea/pigeonpea.

A comprehensive study on soil fertility status in pulse growing regions showed that out of 135 districts, 87 districts were deficient (20-60%) in sulphur. Deficiency of sulphur has gradually developed in these areas due to absence of organic manures, use of sulphur free fertilizers (DAP), leaching losses and increased cropping intensity. The need of sulphur application in pulse crop was realized during early 1990s when multi-location studies under AICPIP showed good response to 20 kg S ha<sup>-1</sup>. In Frontline Demonstrations, yield improvement due to 20 kg S ha<sup>-1</sup> was up to 22% (Table 6). In many regions, response to sulphur is higher than P.

Foliar application of urea in field crops was advocated in 1960’s. However, this could not become popular due to marginal gain in yield. Several studies showed 10-15%



**Table 6.** Effect of sulphur application (20 kg ha<sup>-1</sup>) on yield of pulses (2007-08 to 2012-13)

Crop	No. of FLDs	Yield (kg ha <sup>-1</sup> )		Yield improvement (%)
		Sulphur	Control	
Chickpea	207	1736	1541	12.64
Pigeonpea	495	1323	1092	21.2
Summer/spring mungbean	144	870	733	18.69
Kharif mungbean	47	728	668	9.33
Kharif urdbean	39	833	696	19.77
Rabi urdbean	81	947	838	12.96
Spring urdbean	94	953	795	19.85
Lentil	133	1164	950	22.45
Field pea	12	1683	1374	22.53
Rajmash (Frenchbean)	46	1531	1261	21.45

Source: Singh *et al.* (2014)

yield enhancement with foliar application of 2% urea/DAP at reproductive stage under soil moisture stress (Table 7). Further, studies showed that the main reason for increase in productivity was increased N concentration in the middle leaves which made them photo-synthetically more active and thus higher seed yield (Ali 1984).

During 1980s, response of pulses to micro-nutrients like Zn (Dhingra *et al.* 1979; Saxena and Singh 1977), Mo (Mudhalkar and Ahlawat 1979) and Fe (Saxena and Sheldrake 1980) have been reported. Basal application of 15-20 kg ZnSO<sub>4</sub> ha<sup>-1</sup> has been recommended in Zn deficient soils. Basal application of 10 kg borax or 0.2% foliar spray in chickpea on calcareous and sandy alkaline soils has been found quite beneficial. Nutrient requirements for cereal-pulse rotation as well as for cereal+pulse intercrops have been worked out for different regions.

Enhancement of BNF capacity of pulses received due attention right from beginning of AICPIP. Efficient strains of *Rhizobium* have been identified and genotype-strain interaction as well as efficient mode of their application has been recommended. Dual application with *Rhizobium* culture and Phosphate solubilizing bacteria has been found quite effective. A large no. of field experiments and FLDs has shown a 10-15% increase in yield due to seed inoculation with *Rhizobium* culture. Therefore, INM in pulses should include organics, biofertilizers and mineral nutrients (Ali *et al.* 2002). In some areas, application of Fe, Mo and B have also shown good response.

**Table 7.** Effect of foliar nutrition (2% urea) in different pulse crops (2007-08 to 2012-13)

Crop	No. of FLDs	Average yield (kg ha <sup>-1</sup> )		Yield improvement (%)
		2% urea	Control	
Chickpea	261	1641	1473	11.44
Field pea	2	1295	1075	20.47
Lentil	2	1290	1075	20
Spring / Summer Mungbean	25	993	934	6.32

Source: Singh *et al.* (2014)

**Water management:** Pulses are generally grown under rainfed conditions (84%). However, they respond well to limited irrigation. Some of the pulses like *rabi* frenchbean and summer mungbean/urdbean in northern plains are cultivated under irrigated conditions. Chickpea has maximum area (35%) under irrigation in the country. Various approaches such as crop growth stage (Dastane *et al.* 1971; Saxena and Yadav 1975; Singh *et al.* 1979), IW/CPE ratio (Yadav 1975; Praharaj and Kumar 2011) and cumulative evaporation have been used in scheduling irrigations in different pulses. In field pea, 50% flowering stage was found most critical for irrigation (Panwar and Malik 1977). Similarly, in lentil and chickpea, one irrigation at the early pod filling stage was found most effective (Panwar and Paliwal 1975).

Under micro-irrigation on pulses, initial studies were conducted on sprinkler irrigation (Chandegara and Yadavendra 1998; Dabhi *et al.* 1998) in closely planted short statured legumes like chickpea and mungbean. Three sprinkler irrigations of 60 mm each at sowing time, branching time and pod formation stages were found sufficient for chickpea crop with a water saving of 44% (Chandegara and Yadavendra 1998). Sprinkler irrigation in mungbean, increased yield by 39.7% over surface irrigation and resulted in water saving of 49.8% (Velayutham and Chandrasekaran 2002). In the recent years, drip irrigation has been used in pigeonpea. At IIPR, Kanpur drip fertigation at branching or branching and pod development (with NK @ 10:10 kg ha<sup>-1</sup> in 5-10 kg splits) was found most efficient (Praharaj and Kumar 2011).

Work on application of hygroscopic polymer 'Jal Shakti' was started at IIPR during late 1980s. The furrow placement of 2 kg Jal Shakti ha<sup>-1</sup> was found economical and improve productivity of chickpea by 12% (Singh 1988).

**Integrated weed management:** Pulses on account of their initial low vigour often suffer heavily due to weed infestation. The yield losses due to weeds have been estimated to range from 30-50% in chickpea and up to 90% in pigeonpea (Saxena and Yadav 1975). Studies at IIPR, Kanpur during early 1980s showed that pre-emergence application of pendimethalin @ 1.5 kg ha<sup>-1</sup> were quite effective in frenchbean (Ali 1988). Later on, the programme was extended to other crops during late 1980s. The result showed that integrated weed management system involving pre-emergence application of pendimethalin 0.75 kg ha<sup>-1</sup> and one hand weeding at 30-40 days crop stage was most effective and economical. Therefore, most of the weed management recommendations in pulses are combination of pre-emergence herbicide and manual weeding (Balyan and Malik 1996; Singh *et al.* 2003, Kumar *et al.* 2013). Work on post-emergence herbicides was initiated under AICRP. Some of the post-emergence herbicides like quizalofop-ethyl and imazethapyr have been found quite effective in most of the pulse crops (Kumar *et al.* 2015).

**Rice fallow technology:** Of the 44 Mha area under rice, about 11 Mha remains fallow during *rabi* season due to several bio-physical, biotic and abiotic stresses and socio-economic constraints. Soil moisture is the most critical constraint for cultivation of *rabi* crops in rice fallows. Short duration pulses are considered to be the most ideal crops. Efforts have been made to identify suitable crops and varieties for rice fallows. Lentil, lathyrus and chickpea in eastern and central regions and urdbean/mungbean in peninsular

region have shown great promise. Seed priming (soaking in water for 8-10 h), enhanced seed rate (25-30%), pelleting of seeds with *Rhizobium* culture, single superphosphate and plant protection chemicals, foliar spray of 2% urea at flowering stage and spray of post-emergence herbicide (quizalofop-ethyl) have been found quite effective for establishment of desired plant population, crop growth and yield (Ali *et al.* 2014).

### CROP PROTECTION

Pulses suffer heavily due to a large no. of insect pests and diseases. Among insect pests, gram pod borer (*Helicoverpa armigera*) being polyphagous in nature causes considerable yield loss in chickpea and pigeonpea. Similarly, *Fusarium* wilt is the most widely distributed pathogen affecting chickpea, lentil, peas and pigeonpea. Host plant resistance is the best option for disease management which has been rigorously attempted and for major diseases donors as well as elite varieties are now available. For insect pests, integrated approach combining cultural, botanicals and chemicals have been advocated. Specific integrated approach for wilt and gram pod borer management has been developed.

**Integrated wilt management:** Although a large no. of varieties having resistance/tolerance to *Fusarium* wilt have been developed in chickpea, pigeonpea and lentil but due to pathogenic variability, resistance to different races/pathotypes is still awaited. Work on gene pyramiding of different races of pathogens has been started. Till multiple race/pathotypes resistant varieties are available, integrated management involving cultural (summer ploughing, intercropping of chickpea/lentil with linseed and of pigeonpea with sorghum, crop rotation), seed treatment with fungicides compatible with *Rhizobium* (carbendazim, thiram), soil application of *Trichoderma viride* alone with resistant/tolerant varieties are recommended.

**Integrated management of Gram pod borer:** Gram pod borer is the key pest causing 25-30% yield loss in chickpea and pigeonpea. Since host-plant resistance is elusive for this pest, transgenic or low-cost bio-intensive approach is the only solution. The integrated strategy involves timely sowing to exploit host-plant avoidance phenomenon, intercropping, use of trap crops (*Vicia sativa*, African giant marigold), erection of bird perches, monitoring pest occurrence through pheromone traps, spray of HaNPV and neem seed kernel extracts along with need based chemicals. There is a need to popularize IPM technology and ensure availability of pheromone traps, HaNPV and neem based products.

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## Government Initiatives for Enhancing Pulses Production in India

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### INTRODUCTION

Pulses occupy a unique position in the world agriculture by virtue of being an important source of protein (two to three times higher than cereals), fibre, vitamins and minerals and their capacity to fix atmospheric nitrogen (approx. 40 kg ha<sup>-1</sup>) and contribute to soil carbon, require less water than other crops, have greater adaptability due to inherent ability to modify with dynamic changes in environment and are environment friendly. For a developing country like India, pulses constitute the cheap and readily available source of dietary protein.

Health benefits of pulse are many faceted. Their role in global health including the reduction of non-communicable diseases such as obesity, diabetes, heart disease and neuro-degenerative disease is understated. Keeping in view the large benefits of pulses for human health, the United Nations proclaimed 2016 as the International Year of Pulses.

Despite several benefits from pulses enumerated above, about 87% of their cultivation in India is done under rainfed conditions and are mostly grown in very poor and marginal lands with minimum inputs and very little farm mechanization across various agro-ecologies of 10 major states namely Madhya Pradesh, Rajasthan, Maharashtra, Andhra Pradesh, Uttar Pradesh, Karnataka, Tamil Nadu, Gujarat, Jharkhand and Chhattisgarh, which together account for almost 90% of the total pulses production in India.

India is the largest producer, consumer and also the importer of pulses in the world. Globally, pulses are grown in more than 171 countries. India accounts for about 35% and 27% of the global area and production of pulses, respectively. About 80% of global pigeonpea, 65% of chickpea, 37% of lentil and more than 65% of mungbean and urdbean are produced in India.

There has been substantial increase in the area, production and yield of pulses in the country during the last 15 years. The area has increased by about 43% from 20.5 Mha in 2002-03 to 29.28 Mha in 2016-17, production by about 106%, means more than double from 11.13 Mt in 2002-03 to 22.95 Mt in 2016-17 and the average yield of total pulses has increased by 240 kg ha<sup>-1</sup> over this period (Fig. 1).

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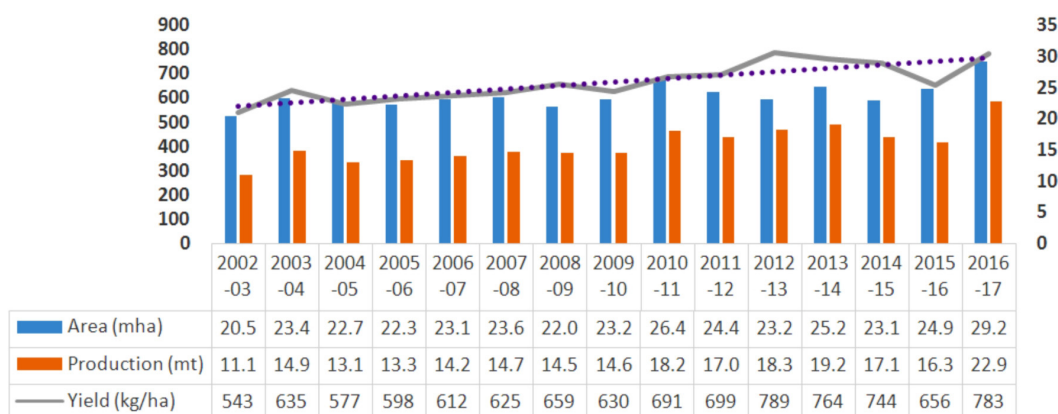


Fig. 1. Area, production and yield of pulses during the last three five-year plans (2002-03 to 2016-17)

### ORGANIZATIONAL SUPPORT FOR RESEARCH ON PULSES IN INDIA

The Indian Council of Agricultural Research (ICAR), an autonomous body under the Department of Agricultural Research and Education of the Ministry of Agriculture & Farmers Welfare, Government of India is engaged in basic and strategic research programmes on different pulses (chickpea, pigeonpea, mungbean, urdbean, lentil, lathyrus, rajmash, fieldpea, mothbean, horsegram and cowpea) at the Indian Institute of Pulses Research, Kanpur and in applied research through four All India Coordinated Research Projects (AICRPS) on Chickpea with 29 centres; Pigeonpea with 26 centres, MULLaRP (mungbean, urdbean, lentil, lathyrus, rajmash and pea) with 32 centres and Arid Legumes with 10 centres, mostly situated in the State Agricultural Universities (SAUs) across the country for developing location specific varieties and suitable production and protection technologies of the pulses.

Initiatives, current action-plans and achievements of ICAR in the development of pulses in India

**1. Pre-breeding for introgression of high yielding QTLs:** Wild species/relatives have been used for the genetic enhancement of pulse crops. The wide crosses were made to increase variation beyond parental limits and to transfer gene(s) for improvement of yield traits, biotic and abiotic stresses and developing CMS system. Interspecific crosses have been attempted in genera *Vigna* to improve mungbean and urdbean. Six varieties of mungbean and two varieties of urdbean have already been released. Efforts are under way to identify useful QTLs for economically important traits in different pulse crops.

**2. Development of climate resilient short duration, high yielding varieties in different pulse crops:** The efforts of ICAR have resulted in the release of total 307 high yielding varieties of different pulses including 59 of chickpea, 53 of mungbean, 40 each of pigeonpea and urdbean, 29 each of fieldpea and lentil and 57 of other pulses (rajmash, cowpea, horsegram, mothbean and lathyrus) have been released for cultivation during the last 15 years (2002-2016) as given in table 1. A list of varieties of pulses released during the last five years have been given in table 2.

**Table 1.** Number of high yielding climate resilient varieties of different pulses released during the last 15 years (2002-2016)

Year	Chickpea	Mung	Pigeonpea	Urd	Fieldpea	Lentil	Other pulses*	Total
2002	3	6	2	1	0	1	0	13
2003	0	1	3	4	1	1	10	20
2004	1	2	2	2	2	0	12	21
2005	2	5	1	5	3	4	6	26
2006	7	2	4	3	4	4	6	30
2007	9	4	8	1	2	1	4	29
2008	4	2	2	4	3	3	2	20
2009	3	7	3	3	0	3	2	21
2010	7	3	1	4	3	2	5	25
2011	2	1	1	2	2	3	1	12
2012	4	3	2	5	2	1	2	19
2013	3	1	3	1	0	0	0	8
2014	1	3	2	1	2	1	2	12
2015	3	2	0	1	1	1	0	8
2016	10	11	6	3	4	4	5	43
Total	59	53	40	40	29	29	57	307

\*Other pulses: Cowpea, horsegram, mothbean and lathyrus

A new extra early, photo-thermo-insensitive short duration (52-55 days) mungbean variety IPM 205-7 having average yield potential of 1.0 t ha<sup>-1</sup> has been released for the first time for cultivation as catch crop in Indo-Gangetic plains, canal command areas of central India which is also finding suitability in new delta areas of Tamil Nadu.

There has been technological breakthrough in pulses in terms of notification of high yielding pest/disease tolerant crop varieties/hybrids that have certain degree of tolerance to common abiotic stresses such as fluctuation of temperature, soil/water salinity, soil alkalinity, soil acidity *etc.* Early maturing, thermo-tolerant crop varieties with higher nutrient and water use efficiency for newer niches and cropping system have also been developed and released for cultivation.

A number of short duration (60-65 days) mungbean varieties such as Samrat, SML668, HUM 16, IPM 2-14, IPM 2-3 and IPM 99-125 are available for different cropping system and agro-ecological niches. Besides extra short duration mungbean variety IPM 205-7, there are six other similar duration varieties *viz.*, IPM 409-4, Pusa 1501, Pusa 1601, Pusa 1602, IPM 9901-8 and NBPGR 150 are under multi-location testing.

Seven short duration (110-120 days) pigeonpea lines are being evaluated in All India Coordinated Research Project (AICRP) on pigeonpea. These varieties are likely to be made available to farmers after a couple of years.

Efforts are also under way to breed short duration (100 days) varieties suitable for *rabi* rice fallows. Identification and introgression of gene(s)/QTL linked with early maturity for development of early duration genotypes through marker assisted breeding is the need of the hour. The productivity of pulses in newer areas such as catch crop after

**Table 2.** Year wise and crop wise list of varieties of pulses released during 2012-2016

Pulse crops (90)	Varieties/hybrids released				
	2012 Total (19)	2013 Total (8)	2014 Total (12)	2015 Total (8)	2016 Total (43)
Chickpea (21)	HK-4, PKV Harita, Raj Vijay Gram 203, L-555	GNG 1958, GNG 1969, NbeG 3	JG-12	Bidisha (BG 1084) Vallabh Kabuli Chana-1, Raj  Vijay Gram 202	Pusa 3022 (BG); PBG7 (GL 26054); Aman (CSJ-515); Nandyal Gram 119; Teej (GNG-2144); JGK-5;  BDNGK 798; GBM 2, Gujarat Junagadh Gram 6; Jawahar Gram 36
Mungbean (20)	Swati, MH-421, BM 2003-2	SML 832	MH 421; DGGV-2; BGS-9 (Somnath)	CO 8 Shalimar Moong-2 (SKUAM- 300)	MH 318; Utkarsh (KM-11- 584); Yadadri (WGG-42); Sri Rama (MGG351); GBM-1; IPM 410-3 (Shikha); IPM 205-7 (Virat); SML-1115; MSJ 118 (Keshwanand Mung 2); ML 2056; RMG 975 (Keshwanand Mung 1)
Urdbean (11)	Vishwas, VBN 6, UH-1, DU-1, TU 40	Pratap Urd-1	DBGV-5	Vallabh Urd-1,	Indira Urd Pratham (RU 03- 14); LBG 787 (Tulasi); PDKV Blackgold (AKU 10-1);
Pigeonpea (13)	Anand Grain Tur-2, BDN 711	Rajeshwari, Rudreshwar PKV TARA	BRG-4 (BRG 10-2); ICPH 2671 (Hybrid)		Prakash (IPA 203); Gujarat Junagadh Pigeonpea-1 (GJP- 1); Ujwala (PRG 176); Mannem konda Kandi (ICPH 2740); GT-102; BRG 5
Lentil (7)	IPL-316	-	Raj Vijay Lentil 31 (JL 31)	Shalimar Masoor-2 (SKUA-L9)	KLB 2008-4 (Krati); KLS-09- 3 (Krish); RLG-5 (Keshwanand Masoor-1); IPL 526
Field pea (9)	HFP 529, Gomati	-	IPFD 10-12; HFP 715	Shalimar Pea-1 (SKUA-P-8)	Indira Matar 1 (REP 2009-1); Central Field pea IPFD 11-5; IPFD 6-3; RFP 4 (Keshwanand Matar 1)
Cowpea (4)	MFC-08-14	-	DCS 47-1		Pant Lobia -3 (PGCP -6), Phule Vithai (Phule CP- 05040)
Horse gram (5)	Gujarat Dantiwada Horsegram-1	-	CRIDAH ARSHA (CRHG 19)		Pratap Kulthi-2 (AK 53); CRIDAVARDHAN (CRHG-22); Phule Sakas (SHG 0628-4)

harvest of wheat, mustard and potato; rice fallows in peninsular and eastern India has been given due attention.

**3. Harnessing heterosis in pigeonpea to increase its yield by 30-40%:** Development of short duration parental lines for synthesizing high yielding hybrids in pigeonpea is being pursued. Nine short duration (140 days) pigeonpea hybrid are under evaluation. About 5000 q hybrid seed of three medium duration pigeonpea hybrids namely ICPH 2671, ICPH 2740 and ICPH 3762 distributed to farmers during *kharif* 2016 and 14400 q hybrid seeds of these hybrids are being produced for distribution during *kharif* 2017. Large-scale demonstrations of these hybrids have been taken up.

**4. Varieties for mechanical harvesting:** In order to bring mechanization in pulses, efforts are under way to breed suitable cultivars with improved standability and podding at appropriate height for mechanical harvesting. Chickpea varieties HC 5, GBM 2 and NBeG 47 suitable for mechanical harvesting have been developed. These varieties are being popularized. Promising lines of chickpea namely RVSSG 8102 and RVSSG 48 are under advance stage of testing.

**5. Genomics in pulses for drought and heat and durable resistance to major diseases:** Terminal heat and drought stress are major constants in *rabi* pulses leading to force maturity and reduced yield. Hot spot QTLs imparting heat and drought tolerance have been identified in chickpea. Most popular short duration chickpea variety JG 11 has been introgressed with this QTL from ICC4958.

The improved JG 11 is proposed for multi-location evaluation during *rabi* 2016-17. Mapping population involving heat responsive genotypes including JG 14, ICC 12155, EC 556270, ICC 15614 (heat tolerant genotypes) and BG 256, Pant-G-114 (heat sensitive genotypes) for identification of genomic regions (QTLs) governing heat tolerance in chickpea is being developed.

Transcriptome dynamics in heat stress responsive genotypes will be studied. This will lead to development of heat tolerant chickpea varieties for various regions of country. Marker assisted backcrossing to transfer resistance to multiple races of *Fusarium* wilt in elite chickpea and pigeonpea cultivars, besides identification QTLs/ genes conferring desirable traits using putative associated markers, candidate R gene based markers and SSR markers.

Efforts were made to map and tag the MYMV resistant gene in blackgram. Molecular marker CEDG 186 has been employed to marker assisted breeding for MYMV resistance in blackgram.

**6. Developing transgenics against pod borer in chickpea and pigeonpea:** Pod borer in chickpea and pigeonpea is a most devastating pest causing severe yield losses. Development of transgenics is the only option to manage this polyphagous insect as the resistant sources are not available. Efforts were made to develop transgenic resistant to pod borer.

A total of five pod borer resistant transgenic lines of pigeonpea comprising of two transgenic lines having *cryIAabc* and three lines having *cryIAc*, have been developed.

These lines expressed 90-100% larval mortality under bioassay in contained conditions. Similarly, five transgenic lines comprising of two transgenic lines having *cryIAabc* and three lines having *cryIAc*, have been developed in chickpea which have 85-90% larval mortality under contained conditions.

All these lines (five in pigeonpea and five in chickpea) have been proposed for event selection trial in coming season and application has already been submitted to Review Committee on Genetic Manipulation (RCGM).

**7. Allele mining and proteomics for MAS under biotic and abiotic stress:** Allele mining of drought responsive factors (DRFs) gene was done to identify alleles for enhanced drought tolerance in chickpea and pigeonpea, based on draft genome sequence. Genotypes were selected from mini core and core set for prospecting alleles of two DRF genes.

Marker assisted selection (MAS) was employed to transfer genes/QTLs for abiotic stress (drought QTLs hotspot) and biotic stress (transgenic chickpea line harboring *Bt-cry2Aa*) from donor to elite cultivars of chickpea.

Thirteen BC<sub>3</sub>F<sub>3</sub> “*QTLs hotspot*” introgressed chickpea (DCP 92-3) lines for drought tolerance by employing linked flanking SSR markers (NCPGR21, TR11 and ICCM0246) were developed.

**8. Intensifying conservation agriculture for increased yield:** Conservation agricultural practices of pulse based cropping systems are being developed in order to increase system productivity and reducing cost of cultivation.

In a permanent raised bed system under maize-chickpea has shown higher nodulation, crop growth and yield (15-25%) over conventional tillage. Similar results were also recorded in conservation tillage in chickpea and lentil after harvest of rice. Under rainfed rice-fallows conditions, following of conservation tillage (zero tillage + residue retention) after harvest of rice has shown yield advantage of 15-35% in lentil, chickpea and urdbean in different parts of the country.

The improvement in soil physicochemical as well as biological properties (microbial biomass carbon, dehydrogenase activity) was also recorded under conservation tillage over zero tillage or conventional tillage.

**9. Life-saving irrigation to enhance the productivity in rainfed areas:** Micro-irrigation management in summer mungbean improved seed yield by 31% along with water saving of 11% and WUE enhanced by 43.2% under precision tillage by laser leveller.

A single drip irrigation cum fertigation with half of N+K fertilizer at branching enhanced grain yield of rainfed pigeonpea variety ‘Narendra Arhar-1’ by 20% in eastern Indo-Gangetic Plains (IGP) in comparison to rainfed pigeonpea.

Drip-fertigation in pigeonpea + urdbean intercropping enhanced pigeonpea grain yield by 14 per cent over the sole crop due to efficient utilization of water and nutrients. Micro-irrigation system is getting popular in the states of Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Maharashtra and Gujarat.

**10. Use of PGPR to enhance productivity:** PGPR improves symbiotic efficiency for N fixation, P availability, increases tolerance to biotic stress and promotes plant health. Synergistic effect of ACC deaminase producing bacterial strains like IIPR-ACC-68 and IIPR-ACC-16, and IIPR-ACC-10 enhanced nodulation and grain yield of chickpea and lentil, up to 15 per cent higher than un-inoculated control.

Interactions among *Piriformospora indica* and potential PGPR strains namely, *Pseudomonas argentinensis* (LPGPR1), *Pseudomonas* sp. (LPGPR2) along with *Pseudomonas* sp. (LK884) and *Mesorhizobium cicerii* (LGR33, MR) had synergistic effect on improving growth, symbiotic efficiency, nutrient acquisition and yield of chickpea.

**11. Breeder Seed Production Programme:** ICAR is the custodian of the breeder seeds of pulses in the country and all the matters regarding seeds of pulses are monitored under Seed Act 1966 of the Government of India. The varieties / hybrids recommended by agricultural research system for cultivation on commercial scale are notified by Central Varietal Release Committee / State Varietal Release Committee for the production of certified seed on large scale for distribution among the growers.

After the notification of a variety based on the demands of various states, DACFW submits indent for breeder seed of different varieties of pulses and ICAR through its AICRP network in the state agricultural universities produces the required quantity and supplies to different seed producing agencies so that quality seeds of improved varieties could be made available to the farmers for cultivation and boost the production of these crops.

Details of indent and production of breeder seed of pulses varieties during the last three five year plans (2002-03 to 2016-17) have been given in table 3.

## **12. Frontline Demonstrations on Pulses Programmes**

Scientists of all the centres of All India Coordinated Research Projects on Pulses have been regularly organizing frontline demonstrations on improved variety and production technology of pulses to receive farmers' feedback and creating awareness among them about the new technology.

A number of varieties and production technology of pulses have proven their potential in the frontline demonstrations (FLDs) at the farmers' fields organized by the ICAR institutes, SAUs and KVKs and sponsored by the DAC&FW. It has been demonstrated that adoption of improved varieties of pulses alone can increase the productivity of pulses by about 15% and the package can increase up to 34% (Table 4).

It is estimated that by bridging this whole package productivity gap of 34% at the farmers' fields, the national pulses production can be increased by 6 million tonnes without bringing any additional area under the pulses and that would be enough to make the country self-sufficient in pulses for the time being. In other words, our country needs to raise the pulses' national productivity up to 1000 kg ha<sup>-1</sup>.



**Table 3.** Breeder seed of pulses indented and produced during the last three five year plans (2002-03 to 2016-17)

Year	Indent by DAC&FW (q)	Production by ICAR (q)
2002-03	4696	6573
2003-04	4764	6746
2004-05	4968	7121
2005-06	5536	6865
2006-07	7349	9383
X plan total	27313	36688
2007-08	9948	11234
2008-09	12268	13585
2009-10	11700	13155
2010-11	12944	15360
2011-12	14303	16656
<b>XI plan total</b>	<b>61163</b>	<b>69990</b>
2012-13	14155	14430
2013-14	12341	12128
2014-15	10427	10817
2015-16	10488	11312
2016-17	18019	20578
<b>XII plan total</b>	<b>65430</b>	<b>69265</b>
Grand total of last three plans	153906	175943

**Table 4.** Productivity gap in pulses at the farmers' fields under frontline demonstration programme

Crop	Average yield in FLD (kg ha <sup>-1</sup> )	Average yield of state (kg ha <sup>-1</sup> )*	Productivity gap over state average yield (%)
Chickpea	1517	1143	33
Pigeonpea	1433	1018	41
Mungbean	1044	787	33
Urdbean	1380	946	46
Lentil	1667	989	69
Field pea	1550	1212	28
Total Pulses	1414	1055	34

\*The average yield of chickpea and urdbean in AP, pigeonpea in Gujarat, rabi/spring mungbean and pea in UP and lentil in Bihar

#### CENTRAL GOVERNMENT'S PROGRAMMES AND INITIATIVES FOR PULSES DEVELOPMENT IN INDIA

The Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW) of the Ministry of Agriculture and Farmers Welfare, Government of India is the nodal agency in the country to monitor progress of sowing of field crops in each season, weekly crop situation in the country, keep watch on impact of adverse weather conditions and insect-pests, diseases on crops and issue advisories to states from time to time and finally fix production targets of individual crop production. The Directorate of Pulses Development at Bhopal, is one of the crop development directorates, for the development of pulses in the country.

Keeping in view the necessity of meeting the ever increasing domestic demands for pulses, the main source of protein particularly for the rural mass, various programmes have been launched during various five-year plan periods. A centrally sponsored “Pulses Development Scheme” was initiated in 1970 during the IV plan period with the aim to introduce improved varieties and production technologies amongst the farmers.

The National Pulses Development Project (NPDP) which merged with the earlier Centrally Sponsored Scheme on pulses has been a boon for the farming communities when the Ministry of Agriculture & Farmers Welfare, Government of India launched it from the VII plan (1984-85 to 1989-90) onwards. In order to supplement the efforts under NPDP, a Special Food Grain Production Program (SFPP) on Pulses was also implemented during 1988-89 on a 100% Central assistance basis.

The Technology Mission on Oilseeds was launched during 1986 by the Central Government to increase the production of oilseeds, to reduce import and to achieve self-sufficiency in edible oils. Subsequently, pulses, oil palm and maize were also brought within the purview of the Mission during 1990-91, 1992 and 1995-96, respectively. It is worth mentioning that under the Government of India-UNDP co-operation (1997-2003), pulses sector was identified as priority sector to be strengthened.

The schemes implemented under Technology Mission are Oilseeds Production Programme (OPP), National Pulses Development Project (NPDP), Accelerated Maize Development Programme (AMDP) and Oil Palm Development Programme (OPDP) and have been merged into one Centrally Sponsored Integrated Scheme of Oilseeds, Pulses, Oil palm and Maize (ISOPOM) from April 2004 and the financial assistance was provided for purchase of breeder seeds, production of foundation seeds, production and distribution of certified seeds, seed minikit, plant protection chemicals and equipment, weedicides, *etc.* to encourage farmers to grow oilseeds and pulses. Subsequently, DAC&FW implemented several developmental programme for pulses in the country, which are described below.

### **1. National Food Security Mission – Pulses**

National Food Security Mission – Pulses (NFSM-Pulses) is one of the components of the centrally sponsored scheme of National Food Security Mission and is implemented by the Department of Agriculture, Cooperation and Farmers Welfare of the Ministry of Agriculture & Farmers Welfare, Government of India since *rabi* 2007- 08. This mega scheme has the objectives: i) restoring soil fertility and productivity at individual farm level, ii) creation of employment opportunities, iii) enhancing farm level economy to restore confidence among the farmers, and iv) creating awareness about the use of improved seed and crop production technology.

The programme began implementation with 100% funding from the Government of India in 16 major pulse producing states of the country including Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. The Indian Council of Agricultural Research (ICAR) and its institute namely Indian

Institute of Pulses Research, Kanpur and two international institutes like International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and International Center for Agricultural Research in the Dry Areas (ICARDA) have been associated with the implementation of the mission since very beginning. The NFSM-Pulses component has undergone a number of changes since its inception and finally has taken the shape of sole centrally sponsored scheme on pulses covering all the 638 districts of 29 states of the country.

### Activities

- Cluster demonstration: (cafeteria of interventions within Rs. 7500 for pulses);
- Seed distribution (Rs. 25 kg<sup>-1</sup> for pulses);
- Micronutrient (zinc, boron @ 50% of the cost limited to Rs. 500 ha<sup>-1</sup>);
- Biofertilizers (*Rhizobium*, PSB @ Rs.300 ha<sup>-1</sup>);
- Soil ameliorants (lime or liming material @ 50% of the cost of material limited to Rs. 750/- ha<sup>-1</sup> for gypsum and Rs. 100 ha<sup>-1</sup> for lime and liming material);
- Plant protection measures (weedicides, pesticides, bio-agents @ Rs. 500/- ha<sup>-1</sup> or 50% of the cost);
- Farm machineries and implements (rotavator, multi-crop planter, seed drill, zero till seed drill, sprayer, ridge furrow planter, thresher);
- Irrigation devices (rain gun, sprinkler, pump set, water carrying pipes);
- Custom hiring charge (Rs. 1500 ha<sup>-1</sup>);
- Capacity building of farmers (cropping system based training);
- Local initiatives (mini *dal* mills, water harvesting structure, storage (50% of the cost for individual farmer and 100% for Government Institutions).

The average production of total pulses during XI plan was 15.86 Mt and the NFSM-Pulses targeted additional production of 4 Mt by the end of XII Plan in 2016-17. As a matter of fact, the country has produced 22.95 Mt pulses, which is 7.09 Mt additional over the XI Plan average.

## 2. Accelerated Pulses Production Programme (A3P)

This programme has been implementing since *kharif* 2010-11 with the objectives to demonstrate plant nutrient and plant protection centric technologies and management practices in compact units of 1000 ha each for five major pulses *viz.*, gram, pigeonpea, urdbean, mungbean and lentil. The DAC&FW implemented this programme in 196 districts of 16 states of the country in association with ICAR institute namely National Centre for Integrated Pest Management (NCIPM), New Delhi. Andhra Pradesh (14), Assam (10), Bihar (13), Chhattisgarh (8), Gujarat (11), Haryana (5), Jharkhand (15), Karnataka (13), Madhya Pradesh (20), Maharashtra (18), Odisha (10), Punjab (7),

Rajasthan (16), Tamil Nadu (12), Uttar Pradesh (19) and West Bengal (5). The figure in parenthesis indicated number of districts covered.

The programme was 100% funded by the Government of India and an allocation of Rs 308.28 crores was made for 2010-11. A financial assistance of Rs.5400, Rs.4800, Rs.4800, Rs.5600 and Rs.5000 was provided for conducting A3P demonstrations in respect of pigeonpea, urdbean, mungbean, gram and lentil, respectively. The items of A3P unit included seed minikit, gypsum, micronutrient (zinc sulphate, borax, ferrous sulphate, and micronutrient mixture), *Rhizobium* culture, PSB culture, urea (foliar spray), fungicide for seed treatment, insecticide / fungicide / bio-agent (NPV), bio-pesticide, weedicides and e-pest surveillance.

### **3. Special initiatives for pulses and oilseeds in dryland areas of 60000 villages programme**

The DAC&FW took a special initiative in 2010-11 under Rashtriya Krishi Vikas Yojna (RKVY) to provide services of mechanization on custom hiring basis, especially for soil preparation and sowing for improving production and productivity of pulses and oilseeds in 60000 villages of seven states namely Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh with 100% funding by the Government of India. Rs.300.00 crores was allocated for 2010-11.

#### **Activities**

- Ensuring timely land preparation and planting of the crops on ridges so as to facilitate *in-situ*-water conservation in watershed.
- Under this approach, a set of implements such as tractors, rotavator and ridge furrow planter along with some working capital at 6000 designated watershed centric locations were provided during 2010-11 to a nominated agency for providing custom hiring services to pulses and oilseeds growers of adjoining 10 villages in a hub and spoke model covering 60, 000 villages.

### **4. Integrated Development of 60000 Pulses villages in Rainfed Areas**

This programme was launched in 2011-12 with the objective to increase production and productivity of pulse crops by disseminating latest production technologies at the farmers' field. The DAC&FW implemented this programme through Commissioners / Directors of Agriculture of 11 states namely Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu and Uttar Pradesh. The programme was 100% funded by the Government of India.

#### **Activities**

- Conducting large scale demonstration on A3P pattern for eight pulses (gram, pigeonpea, mungbean, urdbean, lentil, rajmash, fieldpea and mothbean);
- Construction of farm pond with or without lining and lining of old farm ponds;

- Market linked supply chain by organizing pulses farmers into farmer producer organization;
- Small Farmers' Agribusiness Consortium (SFAC) was assigned the responsibility of organizing the farmer producer organizations and establishing this chain.

### **5. Special Plan to achieve 19+ Mt of Pulses production during *kharif***

This Special Plan to achieve 19+ Mt production of pulses was launched in 2012-2013 with the objective adding new areas under pulses through intercropping, improving planting techniques and irrigation use efficiency for inclusive water management and use of important critical but low cost inputs like sulphur and weedicides and productivity boosters. The DAC&FW implemented this special plan through Commissioners / Directors of Agriculture of eight states namely, Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Karnataka, Madhya Pradesh, Odisha and Rajasthan in their respective areas with 100% funding by the Government of India.

#### **Activities**

- Intercropping of pigeonpea/ urdbean/ mungbean/ mothbean with cotton/ oilseeds/ maize/ sorghum/ pearl millet;
- In-situ moisture conservation (ridge and furrow);
- Critical inputs/plant growth regulators/nutrient mixtures.

### **6. Additional *Rabi/ Summer* Pulses Area Coverage Programme**

In order to enhance the production of pulses, this programme was launched in 2012-13 under NFSM-Pulses Scheme of the Ministry of Agriculture & Farmers Welfare, Government of India with the objective to occupy additional area under pulses during *rabi/summer* 2012-13. The DAC&FW implemented this special plan through Commissioners / Directors of Agriculture of 15 states namely, Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Haryana, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal in their respective areas with 100% funding by the Government of India.

#### **Activities**

- Distribution of certified seed, integrated nutrient management, integrated pest management, water carrying pipes, plant protection chemicals and A3P demonstrations.

### **7. Macro Management of Agriculture (MMA)**

This programme was launched in 2001-02 and continued till 2012-13 with the objective to accelerate the productivity of major crops including pulses in the areas, not covered in other schemes. The DAC&FW implemented this programme through Commissioners / Directors of Agriculture of respective states with 90:10 funding pattern between Central and State Governments.

### Activities

- Additional production of breeder seed, foundation and certified seed;
- Distribution of certified seed;
- Distribution of seed minikit;
- Strengthening of SSCA, integrated nutrient management, integrated pest management *etc.*

### 8. Some Recent Initiatives

The Ministry of Agriculture and Farmers Welfare, Government of India has taken several initiatives in the year 2016-17 for making the country self-sufficient in terms of pulses production. The ICAR and DAC&FW under Ministry of Agriculture & Farmers Welfare, Government of India are jointly working on a road map to achieve production of 24 Mt pulses in 2020-21 with a comprehensive action plan under centrally sponsored scheme of National Food Security Mission (NFSM). The new initiatives are distribution of seed minikits of newer varieties of pulses free of cost to farmers, creation of seed hubs for production of quality seed, cluster frontline demonstration ICAR's KVKs and enhancing breeder seed production.

The ICAR is implementing a NFSM project to establish 150 seed-hubs on pulses in the country for augmenting the availability of quality seeds of pulses to the farmers. The project has made a good headway as already 98 seed-hubs have started producing quality seeds. Each seed-hub has been given a target of supplying minimum 1000 q quality seeds of different pulses annually by 2018-19.

Under new initiative, ICAR is also implanting another NFSM project on additional breeder seed production of suitable and popular varieties of pulses at 12 locations in the country to produce an additional quantity of 3717 q breeder seed by the end of 2016-17 and cumulative 5801 q by the end of 2018-19 over and above the existing level of breeder seed production in pulses.

Cluster demonstrations on improved technology of pulse by ICAR's Krishi Vigyan Kendra (KVK) is also a new initiatives. As a pilot project of NFSM, about 300 Krishi Vigyan Kendras (KVKs) of ICAR demonstrated the productivity potential of latest varieties and management technologies of *rabi* pulses through 33657 demonstrations in about 13462 ha area during *rabi* 2015-16 with a budget outlay of Rs. 12.0 crore. During 2016-17, total 524 KVKs of ICAR will organize 77500 demonstrations in 31000 ha area with enhanced budget outlay of Rs. 25.6 crore.

Another very good NFSM project for establishing and strengthening of production and supply units of *Rhizobium* biofertilizer and *Trichoderma* bio-control agent across the country for increasing indigenous production of pulses is under active consideration of the government. This will ensure sustainable production of pulses, maintaining good soil and plant health by application of *Rhizobium* biofertilizer and *Trichoderma* bio-agent for controlling wilt and other root diseases of pulses.



Efforts have been made by the Ministry of Agriculture & Farmers Welfare to promote the package of practices for pulses through all possible channels such as website of ICAR-IIPR, ICAR website, Seednet, DAC&FW website, websites of state Government, NSC, m-kisan portal, Kisan channel, Facebook, twitter, DD Kisan and ICAR's Division of Crop Science and Agricultural Extension Division.

In order to facilitate remunerative price of pulses to the farmers through procurement at MSP and making pulses available to consumers at reasonable price, the government launched Price Stabilization Fund (PSF) Scheme during last year for the first time creating a buffer stock of around 20 lakh tonnes of pulses. This intervention motivated the pulse growing farmers and aided with favourable monsoon the country achieved an all-time high record production of pulses (22.95 Mt in 2016-17), enabling the Government to create a buffer stock to ensure a fair market price for the consumers.

During International Year of Pulses 2016, several seminars, symposiums, conferences and brain storming sessions were organized by a number of Government institutions and NGOs and a lot of researchable, technological, administrative and policy related recommendations were made. All these recommendations were deliberated by different stakeholders at Agra in December, 2016 and a short list of filtered, precise and workable recommendations came out, which if pursued earnestly by the concerned stakeholders may lead us to sustainable production of pulses in the country to the level of self-sufficiency in near future.

#### **SOME AREAS OF CONCERN**

- The conversion of entire breeder seeds up to certified seeds is a very-very important and big issue for ensuring the availability of quality seeds to the farmers. Several times, indented breeder seeds are not lifted by the states and many times even if they lift, multiplication of breeder seeds into foundation and certified seeds are not done by them, thus seriously hampering the entire seed production process.
- Release of funds through state treasuries leading to delayed disbursement of funds and inadequate field staff in states are two important issues which may affect the success of the central sector schemes and initiatives for enhancing pulses production in the country.

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