



Silent revolution in pulses production – India marching towards self-sufficiency

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ABSTRACT

Globally, India is known to have largest share in acreage and production of pulse crops. At the same time, it is also a largest consumer and processor of pulses in the world. More than a dozen pulse crops are grown across the countries out of which six are major ones. Recently, India has witnessed a silent ‘Pulses Revolution’ whether to say or not but fact is that during 2017–18, the pulse production of 25.23 million tonnes (mt) is 5.98 mt more over 2013–14 (19.25 mt) and by 2.10 mt over 2016–17 (23.13 mt). There has been positive trend in area, production and productivity of pulse crops during last 3 consecutive Five Year Plan periods. This clearly indicates that an indigenous production has not only increased but sustaining as well and India is silently marching towards self-sufficiency in pulses. While the “Green Revolution” that was declared in 1968 when wheat and rice production increased by 4.15 mt and 6.17 mt, respectively in 1967–68 over 1966–67. Pulses revolution could happen due to development of science-led technologies and policy initiatives on similar lines as cereal revolution happened then in late sixties. Pulses revolution has distinction as it is led by the indigenous technologies developed by our research based institutions and then spread across the country. The realized pulses revolution is indigenous, wide spread, environment friendly, sustainable and a step towards ensuring food and nutritional security of the country.

Key words: High yielding varieties, Policies, Pulses revolution, Self-sufficiency, Technologies

India has distinction of having largest acreage, production, processing and consumption of pulses in the world (Kumar *et al.* 2018, Rana *et al.* 2018). In India, more than a dozen of pulse crops are grown in different seasons depending upon the agro-climatic conditions and their local preference for a particular pulse crop. In eastern India, the lentil, pigeonpea and lathyrus; in central India, chickpea, and pigeonpea; and in southern parts of India mungbean and urdbean crops have local preference over other pulse crops. Major pulse crops are chickpea (*Cicer arietinum*), pigeonpea (*Cajanus cajan*), lentil (*Lens culinaris*), mungbean (*Vigna radiata*), urdbean (*Vigna mungo*) and fieldpea (*Pisum sativum*); and other minor pulses include moth bean (*Vigna aconitifolia*), rajmash (*Phaseolus vulgaris*), lathyrus (*Lathyrus sativus*), faba bean (*Vicia faba*), horse gram (*Macrotyloma uniflorum*) and lablab bean (*Lablab purpureus*). Pulses are grown as solo, intercrop, mix; catch/cover crops and fit well in a number of cropping systems (Choudhary *et al.* 2015, Rajpoot *et*

al. 2018, Rana *et al.* 2018). Pulses are integral part of Indian daily diet and are main sources of protein for largely vegetarian Indians. Besides high protein content, pulses are also source of quality fibre and provide ample quantity of vitamins and minerals (Babu *et al.* 2014, Prasad *et al.* 2016). Keeping in view large benefits of pulses for human health, the United Nations proclaimed 2016 as the ‘International Year of Pulses’. Due attention was paid by the Government of India to enhance the production of pulses not only to meet the dietary requirement of the protein but also to raise the awareness about pulses for achieving nutritional, food security and environmental sustainability. Pulses are important components to sustain the agricultural production base as the pulse crops possess wider adaptability to fit into various cropping systems, improve the soil fertility being leguminous in nature and physical health of soil while being used as green manure and making soil more porous due to deep tap root system (Pooniya *et al.* 2015, Varatharajan *et al.* 2019). Considering the importance of pulses for maintaining human and soil health, several promotional schemes to boost pulses cultivation were initiated by the Government of India for pulses research and development (Choudhary *et al.* 2014, Singh *et al.* 2016, Sandhu and Chaturvedi 2018). Continuous efforts of the Government of India paid dividends and India moved towards attaining self-sufficiency in indigenous production of pulses with technologies

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developed by National Agricultural Research and Education System (NARES). It is worthwhile mentioning here that during 2016-17, pulses production touched new peak of 23.13 mt surpassing earlier record of 2013-14 of 19.25 mt by 3.88 mt and again during 2017-18, the pulses production reached to the level of 25.23 mt which is 2.10 mt more than the production of 2016-17 and 5.98 mt over 2013-14. The quantum increase in pulses output during last few years can certainly be termed as 'Pulses Revolution' in India which is helping in saving precious foreign exchange from import.

Retrospection of pulses production in India

Indian farmers are growing a variety of food grains crops which include mainly rice, wheat, coarse cereals, millets, maize and pulses and produced 284.83 mt (2017-18) of food grains which is higher by 9.72 mt in comparison to previous record production of food grains of 275.11 mt achieved during 2016-17 breaking all previous records. During same time (2017-18), total pulses production also attained new height when it reached to 25.23 mt (4th Advance estimates: http://agricoop.gov.in/sites/default/files/pulses_oct.pdf) and is again higher by 2.10 mt than the previous year's record of 23.13 mt of 2016-17 and by 5.98 mt more in comparison to previous record of 19.25 mt of 2013-14. India has witnessed positive trends in acreage, production and productivity of pulses during 3 consecutive five year plan periods (Table 1).

India has witnessed positive trends in acreage, production and productivity of pulses during 3 consecutive five year plan periods (Table 1). Between X and XII Plan periods significant increase in total pulses area (23.6%), production (45.5%) and productivity (27.4%) was recorded and this positive growth continued during 2017-18 also indicating sustainability of the technologies and policy support. The long term trends based on average for decade in area, production and productivity indicate slow growth in pulses sector during early 30 years from 1951 to 1980 because during this period major emphasis was on cereal crops mainly on wheat and rice (Fig 1).

Later, landmark decision of Indian Council of Agricultural Research (ICAR) in 1967 to launch an umbrella project 'All India Coordinated Pulses Improvement Project-AICPIP' for the improvement of pulses systematically led in positive growth in area and production. However, this growth could not be sustained when highly remunerative dwarf varieties of wheat and rice became popular and

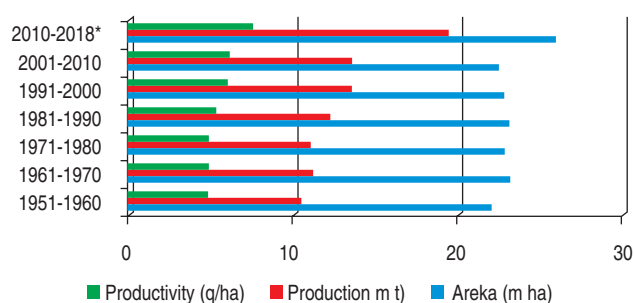


Fig 1 Long term trends in area, production and productivity of total pulses in India.

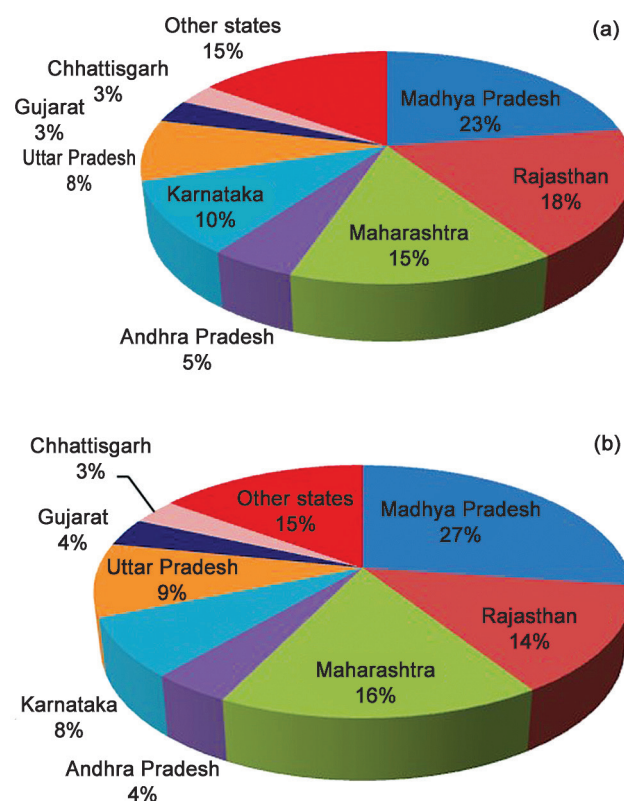


Fig 2 (a) Share (%) of state in total pulses area (2016-17); (b) Share (%) of state in total pulses production (2016-17).

Table 1 Area, production and productivity of total pulses

Period	Area (mha)	Production (mt)	Yield (kg/ha)
X Plan	22.46	13.35	594
XI Plan	23.97	15.86	661
XII Plan	25.28	18.85	745
2017-18*	29.39	25.23	858

*Fourth Advance estimates

country realized 'Green Revolution'. As a consequence, the pulses were pushed from high fertile zone (North India) to comparatively low fertile zone (Central and South India). As per need of new niches, the research efforts resulted in development of short duration varieties of major pulses particularly of chickpea which resulted in marginal increase in production and productivity of pulses during 1971-90. During next 20 year (1991-2010), the pulses sector witnessed positive growth in production and productivity though the pace remained quite slow (Fig 1). This could happen due to positive policy support and growth in research network for pulses, keeping in view more targeted efforts the All India Coordinated Pulses Improvement Project (AICPIP) was trifurcated in 1993 into three All India Coordinated Research Projects (AICRPs), i.e. one each on chickpea (AICRP-Chickpea); pigeonpea (AICRP-Pigeonpea); and

mungbean, urdbean, lentil, lathyrus, rajmash and pea (AICRP-MULLaRP) besides creation of Network project on Arid-Legumes. The Directorate of Pulses Research (DPR) was also upgraded to the level of ICAR-Indian Institute of Pulses Research to emphasize more on basic and strategic research. Later, during last 8 years (2010-2018) several policy and technological interventions were implemented and as a result impressive growth could be realized in pulses sector in terms of area, production and yield and India attained self-sufficiency in indigenous pulses production. It is worthwhile mentioning that during 2016-17 total pulses production was 23.13 mt and it further increased to 25.23 mt during 2017-18. Madhya Pradesh (23%), Rajasthan (18%), Maharashtra (15%), Karnataka (10%), Uttar Pradesh (8%), Andhra Pradesh (5%), Gujarat (3%) and Chhattisgarh (3%) are major pulses growing states covered 85% of the total pulses area (Fig 2a) in India during 2015-16. During same year, Madhya Pradesh (27%), Maharashtra (16%), Rajasthan (14%), Uttar Pradesh (9%), Karnataka (8%), Andhra Pradesh (4%), Gujarat (4%) and Chhattisgarh (3%) contributed about 85% to the total pulses production (Fig 2b). There is vast scope to further increase area in rice fallow and to enhance productivity in states like Bihar, Odisha, Jharkhand, Tamil Nadu and North East Hill states (Singh *et al.* 2016).

Science led Technology developments

Major research achievements made in terms of development of high yielding varieties insulated against major biotic and abiotic stresses, integrated crop management technologies including diseases, insect pests, weeds and production technologies that have paved the way for realizing higher productivity from per unit area cultivation in India (Pooniya *et al.* 2015, Varatharajan *et al.* 2019). These have been summarized in following paragraphs for better understanding of the contributions of technologies generated by NARES and adopted by Indian farmers in recent years for increasing pulses production.

High yielding varieties: More than 510 varieties of

different pulses were developed under ambit of NARES which includes Institutes belonging to Indian Council of Agricultural Research (ICAR) and Agricultural Universities (Sandhu and Chaturvedi, 2018) working under aegis of AICRPs. To break desired productivity barriers, efforts were made to broaden genetic base of pulses varieties (Kumar *et al.* 2008, Rana *et al.* 2016). To diversify the genetic base emphasis were laid on interspecific hybridization in mungbean, urdbean, pigeonpea, chickpea and lentil. These efforts resulted in development of a number of varieties/advance breeding lines. Desi × kabuli introgressions in chickpea led in development of a good number of high yielding varieties possessing wider adaptability. Details of varieties developed of different pulse crops during 2008-2017 are given in Table 2. These varieties are adopted by the farmers to improve yields (Chaturvedi *et al.*, 2014). Though new releases have been included in seed production chain but about 50 mega varieties of various pulses are occupied major area and still quite popular with farmers. The recently established 150 Seed-Hubs will be as act as catalyst in fast spread of newly developed varieties and back up for continue supply of quality seed of these varieties.

Short duration varieties: Development of early maturing varieties of major pulse crops has opened doors for crop intensification and diversification as sole, intercrops and mixed crops in sequential cropping systems or for consumption as vegetable (Sandhu *et al.*, 2002). Some of the recently developed short duration varieties of different crops such as in chickpea JG 14, RSG 963, RVG 202, RVG 203, Pusa 547, Rajas, RSG 991, RSG 974, JAKI 9218, KAK 2, Shubhra and Ujjawal; lentil IPL 81, IPL 316, JL 3, JL 31 and L 4147; fieldpea Ambika, DDR 23, Prakash, Vikas, IPFD 10-12; pigeonpea PAU 881, Pusa 992 and Pusa 16; mungbean Virat, Shikha, IPM 2-14, Samrat, IPM 2-3, HUM 16; and urdbean Pant U 31, Pant U 40, Pant U 35, Shekhar 2, Azad Urid 3 etc. are worth mentioning. LGG series of urdbean varieties could bring improvement in area and production of this crop in coastal belt particularly

Table 2 List of varieties of pulse crops notified during last 10 years (2008–17)

Crop	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Chickpea	4	3	7	2	4	3	1	3	8	10	45
Lentil	3	3	2	3	1	0	1	1	2	6	22
Fieldpea	3	0	3	2	2	0	2	1	4	2	19
Pigeonpea	2	3	1	1	2	3	2	0	5	2	21
Urdbean	4	3	4	2	5	1	1	1	2	1	24
Mungbean	2	7	3	1	3	1	3	2	10	3	35
Rajmash	0	0	1	0	0	0	0	0	0	1	2
Lathyrus	1	0	0	0	0	0	0	0	0	0	1
Cowpea	1	2	3	0	1	0	1	0	1	4	13
Cluster bean	1	0	4	0	0	0	0	0	0	0	5
Horsegram	0	0	1	1	1	0	1	0	2	2	8
	21	21	29	12	19	8	12	8	34	31	195

Source: Seed Section, ICAR, New Delhi

in peninsular India. Early maturing and high temperature stress tolerant chickpea (JG 14, RVG 202, RVG 203, Pusa 547, Pant G 186, IPC 2006-77, Rajas) and lentil (DPL 62, Moitree, HUL 57, Pant L 7, IPL 526) varieties can provide need based stability and fetch additional area in Indo-Gangetic plains. Similarly, short duration pigeonpea varieties (PAU 881, Pusa 16, and Pusa 992) could make dent under irrigated conditions of northern India as pigeonpea-wheat cropping sequence mode.

Zaid/spring pulses: With the development of extra-short duration varieties maturing in 55 to 70 day maturity of mungbean and urdbean helped in a big way to augment the total pulse production and narrowing the shortfall in quality seed production of these two crops in particularly. The potato-mungbean sequence is a reality after development of early maturing mungbean varieties (Virat, Samrat, SML 668, Pusa Vishal, IPM 02-3, HUM 16 and IPM 2-14). It is pertinent to mention that development and release of short duration mungbean varieties like PDM 11 and Samrat (PDM 139) opened doors for bringing additional area under this crop during spring/summer season of north and central India. The summer crops are relatively risk free as attack of insect-pests is minimum due less humidity and other environmental conditions of summer/spring season. It is like a bonus crop for farmers to augment their income. With the development of extra short duration varieties particularly of mungbean helped in long way to introduce a legume crop in predominated rice-wheat cropping system of Indo-Gangetic plains. It is an important intervention for sustainability of rice-wheat cropping system.

Hybrid technology: Hybrid technology has potential to enhance productivity by 20-30% depending upon the heterotic combination. Among the pulse crops, pigeonpea is most suitable to exploit hybrid technology as being often cross pollinated crop. So far breeding effort made at International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Hyderabad led in release of two pigeonpea hybrids (ICPH 2671 and ICPH 2740) and these have been recommended for cultivation in Maharashtra, Andhra Pradesh, Odisha, Telangana, Madhya Pradesh, Karnataka and Jharkhand. Further, there is need to develop economically superior hybrids of pigeonpea for cultivation in different agro-ecologies.

Varieties with Premium Traits: Varieties with premium traits (preferred by consumers and industry) are known to increase farmers' income. Development of high yielding kabuli chickpea varieties like HK 2, Shubhra, Ujjawal, HK 4, CSJK 6, GLK 26155, GLK 28127, NBeG 119, JGK 2, JGK 3, Gauri, Pant kabuli Chana 1, Raj Vijay Kabuli Gram 3, Phule G 0027, Vallabh Kabuli Chana 1, JGK 5, RSGK 6 and BDNGK 798, KAK 2, JGK 1 etc. having seed size of >25 to <40 g/100 seed-weight helped in producing more kabuli chickpea for domestic consumption in India. Later, extra-large seeded kabuli chickpea varieties (PKV kabuli 4-1, Phule G 0517, MNK 1) having more than 55 g 100 seed weight were released for cultivation. This paved the way to produce more kabuli chickpea that played significant

role in enhancing farmers' income and cultivation of kabuli chickpea has taken shape of commercial crop in central and southern India. In the recent past, Kabuli chickpea was being imported and with availability of indigenous varieties of kabuli chickpea, India not only become self-sufficient in kabuli chickpea but also became net exporter. Similarly, large/extra-large seeded lentil (IPL 406, JL 3, and IPL 316), green seeded fieldpea (IPFD 10-12), and green seeded urdbean (Shekhar 1, Shekhar 2) have been developed to fulfil demand of farmers in specific ecologies.

Development of new varieties amenable for mechanical harvesting: Profitability can be increased either by increasing productivity or reducing cost of cultivation. To reduce cost of cultivation mechanization of farm operations from seeding to harvesting/threshing is need of the day as farm labourers are becoming expansive day by day and often not available during peak periods of seeding and harvesting. Recent efforts resulted in development of machine harvestable (tall and erect) chickpea varieties (Phule Vikram, NBeG 47, GBM 2, RVG 204, HC 5 and Shubhra) which are becoming very popular among farmers. Similar efforts are being made to develop machine harvestable varieties of lentil, pea, pigeonpea and mungbean. The added advantage of popularizing tall and erect varieties will be in saving cost of plant protection in managing insect pests due to better spread of insecticides on crop plants. Further, better sunlight penetration inside crop canopy is helping in reducing humidity build up inside crop canopy which in turn help in minimizing incidence of foliar diseases mainly in *rabi* pulse crops.

Integrated crop management: Use of sub-optimal dose of fertilizers or no fertilizer remain major limiting factor in achieving higher yields of pulses in India as farmers often do not fertilize rainfed crops due to low returns. To harvest reasonably good yields balance nutrition and life-saving irrigation need to be given top priority. Application of sulphur @ 20-25 kg/ha can enhance yield by 15-20% irrespective of pulse crops. Application of sulphur becomes very important to boost spring/summer mungbean or urdbean crop when these are sown after harvest of oilseed crops like rapeseed-mustard. Similarly, chickpea, fieldpea, lentil and rajmash exhibit high yields when sulphur is provided. Soil application of 15-20 kg ZnSO₄/ha and @ 10 kg Borax powder (for Boron) has been found to increase grain yields significantly in soils deficient in Zn and B. In Madhya Pradesh, application of 1-1.5 kg Ammonium Molybdate/ha is being promoted for chickpea crop if it is to be sown after soybean crop (Gupta and Gangwar 2012). Application of AM fungi along with applied phosphorus has led to significant yield enhancement in pulses under acid Alfisol soils (Suri and Choudhary 2013, Yadav *et al.* 2015, Kumar *et al.* 2015, 2016, 2017, Bai *et al.* 2017). Among other technologies, ridge sowing, line sowing, sprinkler irrigation, application of herbicides to minimize crop-weed competition, etc. are of economic importance (Varatharajan *et al.* 2019).

Integrated diseases management: Diseases management following integrated pest management (IPM) approach is

the most economical way to minimize losses likely to be caused by diseases prevalent in particular area (Sharma *et al.* 2016). The best strategy to minimize diseases incidence due to soil borne pathogens rests in exploitation of host plant resistance and development of diseases resistant varieties as control for soil borne diseases (wilt and root rots) through use of fungicides at different crop growth stages is neither economical nor feasible at farmers' fields. At initial stage diseases incidence can be minimized if seeds are sown after treatment with Carbendazim + Thiram (1+2 g/kg seed) or *Trichoderma* + Carboxin (4+1 g/kg seed). Soil application of crop specific *Trichoderma* spp. @ 10 g/kg FYM or seed treatment with *Trichoderma* @ 10 g/kg seeds for minimizing wilt and other soil borne diseases have been recommended and adopted. Similarly, to minimize incidence of powdery mildew and rust, foliar spray of wettable sulphur @ 0.3% should be popularized where Mancozeb @ 0.2% can be sprayed for controlling pea and lentil rust.

Integrated insect-pest management: Management of insect pests following IPM approach has helped to minimize insect pest damage in standing crops (Sharma *et al.* 2016). Gram pod borer (*Helicoverpa armigera* Hubner) is the most important and dreaded pest infesting chickpea and pigeonpea crop. IPM modules developed have helped in minimizing damage due to *Helicoverpa armigera* (Shanower *et al.* 1999, Sharma *et al.* 2011). For example, use of pheromone trap @ 4-5 per ha, installation of bird perches (20-25 perches/ha crop) and insecticidal spray when pod borer reaches at economic threshold level, *i.e.* 1-2 larvae per linear meter has been suggested. The first spray of NSKE at 5% followed by second spray of NPV 250 LE and third spray (need based) of Indoxcarb (1 ml/l of water) effectively manages losses due to pod borer in chickpea. In case of early maturing pigeonpea, spray of Indoxcarb @ 1 ml/l of water followed by 5% NSKE helps in managing insect pests. Similarly, in long duration pigeonpea, spray of Dimethoate @ 0.03% followed by 5% NSKE effectively save crop from pod borer damage. Several insecticides have been recommended and are in use to minimize incidence of insect pests in different pulse crops. Foliar spray of Dimethoate @ 0.03% for managing aphids in lentil; and Imidacloprid 17.8 SL @ 2-3 ml/10 litre of water manages insect pests in mungbean and urdbean effectively during *kharif*. Though timely irrigation minimizes thrips infestation but foliar spray of Indoxcarb (1 ml/l of water) or Dimethoate 0.03% against pod borers and sucking pests has to be promoted to control save mungbean and urdbean from thrips.

Policy interventions: National Food Security Mission (NFSM) and Rashtriya Krishi Vikas Yojana (RKVY) were launched in 2007-08 to accelerate the rice, wheat and pulses production under NFSM and overall agriculture development under RKVY. The initial out lays of NFSM was ₹ 4883 crores and RKVY was of ₹ 25000 crores. In NFSM, substantial funds out of total allocation were provided to boost the pulses production in country and almost all states (468 districts) were covered under this programme. One of objectives of NFSM was technologies transfer and to achieve

this objective subsidy was provided for seed production and supply of quality seed through minikits to farmers, secondly large scale cluster demonstrations of 100 ha each were planned and conducted with improved varieties and packages of practices, thirdly farmer field schools were organized to provide practical trainings to the farmers while growing pulse crops at their own field. In second objective of NFSM to provide balance fertilizers under this programme bio-fertilizers and micro-nutrients were supplied as per soil test report. The pulses generally needs one or two irrigations to meet this requirements under NFSM/RKVY at subsidized rate water carrying pipes, sprinkler and drip irrigations systems were also provided to farmers. These mega initiatives of Govt. of India worked as a catalyst to enhance the pulses production (Sandhu *et al.* 2014, Sandhu 2016). The impact of these programmes was visible in 2013-14 when pulses production was recorded 19.25 mt over the pulses production in 2007-08 of 14.76 mt. The pulses production came down in the years 2014-15 and 2015-16 due to two consecutive poor monsoon years as pulses are largely grown under rainfed (~75% area) conditions (Sandhu 2014). Second policy intervention was inevitable to bring the confidence of pulse farmers and accordingly about 500 crores rupees extra fund besides NFSM funding, were sanctioned with strategy to strengthen the seed chain to ensure the availability of sufficient quantity of breeder seed of latest varieties and their further multiplication as foundation and certified seeds. One hundred fifty seeds hubs are created to maintain continuous supply of quality seed of improved varieties for large scale demonstrations by the Krishi Vigyan Kendra (KVKs), Agricultural Universities (AUs) and funds (₹ 50 lakh) are also made available for seed processing plant and storage to made available processed seed as and when required and ₹ 100 lakh as revolving fund to each of seed hubs to support the seed production programme in a long run. These are unique interventions of Govt. of India. To back up whole programme with ensuring remunerative minimum support price (MSP) to farmers (Table 3) and first time procurement of pulses at MSP by the Government led to revitalize the pulses production. Other ambitious development programmes of Govt. of India like Pradhan Mantri Fasal Bima Yojna (PMFBY), Pradhan Mantri Krishi Sinchai Yojna (PMKSY) also helped in building confidence of pulse growers and bringing additional area under pulses cultivation. Both technologies and policy interventions equally contributed reaching to land mark achievement in pulses production of 25.23 mt in 2017-18. This production level is likely to sustain in future with the positive policy support of the Government.

Green Revolution versus Pulses Revolution

Cereal revolution termed as *Green Revolution* which triggered in mid-sixties with the introduction of high yielding dwarf varieties of wheat from Mexico and rice from Philippines as a technology intervention of Govt of India. Large quantity of 30000 tons of Mexican wheat seed was imported in one-go which is itself a history in the

Table 3 Minimum support price (₹/q) of pulses for the last 5 years

Crops	Minimum support price (₹/q) of pulses							
	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Pigeonpea	3200	3850	4300	4350	4625	5050	5450	5675
Chickpea	2800	3000	3100	3175	3500	4000	4400*	4620
Mungbean	3500	4400	4500	4600	4850	5225	5575**	6975
Urdbean	3300	4300	4300	4350	4625	5000	5400**	5600
Lentil	2800	2900	2950	3075	3400	3950	4250***	4475

Sources: Commission for Agricultural Costs and Prices (CACP).

*Including bonus of ₹ 200/quintal, **including onus of ₹ 150/quintal and,

*** including bonus of ₹ 100/quintal

world agriculture. These dwarf varieties were responsive to agronomic management like agro-chemicals, irrigation and amenable to combine harvesting. As a policy support Govt of India provided financial support to make available quality seeds at reasonable price to the farmers, create irrigation infrastructure, mechanisation, and agro-chemicals, subsidized electric supply for pumping out irrigation water and above all ensured procurement of farmers produce at minimum support price (MSP). These interventions of technology and policy support brought green revolution in cereal production in India and country attained food grains (mainly cereal grains) self-sufficiency in a decade period. While pulses revolution is achieved almost on similar lines of cereal revolution with the distinction that it happened with indigenous technologies developed by our own scientists. Pulses revolution spread across the country and not restricted to only few states as it has been happened in case of cereal revolution. Pulses revolution is more inclusive as it is environment friendly required less natural resources, promote sustainability as pulses improve soil health and ensure nutritional security as well.

Tremendous scope exists for further enhancement in yield potential and bringing desired stability in productivity through appropriate technologies development while negating effect of climate changes. Integrated breeding approaches involving genomics (Ojiewo *et al.* 2018) for increasing efficiency of selection from large segregating populations has been advocated to reduce space requirement as a cost effective efficient method. Deployment of molecular markers in large breeding populations in crops like pulses will be rewarding (Varshney *et al.* 2013). Recently concept of speed breeding (Watson *et al.* 2018) has been conceptualized and being implemented for rapid generation turnover in pulses breeding. Efforts are being made to develop varieties possessing tolerance against high temperature (Basu *et al.* 2010, Gaur *et al.* 2014, Paul *et al.* 2018) and drought (Gaur *et al.* 2018) stress, and bringing herbicide tolerant genes in desirable backgrounds to minimize crop loss due to seasonal weeds as genetic variations have been observed for herbicide tolerance in chickpea (Chaturvedi *et al.* 2014) and fieldpea. To minimize losses being caused due to gram pod borer (*Helicoverpa armigera*) transgenic are being developed in case of chickpea (Das *et al.* 2017) as a viable

strategy to minimize losses due to this dreaded insect pest. With the availability of draft genome sequences (Varshney *et al.* 2013) it has now become easy to develop and utilize large genomic resources (Pratap *et al.* 2011, Varshney *et al.* 2013) for crop improvement and deploying molecular markers in routine breeding programs.

Conclusion

Pulses revolution has been led by science based indigenous technologies, their successful transfer, strong back-up of seed supply system, guided by policy initiatives and favorable market price structure. Pulses revolution is a sustainable, environment friendly and ensures nutritional security of the country. Sustained investment in research, marketing, modernization of processing, opening up export with policy back-up will be a long-term strategy to meet the ever increasing demand of pulses in India and elsewhere.

REFERENCES

- Babu S, Rana D S, Choudhary A K. 2014. Effect of sunflower stover and nutrients management on energetics, nutrient acquisition and soil nutrient balance of pigeonpea (*Cajanus cajan*)–sunflower (*Helianthus annuus*) cropping system. *Indian Journal of Agronomy* 59(4): 549–55.
- Bai B, Suri V K, Kumar A and Choudhary A K. 2017. Tripartite symbiosis of *Pisum*–*Glomus*–*Rhizobium* lead to enhanced productivity, nitrogen and phosphorus economy, quality and biofortification in garden pea in a Himalayan acid Alfisol. *Journal of Plant Nutrition* 40(4): 600–13.
- Basu P S, Ali M and Chaturvedi S K. 2010. Terminal heat stress adversely affects chickpea productivity in northern India-Strategies to improve thermo-tolerance in the crop under climate change. *Proc: ISPRS Archives XXXIII-8/W3 Workshop*, pp 189–93.
- Chaturvedi S K, Mishra N and Aski M. 2014. Genetic variation for herbicide tolerance in chickpea. *Indian Journal of Agricultural Sciences* 84(8): 968-970
- Chaturvedi S K, Mishra N and Gaur P M. 2014. An overview of chickpea breeding program in India. *Legumes Perspectives* 3: 50–52.
- Choudhary A K and Suri V K. 2014. Scaling-up of pulse production under frontline demonstration technology transfer program in Himachal Himalayas, India. *Communications in Soil Science and Plant Analysis* 45(14): 1934–48.
- Choudhary A K, Rana D S, Bana R S, Pooniya V, Dass A, Kaur

- R and Rana K S. 2015. *Agronomy of oilseed and pulse crops*. Post Graduate School, Indian Agricultural Research Institute, New Delhi and Indian Council of Agricultural Research, Department of Agricultural Research and Education, New Delhi, India, pp 218 + viii.
- Das A, Datta S, Thakur S, Shukla A, Ansari J, Sujayanand G K, Chaturvedi S K, Kumar P A and Singh N P. 2017. Expression of a chimeric gene encoding insecticidal crystal protein Cry1Aabc of *Bacillus thuringiensis* in chickpea (*Cicer arietinum* L.) confers resistance to gram pod borer (*Helicoverpa armigera* Hubner.). *Frontiers in Plant Science* doi: 10.3389/fpls.2017.01423
- Gaur P M, Jukanti A K, Srinivasan S, Chaturvedi S K, Basu P S, Babbar A, Jayalakshmi V, Nayyar H, Devasirvatham V, Mallikarjuna N, Krishnamurthy L and Gowda C L L. 2014. Climate change and heat stress tolerance in chickpea. (In) *Climate Change and Plant Abiotic Stress Tolerance*, First Edition, pp 839-55. NarendraTuteja and Sarvajeet S Gill (Eds). Wiley-VCH Verlag GmbH & Co. KGaA.
- Gaur P M, Srinivasan S, Thudi M, Tripathi S, Sajja S B, Jayalakshmi V, Mannur D M, Vijayakumar A G, Nadigatla V. P. R. Ganga Rao N V P R, Ojiewo C, Fikre Asnake, Kimurto Paul, Kileo Robert O, Girma N, Chaturvedi S K, Varshney R K and Dixit G P. 2018. Integrated breeding approaches for improving drought and heat adaptation in chickpea (*Cicer arietinum* L.). *Plant Breeding* DOI: 10.1111/pbr.12641
- Gupta S C and Gangwar S. 2012. Effect of molybdenum, iron and microbial inoculants on symbiotic traits, nutrient uptake and yield of chickpea. *Journal of Food Legumes* **25**(1): 45–49. http://agricoop.gov.in/sites/default/files/pulses_oct.pdf
- Kumar A, Choudhary A K and Suri V K. 2016. Influence of AM fungi, inorganic phosphorus and irrigation regimes on plant water relations and soil physical properties in okra (*Abelmoschus esculentus* L.) – pea (*Pisum sativum* L.) cropping system in Himalayan acid Alfisol. *Journal of Plant Nutrition* **39**(5): 666–82.
- Kumar A, Choudhary A K and Suri V K. 2017. Agronomic bio-fortification and quality enhancement in okra-pea cropping system through arbuscular mycorrhizal fungi at varying phosphorus and irrigation regimes in Himalayan acid Alfisol. *Journal of Plant Nutrition* **40**(8):1213–29.
- Kumar A, Suri V K and Choudhary A K, Yadav A, Kapoor R, Sandal S and Dass A. 2015. Growth behavior, nutrient harvest index and soil fertility in okra-pea cropping system as influenced by AM fungi, applied phosphorus and irrigation regimes in Himalayan acid Alfisol. *Communications in Soil Science and Plant Analysis* **46**(17): 2212–33.
- Kumar J, Pratap A, Solanki R K, Gupta D S, Goyal A, Chaturvedi S K, Nadarajan N and Kumar S. 2011. Genomic resources for improving food legume crops. *Journal of Agricultural Sciences Cambridge* **150**: 289-318.
- Kumar S, Choudhary A K, Rana K S and Sarkar A and Singh M. 2018. Bio-fortification potential of global wild annual lentil core collection. *PLoS One* **13**(1): e0191122.
- Kumar S, Gupta S and Chaturvedi S K. 2008. Narrow genetic base of pulses. (In) Kharkwal M C (ed.). *Food Legumes for Nutritional Security and Sustainable Agriculture*, Vol. II, pp 131-6. Indian Society of Genetics and Plant Breeding, New Delhi.
- Ojiewo C O, Monyo E, Desmae H, Boukar O, Mukankusi-Mugisha C, Thudi M, Pandey M K, Saxena R K, Gaur P M, Chaturvedi S K, Fikre A, Ganga Rao N V P R, Sameer Kumar C V, Okori P, Janila P, Rubyogo J C, Godfree C, Akpo E, Omoigui L, Nkalubo S, Fenta B, Binagwa P, Kilango M, Williams M, Mponda O, Okello D, Chichaybelu M, Miningou A, Bationo J, Sako D, Diallo S, Echekwu C, Umar M L, Oteng-Frimpong R, Mohammed H, Varshney R K and Ordon F. 2018. Genomics, genetics and breeding of tropical legumes for better livelihoods of smallholder farmers. *Plant Breeding* (TSI) : 1–13.
- Paul P J, Samineni S, Thudi M, Sajja S, Rathore A, Das R R, Khan A W, Chaturvedi S K, Lavanya G R, Varshney R K and Gaur P M. 2018. Molecular mapping of QTLs for heat tolerance in chickpea. *International Journal of Molecular Sciences* (TSI) **19**(8) (2166): 1-20.
- Pooniya V, Choudhary A K, Dass A, Bana R S, Rana K S, Rana D S, Tyagi V K and Puniya M M. 2015. Improved crop management practices for sustainable pulse production: An Indian perspective. *Indian Journal of Agricultural Sciences* **85**(6): 747–58.
- Prasad D, Rana D S, Babu S, Choudhary A K and Rajpoot S K. 2016. Influence of tillage practices and crop diversification on productivity and soil health in maize (*Zea mays* L.) / soybean (*Glycine max* L.) based cropping systems. *Indian Journal of Agricultural Sciences* **86**(1): 96–102.
- Rajpoot S K, Rana D S and Choudhary A K. 2018. Bt-cotton-vegetable-based intercropping systems as influenced by crop establishment method and planting geometry of Bt-cotton in Indo-Gangetic plains region. *Current Science* **115**(3): 516–22.
- Rana D S, Dass A, Rajanna G A and Choudhary A K. 2018. Fertilizer phosphorus solubility effects on Indian mustard-maize and wheat-soybean cropping systems productivity. *Agronomy Journal* **110**(6): 2608–18.
- Rana J, Gautam N K, Gayacharan, Singh Mohar, Yadav R, Tripathi K, Yadav S S, Panwar N and Bhardwaj R. 2016. Genetic resources of pulse crops in India: An overview. *Indian Journal of Genetics and Plant Breeding* **76**: 420–36.
- Sandhu J S and Chaturvedi S K. 2018. Increasing pulses production in India. *Kurukshetra* February 2018 : 54–59.
- Sandhu J S, Bains T S and Sidhu P S. 2002. Evaluation of super early chickpea genotypes for vegetable purpose as a catch crop. *International Chickpea and Pigeonpea Newsletter* **9**: 10–2.
- Sandhu J S. 2016. Spatially-explicit analyses related to local and global challenges. 10 Year Research Strategy for Pulse Crops. Global Pulse Confederation (GPC), pp 38-42.
- Sandhu J S, Lohiya Sanjay and Malik D P. 2014. Impact evaluation studies of technical component of National Food Security Mission (NFSM II). Government of India, New Delhi, p 154.
- Sandhu J S, Sekhon H S, Singh Gurqbal, Bains T S, Gupta S K, Kaur A, Saxena A K and Sharma S. 2007. Short-duration chickpea (*Cicer arietinum* L.) for vegetable purpose. *Indian Journal of Agricultural Sciences* **77**: 639–41.
- Sandhu J S. 2014. India's food security–Fallout of pro-agro policies. Agriculture Year Book 2014. Edited by M J Khan. pp 61–63.
- Shanower T G, Romeis J and Minja E M. 1999. Insect pests of pigeonpea and their management. *Annual Review of Entomology* **44**: 77–96.
- Sharma O P, Bhosle B B, Kamble K R, Bhede B V and Seeras N R. 2011. Management of pigeonpea pod borers with special reference to pod fly (*Melanagromyza obtusa*). *Indian Journal of Agricultural Sciences* **81**(6): 539–43.
- Sharma O P, Patange N R, Rachappa V and Venilla S. 2016. Integrated disease and insect pest management for enhancing production of pulse crops. *Indian Journal of Genetics and Plant Breeding* **76**(4): 451–8.

- Singh N P, Praharaj C S and Sandhu J S. 2016. Utilization untapped potential of rice fallow East and North-east India through pulse production. *Indian Journal of Genetics and Plant Breeding* **74**: 388–98.
- Suri V K and Choudhary A K. 2013. Effects of vesicular arbuscular mycorrhizae and applied phosphorus through targeted yield precision model on root morphology, productivity and nutrient dynamics in soybean in an acid Alfisol. *Communications in Soil Science and Plant Analysis* **44**(17): 2587–604.
- Varatharajan T, Choudhary A K, Pooniya V, Dass A and Harish M N. 2019. Integrated crop management practices for enhancing productivity, profitability, production-efficiency and monetary-efficiency of pigeonpea (*Cajanus cajan*) in Indo-Gangetic plains region. *Indian Journal of Agricultural Sciences* **89**(3): 559–63.
- Varshney R K *et al.* 2013. Draft genome sequence of chickpea (*Cicer arietinum* L.) provides a resource for trait improvement. *Nature Biotechnology* **31**: 240–46.
- Varshney R K, Mohan S M, Gaur P M, Gangarao N V P R, Pandey M K, Bohra A, Sawargaonkar S L, Gorantla A, Kimurto, P K, Janila P, Saxena K B, Fikre A, Sharma M, Rathore A, Pratap A, Tripathi S, Datta S, Chaturvedi S K, Mallikarjuna N, Anuradha G, Babbar A, Choudhary A K, Mhase L B, Bharadwaj C, Mannur D M, Harer P N, Guo B, Liang X, Nadarajan N and Gowda C L L. 2013. Achievements and prospects of genomics-assisted breeding in three legume crops of the semi-arid tropics. *Biotechnology Advances* doi.org/10.1016/j.biotechadv.2013.01.001
- Watson A, Ghosh S, Williams M J, Cuddy W S, Simmonds, J, Rey M D, Hatta M A Md, Hinchliffe A, Steed A, Reynolds D, Adamski N, Breakspear A, , Korolev A, Rayner T, Dixon L E, Dixon L E, Riaz A, Martin W, Ryan M, Edwards D, Batley J, Raman H, Rogers C, Domoney C, Moore G, Harwood W, Nicholson P, Dieters M J, DeLacy I H, Zhosji, Uauy C, Boden S A, Park R F, Wulff B B H and Hickey Lee T. 2018. Speed breeding: a powerful tool to accelerate crop research and breeding. *Nature Plants* **4**: 23–9.
- Yadav A, Suri V K, Kumar A, Choudhary A K and Meena A L. 2015. Enhancing plant water relations, quality and productivity of pea (*Pisum sativum* L.) through AM fungi, inorganic phosphorus and irrigation regimes in a Himalayan acid Alfisol. *Communications in Soil Science and Plant Analysis* **46**(1): 80–93.