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Perspective

PULSES CULTIVATION IN PRE- AND POST-GREEN REVOLUTION ERAS IN PUNJAB

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In Punjab whenever, we think of food, *daal-roti* are the two words which come to our mind. Evidently, pulses are and have been an important component of our meals along with wheat, the main staple cereal. At the time of independence, there were four important pulses under cultivation in the Punjab state. Chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) were grown during *rabi* season and urdbean (*Vigna mungo*) and mungbean (*V. radiata*) during *kharif* season. But the acreage under pulses underwent a sea change thereafter.

During *kharif* 1950-51, cotton (280 thousand ha), maize (252 thousand ha) and rice (120 thousand ha) occupied the first, second and third positions, respectively, with respect to area under their cultivation in Punjab. In *rabi* season, wheat was and continues to be the most important crop since then. The area under both wheat and rice increased at a slow rate up to mid-1960s, i.e. in the pre- Green Revolution era. Thereafter, it increased rather rapidly. Wheat was cultivated on 1137 thousand ha in 1950-51 which increased to 3520 thousand ha in 2018-19. Rice was cultivated on 120 thousand ha in 1950-51 and increased to 3103 thousand ha during 2018-19. Rice is being cultivated on the largest area in the *kharif* season since 1976-77. In this background, a perception has developed that pulses have been edged out by Green Revolution crops, namely rice and wheat.

Intensive agriculture based on rice-wheat cropping system accompanied by increased cropping intensity has resulted in many adverse effects. There is depletion of underground water resources at an alarming rate, increased use of agro-chemicals and fertilizers and burning of crop residues which have affected soil health (physical and biological) and environment. The movement of about 80% wheat and rice produce out of Punjab has disrupted natural recycling of nutrients leading to their depletion and micro nutrient deficiencies in soil due to their mining. Under these circumstances, there is an urgent need to diversify the rice-wheat cropping system. Since the most serious challenge is rapid depletion of groundwater resources, the reduction of area under rice (a water loving crop) has emerged as the top priority.

Punjab is making intensive efforts for crop diversification. There has been good progress with respect to the area under vegetables and fruits. Their area has risen from 239 to 360 thousand ha i.e. by 50% during previous 10 years (2009-10 to 2018-19). The scope of further rapid expansion of area under vegetables and fruits is limited because of poor marketing and processing infrastructure, cold chains, and weak linkages with markets within and outside the country. These crops are also more sensitive/ susceptible to climate variability, diseases and pests and to market fluctuations. For diversification, among field crops the main candidates are maize and cotton. The expansion of cultivation of maize is limited by market demand and lack of policy support in marketing. In cotton, though some support is provided by the Cotton Corporation of India through market intervention when prices fall down but further expansion of area needs a better support and if possible, similar to that in wheat and rice. Also, cotton is very prone to diseases and pests. Its productivity was seriously affected by American bollworm during 1990s, mealy bug in 2007 and whitefly in 2015.

Under these circumstances, pulses are considered as an alternative for diversification of rice-wheat cropping system. The apparent attractions are that pulse crops have low water requirement, fix atmospheric nitrogen (N) and need less input of N fertilizer. Further, there is huge domestic demand for pulses as the country generally imports a large quantity. The Indian Council of Medical Research has recommended 52g/capita/day of pulses (Anonymous, 2015). According to a rough estimate based on this recommendation, Punjab needs about 5.0 lakh tonnes of pulses annually, while at present, Punjab state is producing only around 30 thousand tonnes of pulses.

Therefore, the pulses scenario is examined for area, production, yield and research focus. There is greater focus on *kharif* season as pulses have less water requirement than rice and therefore offer a good alternative to save water besides other factors.

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Area, production and yield

Grow More Food Campaign

The Government launched 'Grow More Food Campaign' in 1948. As a result of the efforts under this Campaign, the area under wheat and rice increased (Table 1). But the area under pulses registered opposite trends in *kharif* and *rabi* seasons. During 1950-51 to 1965-66, the area under *kharif* pulses (mungbean and urdbean) declined from 68.0 to 17.8 thousand ha (mungbean decreased from 16.8 to 3.1 thousand ha and urdbean, from 51.2 to 14.7 thousand ha). The area under *rabi* pulses initially went up, for chickpea it peaked (1002 thousand ha) in 1955-56 and for lentil (30.8 thousand ha) in 1962-63 (Table 2). Thereafter, it started declining. During 1965-66, chickpea was cultivated on 602 thousand ha and lentil on 22 thousand ha.

During 1950s, the installation of tube wells got a push. First fertilizer factory at Sindri in the then Bihar state started production of Ammonium Sulphate. These factors accompanied by extension efforts led to expansion of area under crop cultivation. With the strengthening of irrigation facilities, the cropping system started shifting towards higher yielding and more remunerative crops though, having higher irrigation water demand, i.e. the area under pulses shifted to more remunerative crops like wheat in *rabi* season and maize and cotton in *kharif* season. Apparently, the reduction in area under pulses in both *kharif* and *rabi* seasons started before Green Revolution.

Green Revolution

There was a bumper harvest of wheat crop in 1967-68. To commemorate this phenomenal success, a new term 'Green Revolution' was first used in 1968. The impact of the bumper harvest was a dramatic increase in the area under wheat in 1968-69, i.e. 2063 thousand ha from 1790 thousand ha during 1967-68. High yielding varieties of rice and the improved package of technology for their cultivation also became available immediately thereafter. There was a substantial increase in area under rice cultivation, from 359 in 1969-70 to 450 thousand ha during 1971-72.

The area under *rabi* pulses, namely chickpea and lentil, continued downward trend which had started during pre-Green Revolution era (Table 1). The *kharif* season pulses, urdbean and mungbean, registered different trend. The area under urdbean recovered somewhat after mid-1960s and during 1970s compared to the period from mid-1950s to mid-60s. But after 1970s, its acreage again started reducing. Mungbean cultivation started gaining popularity during 1980s

Table 1. Trends in area under rice, wheat and pulse crops in Punjab since 1950-51

Year	Area (thousand ha)									
	Kharif season						*Rabi* season			
	Rice	Mung-bean	Urd-bean	Pigeon-pea	Mung-bean +urd-bean	Mung-bean+ urdbean+ pigeon-pea	Wheat	Chick-pea	Lentil	Chick-pea+ lentil
1950-51	120.0	16.8	51.2	NA	68.0	NA	1137.0	851.0	20.8	871.8
1955-56	149.0	16.4	35.4	NA	51.8	NA	1292.0	1002.0	18.0	1020.0
1960-61	227.0	5.8	19.3	NA	25.1	NA	1400.0	838.0	29.8	867.8
1965-66	292.0	3.1	14.7	NA	17.8	NA	1550.0	602.0	22.0	624.0
1970-71	390.0	6.9	25.9	3.0*	32.8	35.8	2299.0	358.0	13.3	371.3
1975-76	567.0	5.9	23.9	5.6*	29.8	35.4	2439.0	381.0	15.8	396.8
1980-81	1183.0	15.1	21.5	21.3	36.6	57.9	2812.0	258.0	19.8	277.8
1985-86	1714.0	46.4	12.9	40.0	59.3	99.3	3112.0	108.0	11.7	119.7
1990-91	2015.0	50.3	8.5	14.5	58.8	73.3	3273.0	60.0	9.7	69.7
1995-96	2185.0	52.6	6.0	10.0	58.6	68.6	3221.0	20.0	6.0	26.0
2000-01	2612.0	29.5	3.5	8.7	33.0	41.7	3408.0	8.0	4.7	12.7
2005-06	2647.0	11.8	2.9	7.7	14.7	22.4	3464.0	4.0	2.3	6.3
2010-11	2826.0	8.5	2.9	4.4	11.4	15.8	3510.0	3.0	1.2	4.2
2015-16	2970.0	10.5	2.1	2.8	12.6	15.4	3506.0	1.9	0.8	2.7
2018-19	3103.0	3.2	2.0	2.3	5.2	7.5	3520.0	1.9	0.7	2.6

Source: Statistical Abstract of Punjab (various issues); NA: Data not available;
*: Project Coordinator's Report, Annual Group Meet-2018-19, All India Coordinated Research Project on Pigeonpea, ICAR-Indian Institute of Pulses Research, Kanpur

engineered by sharp increase in productivity from 551 kg/ha in 1979-80 to 735 kg/ha in 1980-81. As a result of development and adoption of high yielding disease resistant varieties, its area touched all time high, i.e. 54.9 thousand ha in 1994-95 (Table 2). But thereafter, the area under its cultivation declined.

Interestingly, since 1981-82, mungbean occupied larger area compared to urdbean, the crop which was earlier more important than mungbean as is evident from the larger area under urdbean (51.2 thousand ha) compared to mungbean (16.8 thousand ha) during 1950-51 (Table 1). One reason for decline in urdbean area may be that its cultivation was mainly confined to sub-mountainous zone of the state due to its sensitivity to high temperature, while mungbean could be grown in whole of the state. Another reason may be the development of promising high yielding varieties of mungbean. Lower productivity of urdbean seems to be a reason for decline in its area as the average productivity of mungbean is higher (~825 kg/ha) as compared to urdbean (~550 kg/ha) in Punjab. It is interesting to note that there was practically no adverse effect on sum total of area under urdbean and mungbean combined together from 1960-61 to 1980-81. There was rather a slight increase during 1967-68 to 1975-76. The cultivation of pigeonpea in Punjab was started by the end of 1960s. The area under its cultivation expanded up to 1984-85, when it covered 42.5 thousand ha and declined thereafter (Tables 1, 2).

Highest area and production of kharif pulses

The TE1986-87 saw the largest area under the cultivation of all *kharif* pulses considered together and their highest production (Table 3). However, during the following year, 1987-88, the area and production registered a sharp downfall to 76.5 thousand ha and 57.9 thousand tonnes, respectively. There does not seem to be any apparent reason responsible for this decline, biotic/ abiotic stress and/or unfavourable market forces.

After this TE, the total area under *kharif* pulse crops continued to decrease, though, area under mungbean increased up to 1994-95. There was a sharp fall in total area under these pulses during 1998-99 to 55.7 thousand ha from 65.5 thousand ha during 1997-98. This was most probably due to the decision of the State Government in January 1997 to provide free of charges electric power to tube wells for irrigation to the farmers having land holdings up to 3 ha and extension of this facility to all farmers irrespective of size of land holding in February of the same year. As a consequence of this, the area under rice increased from 2281 in 1997-98 to 2519 thousand ha in 1998-99.

Earlier, the electricity was charged on the basis of number of Units (kWh) consumed by the tube wells. In late 1970s, the State Government replaced that by charging flat rate on the basis of the Horse Power (BPH) of electric motors. That went into favour of the crops which needed more irrigation (rice area increased from 858 thousand ha in 1977-78 to 1052 thousand in 1978-79). The Government reverted back to charging for electricity on the basis of BHP in October 2002, but it again restored free electricity supply to all farmers in September 2005. It may be noted that there was no increase in the acreage of rice during 2003-04 to 2007-08, which ranged between 2609 and 2645 thousand ha. Thereafter, it jumped from 2609 in 2007-08 to 2735 thousand ha in 2008-09.

Table 2. Maximum area occupied by rice, wheat and pulses in Punjab since 1950-51

	***Kharif* season**				***Rabi* season**		
	Rice	**Mung-bean**	**Urd-bean**	**Pigeon-pea**	**Wheat**	**Chick-pea**	**Lentil**
Area (thousand ha)	3103.0	54.9	51.2	42.5	3520.0	1002.0	30.8
Year	2018-19	1994-95	1950-51	1984-85	2018-19	1955-56	1962-63

Source: Statistical Abstract of Punjab (various issues)

Table 3. Area and production of *kharif* pulses in Punjab during TE1986-87*

Year	**Area (thousand ha)**			**Total**	**Production (thousand tonnes)**			**Total**
	Mung-bean	**Urd-bean**	**Pigeon-pea**		**Mung-bean**	**Urd-bean**	**Pigeon-pea**	
1984-85	34.4	12.0	42.5	88.9	29.1	7.1	46.3	82.5
1985-86	46.4	12.9	40.0	99.3	41.3	7.6	43.7	92.6
1986-87	52.1	11.6	31.4	95.1	47.0	6.6	31.1	84.7
TE1986-87	44.3	12.2	38.0	94.4	39.1	7.1	40.4	86.6

Source: Statistical Abstract of Punjab (various issues)
*During TE1986-87, the combined area and production of *kharif* pulses was the highest in Punjab since 1950-51

Post-TE 1986-87 productivity trends of kharif *pulses*

During the TE1986-87, when the highest production was recorded, urdbean (592 kg/ha during 1984-85) and pigeonpea (1093 kg/ha during 1985-86) had the highest yield, and mungbean the second highest yield (902 kg/ha during 1986-87). After the TE1986-87, the yield of urdbean decreased and ranged between 324-545 kg/ha during 1987-88 to 2007-08 except one year, 2010-11 (586 kg/ha). However, it increased to 524-563 kg/ha during recent five years (2014-15 to 2018-19). After 1986-87, the yield of pigeonpea fluctuated at a slightly lower level, i.e. 843-1055 kg/ha, and even lower during three years in post-TE 1986-87 years. In the years following TE1986-87, the yield of mungbean was slightly lower but it picked up, being at least 800 kg/ha since 2003-04, and it reached peak (943 kg/ha) in 2009-10.

Marginalization of pulse crops

Urdbean and lentil are being now cultivated on less than 10 thousand ha since 1989-90, pigeonpea since 1998-99, chickpea since 1999-2000, and mungbean since 2008-09. Each of these is occupying less than 5 thousand ha and the total area during 2018-19 was 7.5 thousand ha and 2.6 thousand ha under *kharif* and *rabi* pulses, respectively. Apparently, all these have now become marginal crops. Further, these are being cultivated on poor soils, do not get attention for application of inputs like irrigation, nutrients (fertilizers/bio-fertilizers) and plant health care. These factors are adversely affecting their yield.

Policy support

Government support to rice and wheat focused rightly on ensuring national food security, has greatly favoured expansion of area under these crops. An important policy intervention is procurement of the produce of these two crops at remunerative minimum support price. Thus, these crops enjoy 'no risk' marketing. Another equally important policy measure for rice is free supply of electric power to tube wells and canal water for irrigation. This support gave a strong thrust to the expansion of area under cultivation of rice. Further, large infrastructure developed for irrigation, transport, marketing, and subsidized supply of inputs like seed, fertilizers and agro-chemicals are being largely utilized by rice and wheat. Even, the research on rice and wheat got greater thrust and resources compared to pulses as discussed later.

Research at National and International Levels

Germplasm resources and evolution

Chickpea and lentil originated in Middle East (Turkey, Syria and adjoining areas). The area under chickpea cultivation is concentrated in the Indian subcontinent, followed by Australia, Iran, Myanmar, Turkey and Ethiopia. Lentil is predominantly grown in India and Canada. Pigeonpea (*Cajanus cajan*) originated in India and is mostly grown in India and Myanmar. Mungbean and urdbean also originated in the Indian subcontinent and are predominantly cultivated in the subcontinent.

The three pulse crops of interest in Punjab for replacement of area under rice during *kharif* season are pigeonpea, mungbean and urdbean. All these have originated in India/Indian subcontinent and are predominantly cultivated in India. In India, these crops as well as chickpea and lentil used to be planted under poor natural-resource endowment and management conditions (un-irrigated, less fertile soil, poor nutrition and plant health care). The evolution of germplasm over millennia under such conditions resulted in the development of the landraces and farmers' varieties in which the genes for tolerance to stresses and low yield got accumulated, but those for better performance under favourable natural endowments and / or responsiveness to high inputs (irrigation, fertilizers) and

Table 4. Maximum productivity of pulses obtained in Punjab vis-a-vis productivity in 1950-51

	Productivity (kg/ha)				
	Kharif pulses			*Rabi* pulses	
	Mung-bean	Urd-bean	Pigeon-pea	Chick-pea	Lentil
Productivity during 1950-51	352	332	400* (1970-71)	600	558
Maximum productivity (year)	943 (2009-10)	592 (1984-85)	1093 (1985-86)	1413 (2012-13)	833 (2008-09)
Per cent increase	168	78	173	136	49
Productivity during 2018-19	844	550	1043	1330	714

Source: Statistical Abstract of Punjab (various issues);
*: Project Coordinator's Report, Annual Group Meet-2018-19, All India Coordinated Research Project on Pigeonpea, ICAR-Indian Institute of Pulses Research, Kanpur

better management could not be identified and were probably lost.

National and international research set up

India is the largest producer of pulses. The pulses are of utmost importance to us in terms of area under cultivation and consumption. Major research efforts should have been made in our country but unfortunately it did not happen. The main focus was and continues to be on staple cereals to ensure national food security. The Indian Council of Agricultural Research (ICAR) has two research institutes devoted solely to rice, one to wheat and barley, but only one institute for eight pulse crops, namely chickpea, pigeonpea, urdbean, mungbean, lentil, fieldpea, rajmash and lathyrus. The cadre strength of the research institutes on rice, namely National Rice Research Institute at Cuttack and Indian Institute of Rice Research at Hyderabad, is 169 scientists and 129 technical staff, Indian Institute of Wheat and Barley Research at Karnal is 62 scientists and 48 technical staff, whereas the Indian Institute of Pulses Research at Kanpur having the mandate of eight pulse crops, has cadre strength of only 88 scientists and 59 technical staff. Same is the situation in well-known agricultural universities in the region, namely Punjab Agricultural University (PAU), Chaudhary Charan Singh Haryana Agricultural University and Govind Ballabh Pant University of Agriculture & Technology.

The situation is not different even among the international agricultural research institutions working under the well-known umbrella organization, the Consultative Group of International Agricultural Research (CGIAR). International Rice Research Institute (IRRI) in the Philippines is solely devoted to rice and International Maize and Wheat Improvement Center (CIMMYT) in Mexico, to wheat and maize. Two CGIAR institutes, namely International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India and International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria/Lebanon, work on a number of crops including some pulses of our interest. The mandate of ICRISAT includes chickpea and pigeonpea and that of ICARDA, lentil and *Kabuli* chickpea. The research efforts of IRRI on rice and of CIMMYT on wheat are well known and appreciated in the world. These have created greater impact on Indian agriculture compared to that of ICRISAT in chickpea and pigeonpea, even though ICRISAT is located in India. It may be added that another international research institution, World Vegetable Center (WVC) in Taiwan is working on mungbean. Further, some research institutions in Australia and Canada are working on chickpea and lentil, respectively. The germplasm developed by various institutes including ICRISAT, ICARDA and WVC are being used by PAU. The germplasm obtained from Australia and Canada, however, has not shown worth for funneling the same into our crop improvement programmes due to poor adaptation of varieties/germplasm, particularly susceptibility to locally prevalent pathogen-races of major diseases. Further, the Canadian lentil germplasm is of longer maturity duration and does not fit well under our conditions.

On the contrary, there are very strong rice and wheat improvement programmes in different countries, besides IRRI and CIMMYT, which have been working in collaboration with highly positive results. The outcome has been development of germplasm having enhanced productivity as well as resistance to some insect pests in rice and a large number of serious diseases in both wheat and rice. These two crops also got priority over pulses for research to develop crop production-protection technology. Further, the farmer readily provides nutritional inputs as well as applies agro-chemicals whenever there is an incidence of insect pest or disease, the most well known example in our region being yellow rust of wheat. On the other hand, yellow mosaic disease (YMD) in mungbean and urdbean, pod borer complex in pigeonpea, Ascochyta blight in chickpea and rust in lentil continue to be serious bottlenecks in their cultivation. Ascochyta blight in chickpea may sometimes cause even 100% yield loss.

Climate resilience of rice versus pulses

Rice, the crop of rainy season, possesses not only high yielding ability but also better stability of performance than the other crops of that season. It has wide adaptation and climate resilience because of its evolutionary (cultivation in highly diverse eco-systems and different seasons) and improvement history. The main eco-systems are irrigated and rainfed (upland and lowland). In rainfed lowland eco-system rice is grown under shallow water (up to 50 cm depth of water), semi-deep water (50-100 cm depth) and deep water (>100 cm depth) conditions. Further, it is cultivated in different seasons, namely *kharif*, winter and pre-*kharif*. In many regions, it is grown round the year. In Punjab, rice is grown under assured irrigation and when there is drought, the crop yields higher because of longer sunshine hours and fewer incidences of diseases. If there is erratic and/or high rainfall, rice, being water loving plant, suffers the least compared to other *kharif* crops. The yield of pulses drastically drops down in case of higher rains or drought due to various reasons such as excessive/reduced growth, high incidence of diseases and insect pests and even plant mortality.

Yield gains in pulses

The general perception is that there has been no yield enhancement in pulse crops. In fact, there are

appreciable gains in yield of mungbean and chickpea (135-168%) compared to 1950-51, and in pigeonpea (173%) compared to 1970-71 (Table 4). Though, less than wheat and rice (317-332%), it is satisfying in context of resources allocated to pulse crops for research and development and even crop care by the farmer compared to rice and wheat. The yield of urdbean peaked in 1984-85 and that of pigeonpea in 1985-86, that is more than one-third of a century ago and it is a matter of serious concern. The breeding strategy in these crops needs a critical analysis and modifications, particularly in pigeonpea which has very rich germplasm resources. The National Seed Genebank, ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi has 11,411 accessions of pigeonpea, 4017 of mungbean and 2773 of urdbean.

It is pertinent here to consider resource allocation also. Lentil was the first pulse to be cultivated in less than 10,000 ha and urdbean, the second. It happened in 1983-84 for lentil and in 1989-90 for urdbean. The resultant reprioritization due to reduction in area accompanied by resource crunch, resulted in weakening the lentil and urdbean improvement programmes.

It may, however, be added that expression of yield depends on genotype (genes for yield and resistance/ tolerance to diseases and insect pests and other traits), environment (seed and soil quality, water and fertilizers/ biofertilizers application, plant health care besides climatic conditions) and interaction between genotype and environment (ability to withstand abiotic stresses and respond to better management).

With the declining importance of pulse crops, these were not much favoured by the farmers and were shifted to marginal lands and received less care for seed quality, nutrition and plant health care compared to rice, wheat and other crops like maize, cotton, sugarcane and brassicas. Under these conditions, the genotype does not express its potential. Therefore, the pulses have wider gap between the yield obtained by the scientists in demonstrations and that by farmers when compared with rice and wheat. With an aim to get higher yield, farmers apply sometimes higher than optimal dose of fertilizers and irrigations to rice, fertilizers to wheat and pesticides in rice even when the insect-pest incidence is below the threshold level. In fact, the cultivation practices for pulses *vs* rice and wheat are so diverse that a comparison of yield improvement under farmer field conditions does not look to be a justifiable exercise.

Prospects

There is an urgent need to strengthen the germplasm base and research. The literature should be surveyed for the germplasm of our interest not only of cultivated pulses but also of their wild relatives should be obtained from indigenous and exotic sources. The important common traits for all major pulses are response to better management, high productivity, desirable plant type, maturity duration and quality traits such as high protein, tryptophan, good culinary properties and low anti-nutritional factors. Incidence of diseases and insect pests had adversely affected the productivity and production of various pulse crops in the past, e.g. pod borer complex (*Maruca vitrata* and *Helicoverpa armigera*) in pigeonpea; YMD in mungbean and urdbean; rust in lentil; and outbreak of Ascochyta blight epidemics in second half of 1960s and in 1980-81 and 1981-82 in case of chickpea (Singh *et al*., 1982, 1984).

There is need to incorporate resistance to pod borer complex and Phytophthora stem blight, dwarf plant type, and synchronous and early maturity in pigeonpea; long maturity duration, resistance to YMD and other foliar diseases (Cercospora leaf spot, bacterial leaf spot), and synchronous maturity in mungbean and urdbean; Ascochyta blight and Botrytis grey mould diseases, tall and erect plant type in chickpea; and resistance to lentil rust and tall and erect plant type in lentil: herbicide tolerance and plant type suitable for mechanical harvesting in all crops using indigenous/ exotic germplasm resources and wild relatives.

The breeding programmes including prebreeding need to be enlarged with a focus on enhancement of yield and incorporation of resistance/ tolerance to major diseases and insect pests and impart climate resilience to minimize the adverse effects of climate volatility. In *kharif* season, pulse crops suffer badly from excess water stress. Research on breeding stress tolerance should be accompanied with agronomic manipulations, such as date of sowing, bed sowing, etc. Chickpea, lentil and pigeonpea respond to high fertility soils, but increased application, primarily of N is often counterproductive. Dosage splitting based strategies augmented with micronutrient application in light soils may prove useful. In case of pest control, integrated pest management strategies based on minimal use of chemical pesticides is the need of hour. A package of all these technologies will pave the way for higher and stable yields. Further, mechanization of various operations is also going to play an important role in making these crops competitive with rice, wheat and other crops in Punjab.

To promote the cultivation of pulses by the farmers, there is an urgent need to provide a level playing ground for supply of inputs and marketing. Initially the support needed must be high to create infrastructure and make these crops more remunerative than rice and wheat. With time the pulses may retrieve fertile soils and regain faith of the farmer, the support may be decreased to

the level of rice and wheat. The promotion of pulses cultivation will help the state to save electricity, irrigation water and fertilizers and will also improve soil health.

There is an urgent need to relook into the experimental variety testing system. In India, pulses are mostly cultivated under low input, marginal, rainfed or limited irrigation expanses in Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Uttar Pradesh, etc. Therefore, ICAR-All India Coordinated Research Project (AICRP) has to focus on these agro-ecologies. The breeding material, thus developed, is adapted to suboptimal conditions. Thus, the AICRP programme may be blurring the pulse research focus at PAU, as Punjab has irrigated, relatively high input and better managed agricultural system and needs stress tolerant and input responsive varieties and technologies. Keeping this in view, PAU started evaluation of germplasm of mungbean, chickpea and lentil and under irrigated, high input (nitrogen, phosphorus) conditions in 2018-19 to identify those carrying high yield genes. It is planned to expand it to have a pulses research sub-programme catering to the specific agro-ecology of this region.

In pigeonpea, moderate level of tolerance to pod borer complex has been introgressed from wild relative (*C. scarabaeoides*) and an interspecific derivative, AL 1747, has been registered as a genetic stock by NBPGR. Recently interspecific derivatives have been developed from another cross of cultivated pigeonpea with *C. scarabaeoides* which recorded less than 10% pod damage by *M. vitrata*, and some others were found resistant to Phytophthora stem blight.

Initially, the varieties of pigeonpea (e.g. T21 released in 1973) had long duration of about 160 days. The long duration varieties did not fit well in pigeonpea-wheat rotation. Therefore, the major focus of the breeding programmes has been to shorten crop duration. There has been significant progress with respect to this objective. The latest variety AL 882, released in 2018 matures in less than 135 days, and it has also shown promise under new agronomic plant geometry-high plant density under late planting conditions. With this success in shortening the maturity duration, it is right time to focus breeding objectives towards yield and stability of performance.

A mungbean variety, ML 2056, released in 2016 has resistance to YMD and is performing well at farmers' fields. Further, the resistance to YMD has been incorporated in mungbean from urdbean and ricebean (*V. umbellata*) and the interspecific derivatives, SML 1808, SML 1839 (mungbean x urdbean) and SML 2015 and SML 2016 (mungbean x ricebean) having high level of resistance and good yield potential have been identified and are under initial replicated evaluation . In addition, some promising donors, ML 1194, ML 1299 and ML 1354, possessing stable resistance to YMD have been identified. In case of urdbean, variety Mash 114 has been developed from urdbean x ricebean cross and was released for cultivation in Punjab in 2008. It has maintained resistance to YMD.

A high yielding chickpea variety, PBG 7, resistant to Ascochyta blight has been released in 2015 and it is performing well in farmers' fields. Further, a number of highly stable breeding lines for Ascochyta blight resistance have been developed and two genetic stocks (GL 84100, GL 87045) have been registered with NBPGR. Resistance to Ascochyta blight and Botrytis grey mould diseases has been introgressed into elite chickpea lines from wild species (*C. pinnatifidum, C. reticulatum and C. judaicum*). A high yielding variety GL 13042, developed from interspecific cross, is being tested in adaptive research trials (ARTs) in the farmer fields, the last step in the evaluation protocol, during 2019-20. It has moderate level of resistance to Ascochyta blight and Botrytis grey mould diseases. This will be the first variety developed from interspecific cross of cultivated chickpea with *C. judaicum*.

A rust resistant variety LL931 was developed in 2009 which has now become susceptible. A new rust resistant variety LL1373 is under evaluation in ARTs during *rabi* 2019-20. Further, high yielding germplasm should be obtained from Canada and channeled into recombination breeding to develop materials having maturity and other traits enabling good performance under Punjab agro-ecology.

Conclusions

Pulses are an integral part of our diet and these crops used to be an important component of our cropping system. The area under mungbean, urdbean and chickpea started decreasing in 1950s and that under lentil in early 1960s, i.e. before the era of Green Revolution ushered in. The factors responsible for it were launch of 'Grow More Food Campaign' in 1948, emphasis on expansion of irrigation facilities, availability of chemical fertilizers and above all focus on achieving national food security based on two most important staples, rice and wheat. The process of dominance of rice and wheat got accelerated with Green Revolution which was technology led and supported by many other factors. In spite of that the area under urdbean picked up in second half of 1960s and that under mungbean in 1980s. The area under *kharif* pulses was also augmented by the cultivation of pigeonpea by the end of 1960s. In TE1986-87 *kharif* pulses registered highest total area and production. There was decline thereafter and overtime all pulse crops have been marginalized and each of these is now being cultivated in less than 5,000 ha. The factors responsible for this include inherent

lower yield and responsiveness to better management and high inputs (irrigation, fertilizers) due to evolutionary history, less intensive research efforts (particularly in mungbean, urdbean and pigeonpea) compared to rice and wheat and framing of policies focused on achieving national food security. Besides allocation of larger resources to research, there have been incentives to develop irrigation facilities, provision of inputs like seed, fertilizer and agro-chemicals at subsidized price, development of marketing infrastructure and above all assured procurement of rice and wheat at remunerative minimum support price and supply of free electricity and canal water that favoured particularly cultivation of rice. It is concluded that predominance of rice-wheat cropping system at the cost of pulse crops is result of many factors rather than due to Green Revolution alone as is generally believed.

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