# Policy Paper

## Diversification of Cropping System in Punjab and Haryana through Cultivation of Maize, Pulses and Oilseeds


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Soybean: Nita Khandekar and Sanjay Gupta
Mustard: P.K. Rai and R.S. Jat

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# MESSAGE

I am happy to note that a policy paper on "Diversification of Cropping System in Punjab and Haryana through Cultivation of Maize, Pulses and Oilseeds" has been conceptualised. This policy paper presents the potential of alternate cropping systems compared to the traditional rice-wheat system. The Green Revolution brought significant growth in agricultural production. The technology-driven revolution made Punjab and Haryana as the epicentre of 'Green revolution'. The paradigm shift brought by the green revolution technology was cultivation of rice, an alien and water-intensive crop to these states and made rice-wheat rotation the most prevalent cropping pattern. These two states experienced a rapid expansion of area under paddy. Policy support for MSP in favour of rice and wheat phased out the other crops. The rice - wheat cropping system threatened the sustainability of agriculture in this region with lowering of water table and rice residue burning causing serious threat to human and animal health.

I hope that the publication will be useful to the policy makers, researchers and extension personnel. I congratulate the authors and contributors in bringing out this useful Policy Paper.

**(T. Mohapatra)**

**Date: 17th June 2021**
**Place: New Delhi-110 001**

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# FOREWORD

Punjab and Haryana have contributed significantly towards ensuring food security of the nation by revolutionizing the cultivation of rice and wheat. The dramatic changes in the scenario took place in mid 1960s when area under rice and wheat started increasing in these states. This was coupled with steady increase in productivity due to improved seeds, better crop management encompassing irrigation and fertilizer application and assured procurement under minimum support price (MSP) of these two crops. Though comparable technologies in terms of varieties and crop production are available, the policy support favoured rice and wheat, marginalizing other crops like maize, pulses, mustard and cotton. Though wheat has been a predominant crop in the region for ages, rice was a new introduction. With lucrative return due to policy support the rice-wheat cropping system rapidly spread across Punjab and Haryana, leading to largely mono cropping in the region. Though the rice-wheat cropping system started with canal irrigation, soon tube well irrigation replaced other, putting tremendous pressure on ground water on one hand and the energy budget on the other. Rampant use of agro-chemicals to realize higher productivity adversely affected the environment. The increase in rice and wheat led to massive procurement of these two crops resulting in pressure on public expenditure on procurement and storage. Rice crop with lower decomposition rate has created the problem of residue management. Widespread rice straw burning is attributed to poor air quality in the north-western Indo-Gangetic plains and in the National Capital Region, which has put the country on the world radar. Over the last three years Government of India has invested heavily in supplying machinery to manage rice straw. However, this has given limited result. It is right time to give renewed emphasis on alternate crops to address the adverse issues due to rampant cultivation of rice. Crop diversification is bound to bring a lot of changes in the scenario. However, the process of diversification needs to be seen in the prism of system approach rather than individual crop basis.

Maize, soybean and pigeonpea have the potential to diversify the rice cultivation during *kharif* season. During *rabi* season mustard can be an alternative to diversify the wheat cultivation. Maize has dual advantage as it is both, an industrial as well as food and fodder crop. In this context, the Policy Paper on "*Diversification of Cropping System in Punjab and Haryana through Cultivation of Maize, Pulses and Oilseeds*" can throw light on the advantages of various alternate cropping systems compared to the traditional rice-wheat cropping system, in which ICAR will play the role o technology provider implemented by the state governments. I appreciate the efforts of the ICAR Crop Science Division Institutes in bringing out this timely Policy Paper. I am sure that this will give new direction towards diversification of cropping system in Indo-Gangetic Plains benefitting the farmers, consumers and environment. I complement the authors and contributors for their significant contribution to this Policy Paper.

**(T.R. Sharma)**

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# PREFACE

Rice and wheat have contributed significantly to bring India from a situation of ship-to-mouth to self-sufficiency in food production through the most celebrated phenomenon in agriculture, *the Green Revolution*. As a result, the food production has risen from 82.02 million tonnes in 1960 to 305.44 million tonnes in 2020-21. The states of Punjab and Haryana played a crucial role in this regard wherein the acreage under rice-wheat cropping system surpassed all the crops and cropping systems. Cereal based monocropping is the most common phenomenon in the region. Overdependence of these dual cereal crops (rice and wheat) on tube well irrigation has resulted in depletion of the ground water to its critical level. In addition, wide spread utilization of fertilizers and plant protection chemicals have further contaminated both ground water and environment causing adverse effects on health of both human and animals. Large scale procurement of rice and wheat, and their storage and distribution have also put huge budgetary pressure on the economy, which has become unsustainable in long run. Besides these, the huge left over crop residue from rice, with poor nutritive value and poor decomposition rate, has become the most challenging task to manage it in a sustainable manner. Happy seeder, super seeder, rice-based power plant and paddy straw decomposer have received a lot of attention in recent years with the support from Central Sector Scheme on *in-situ* Management of Paddy Straw. However, these have given limited success. Such schemes alone may not yield desired results unless complemented with diversification of the rice-wheat cropping system with much more viable and profitable cropping systems. Efforts have been made in this Policy Paper on "*Diversification of Cropping System in Punjab and Haryana through Cultivation of Maize, Pulses and Oilseeds*" to propose alternate cropping systems for maximization of system productivity and return, which would also address the issues concerning ground water depletion, residue burning and pressure on public exchequer. Implementation of the alternate cropping systems in at least 40-50% of currently area under rice-wheat in Punjab and Haryana could significantly reduce the adverse effects of rice-wheat cropping system. While implementing the policy, ICAR and its constituent institutes will provide the technological stopgap, while implementation will have to be made by respective state governments and state agricultural universities through its network of Krishi Vigyan Kendras and extension agencies under the departments of agriculture.

The authors sincerely thank the Secretary DARE & Director General, ICAR and Deputy Director General (Crop Science), ICAR for their critical comments in improving the discussion and content in the paper. Without their support and encouragement it would not be possible to bring out the document. The inputs from the Directors of ICAR-Indian Agricultural Research Institute and ICAR-National Institute of Agricultural Economics and Policy Research are sincerely acknowledged. The authors deeply value the contribution of many scientists, who could not be named here, in formulating this document.

**Authors**

# CONTENTS

**Irrigation in rice field**

**Rice straw burning**

## 1. Operating environment and background

The Green Revolution of 1960s transformed the course of Indian agriculture bringing about an exponential growth in agricultural production and helped to achieve food security. The technology-driven revolution was comprised of a package of subsidized modern inputs – irrigation, improved seeds, fertilizers and pesticides complemented with public procurement and price support policies and extension services.

- The states of Punjab and Haryana became the epicentre of 'Green Revolution'. These two states experienced a rapid expansion of area under paddy, from 4.77 lac ha in 1966 to 45.50 lac ha in 2018 (Fig. 1). The total area under wheat in these two states also increased from 23.53 lac ha in 1966 to 60.73 lac ha in 2018. During the same period, the area under maize declined drastically. In Punjab, maize area has reduced from 4.44 lac ha to 1.09 lac ha during the mentioned period, while in Haryana the corresponding figures are 87 thousand ha and 5.9 thousand ha, respectively. The cumulative area under pigeonpea during 1966 was 7.2 thousand ha, which dropped to 4.2 thousand ha. The area under rapeseed and mustard showed a declining trend in Punjab from 116 thousand ha in 1966 to 30.5 thousand ha in 2018. However, in Haryana it increased from 198 to 609 thousand ha during the same period.

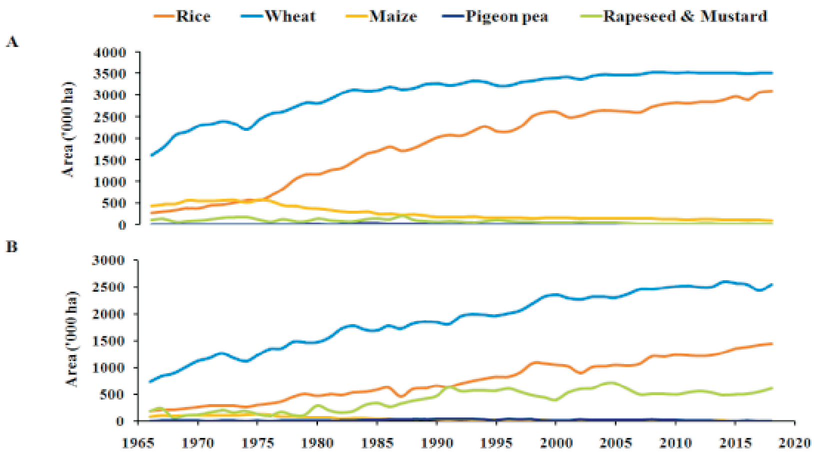



**Fig. 1. Trends of area under rice, wheat, maize, pigeonpea, rapessed & mustard in Punjab (A) and Haryana (B)**

- In Punjab alone the rice area increased from 5.5% to about 39.5% of the gross cropped area during the period from 1966 to 2018 (Fig. 2).The rice-wheat cropping pattern has inflated from about 37% of the total cultivated area in 1966 to about 84% in 2018 and marginalized the traditional maize-wheat cropping pattern and other coarse cereals and pulses.
- Haryana experienced shift in area share of rice-wheat cropping system from 20% in 1966 to about 61% of the gross cropped area in 2018, further marginalizing prevalent crops like maize, oilseeds and pulses.

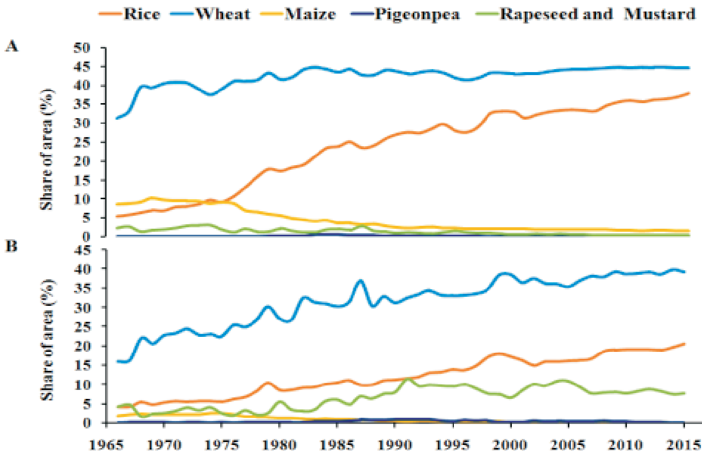



**Fig. 2. Trends of share of area(%) under rice, wheat, maize, pigeonpea, rapessed & mustard in Punjab (A) and Haryana (B)**

- Expansion of canal irrigation system in Punjab has significantly contributed towards initial increase in rice area. However, with the irrigation sources expanded from surface canal systems to tube-well based irrigation the share of canals plunged from 38.5% in 1966 to 28.6% in 2018, while that of tube-wells increased from 21.2% to 71.0% during the same period. Rural electrification and subsidised power have caused overdependence on ground water and notably the number of tube-wells increased from 1.92 lakhs in 1970 to 6.0 lakhs in 1980 and to more than 14.76 lakhs in 2019-20 (GoP, 2020). In other words, currently there are about 36 tube-wells per sq. km of the net sown area in Punjab. Out of the total tube wells, 13.36 lakhs (>90%) are electric operated tube wells (GoP, 2020).
- In Haryana, the share of tube well irrigated area is about 62% in 2018. During 2018, more than 8.21 lakhs tube wells were operated for irrigation purpose. About 5.46 lakhs tube wells (>66%) are electricity powered (GoH, 2020).
- Over exploitation of groundwater led to the decline in ground water table in north western India between 1973 and 2001 @ ~0.2 m per year, which has accelerated by five-fold (@ 1.0 m per year) between 2000 and 2006 (Jat *et al.*, 2019). This has also led to increased energy demand for pumping and increased cost for installing deeper submersible pumps. The Punjab government gave free electricity worth of around Rs.7180 crores to the farmers during 2020-21, over 70% of this goes to rice crop cultivation alone (Anonymous, 2021). On the other hand in Haryana, the electricity supply to farmers is highly subsidized and, on average, farmers pay only Rs. 0.11/kWh against a cost of supply of Rs. 7.34/kWh. Annual farm subsidy burden of Rs. 6196.90 crores, amounting to an average per pump annual subsidy of Rs. 101220 (Anonymous, 2019).
- The groundwater development (ratio of gross groundwater draft for all uses to net groundwater availability) in Punjab and Haryana is 166.0% (highest in the country)

and 137.0%, respectively, which is well above the national average of 63.3%. Out of the 138 blocks in Punjab assessed for ground water, 109 blocks have been categorized as 'Over-exploited', two as 'Critical', five as 'Semi-critical' and 22 as 'Safe' with no saline block in the state. In Haryana, out of total 128 blocks assessed for ground water, 78 have been categorized as 'Over-exploited', three as 'Critical', 21 as 'Semi Critical' and 26 as 'Safe'(CGWB, 2019).

- With increase in area under rice and wheat in Punjab and Haryana, the rice production has increased from 5.61 lakh tonnes to about 173.38 lakh tonnes between 1966 and 2018, while wheat production has increased from 35.48 lakh tonnes to 308.36 lakh tonnes during the mentioned period. Public procurement of rice and wheat has caused tremendous pressure on the capacity of storage of the grains. Both public procurement and storage have incurred huge investment of public money, which often turns out to be unsustainable. During 2018, 152.75 lakh tonnes of rice and 179.86 lakh tonnes of wheat were procured from these two states (GoI, 2019), which amounts to Rs. 26,731.25 crores and Rs. 33,094.24 crores, respectively .
- In addition, rice cultivation has created some serious problems and environmental threats, *viz*., depletion of inherent soil fertility, lowering of water table, increased soil and water pollution (Chauhan *et al*., 2012) and enhanced greenhouse gas (GHG) emission in rice cultivation (Gupta *et al*., 2015) or burning of its residue resulted in serious threat to human and animal health (Bhuvaneshwari *et al*., 2019). Of late the growth rates of rice and wheat yields are either stagnating or declining, say rice yield growth rate in Punjab in 1970s was 1.9% (1970-1980) which is currently at 0.3% (2008-2018). During the same time, the growth rates of wheat yields was 2.0% (1970-1980) and 1.5% (2008-2018), respectively. Corresponding figures for Haryana are 1.9% and -0.7% for rice, and 1.3% and 1.2% for wheat, respectively (DAC, 2021).

## 2. Candidate crops for diversification of rice-wheat cropping system

The adverse environmental, economic and health impacts of rice-wheat cropping system in the north-western Indo-Gangetic plains calls for immediate diversification of this cropping system through introduction of more sustainable cropping system(s). This requires three considerations, *viz*.,

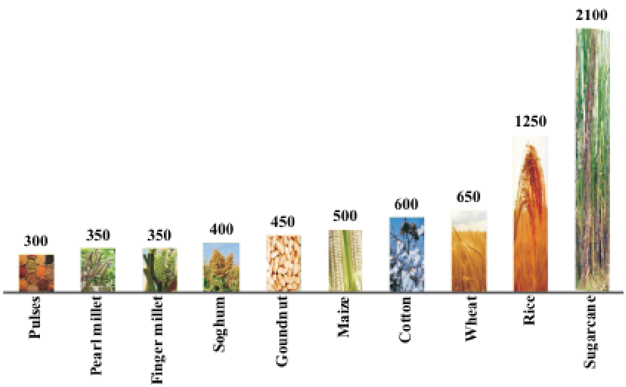



**Fig. 3. Relative water requirement (mm) of various crops**

water requirement of the crops, economic return and possible market. With relative lower water requirement coarse cereals, pulses and oilseeds can be a potent alternative to water guzzling crops like rice and sugarcane (Fig. 3). Considering water requirement and possible market demands and economic returns major crops which can replace rice during *kharif* season are maize, pigeonpea and soybean, and mustard and chickpea during *rabi* season to replace wheat. Mungbean with short duration can fit excellently well in these alternate crops-based cropping systems ensuring additional income to the farmers and additional fertility to the soil.

## A. Maize

Maize has almost one third water requirement of rice and less than one fourth of sugarcane, with cropping duration (100-110 days) less than rice (120 days) and sugarcane (~300 days). One Kg of maize grain requires 800-1000 lt of water against 3000-3500 lt of water for one Kg rice production. Maize residue with higher C:N ratio than rice has faster decomposition, thus has ability to add organic carbon to the soil and improving soil quality. Maize, particularly specialty corns can effectively be grown under organic system as sole or inter crop with other vegetables in peri-urban agriculture, giving avenue for additional income to the farmers. Maize followed by wheat has higher system productivity than rice-wheat system due to scope for early sowing of wheat crop leading to escape of terminal drought. Maize (900-1400 kg $CO_2$ eq/ha) has very less global warming potential (GWP) as compared to rice (3700-4700 kg $CO_2$ eq/ha). Rice production gives nearly 300-400 kg $CO_2$ eq/ha due to methane emission which is not with maize cultivation. Maize production consumes only 278 kwh/ha electricity as against that of rice with 2925 kwh/ha.

Maize has predominantly industrial uses like in feed, starch and recently for ethanol production, besides having niche area in processed foods in form of breakfast cereals, snacks and pet food in addition to use of specialized maize, *viz*., baby corn, sweet corn, popcorn and silage maize. Supply of good quality (dry and aflatoxin free) maize in bulk quantity can potentially help in establishment of such industries in the states and encourage contract farming benefitting both maize farmers and the industries besides generating employments and addressing environmental and health issues.

a. *Feed industry*: Maize with high energy value and less anti-nutritional properties like low fibre content has tremendous demand in feed industry. Over 47% maize is currently used in poultry feed and 13% in animal feed (Fig. 4). The current size of feed industry is 85-90 million tonnes. With projected growth rate of 8% in feed sector, particularly in poultry and cattle feed, demand for maize will increase by many folds. Punjab and Haryana can be a major supplier of maize in this regard.

b. *Starch industry*: The starch industry in India has a crushing capacity of approximately 65 lakhs tonnes. Maize is the most common raw material in starch industry. With projected growth of 5.1% in starch industry, demand for maize is going to increase further. Maize starch has wide utility in food, paper, pharmaceutical and textile industry, and it can be used for production of bio-plastics, a way to address the issue of plastic pollution. A steady supply of maize will open up the avenue of employment generation in the region.

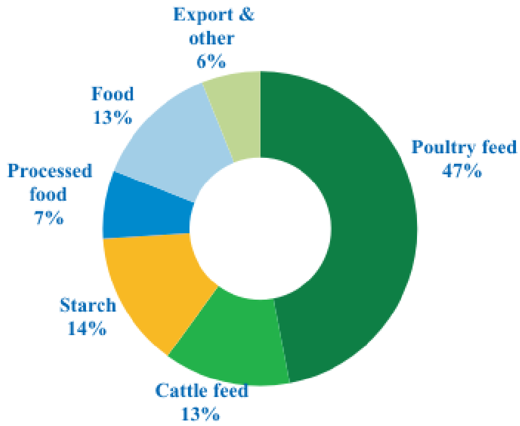



**Fig. 4. Pattern of usage of maize in India**

c. *Ethanol industry*: The government has set targets of 10% bio-ethanol blending of petrol by 2022 from current target of 5%, which is further aimed to reach 20% by 2030 to curb carbon emissions and reduce dependence of the India on imported crude oil. With 5% targeted blending the demand for ethanol stands at 4.2 billion litres, which by 2022 with 10% blending target sets to cross 6 billion litres, and by 2030 with 20% blending target the demand will cross 10 billion litres. Against this, the current production of bio-ethanol in the country is around 3.0 billion litres. Sugarcane is the main source of bio-ethanol in India, while across the world maize grains are extensively used for ethanol production. Contrary to maize, sugarcane requires over four times water (Fig. 3) and has crop duration of 10-15 months against maize of around 100-110 days. The yield of ethanol from sugarcane is ~5000 l/ha (70 t/ha cane yield) while maize gives ~2000 l/ha (5 t/ha grain yield). Thus, per unit time energy output from maize is much higher than sugarcane with much lesser water footprint. Maize in ethanol production also gives a high protein and oil rich nutritious feed DDGS (Distilleries Dried Grains and Soluble) as a valuable by-product. Ethanol industry with growth rate of 12.5% can create huge market demand for maize grains.

d. *Processed food industry*: Nearly, 10 lakh tonnes of maize is consumed in processed food industry to prepare snacks, breakfast cereals and pet foods. Processed food industry with 11.5% growth rate can absorb significant proportion of maize produced in the country. Popcorn industry has current size of 90,000 tonnes with a market cap of around Rs. 550 crores. However, 40% of the popcorn is imported, mainly from the USA. Baby corn and sweet corn also have huge potential to create rural entrepreneurship and catching international market with added advantage to supplement the dairy industry with its by- products.

e. *Silage maize, as alternate source of fodder and livelihood*: Maize silage has huge potential with current market size of 4-5 million tons. With roughly 4.5% growth rate of dairy sector, silage business is going to play an important role. Silage maize with duration of around 80 days can increase the cropping intensity significantly and help in doubling farmers' income.

The cumulative demands as food, feed and starch have driven the maize production in the country, which has increased by over 12 folds as compared to 1960s. However, the projected growth rates in respective maize-based industries the demand for maize is expected to increase to 33 million tonnes by 2025 and nearly 43 million tonnes by 2030 (Fig. 5). In 2020-21 India has produced record maize production of 30.24 mt. Thus, there is immense scope that increased demand of maize in domestic market itself can absorb the increased production. International demand for maize is also very high and India has strategic advantage to cater the need of maize in South-East Asian (SEA) countries. With increased international maize price, Indian maize can have better access in world trade of maize grains.

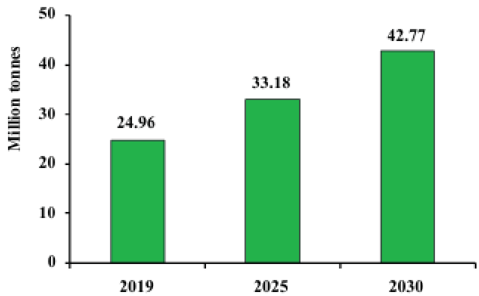


**Fig. 5. Projected demand (million tonnes) of maize in India**

## B. Pulses

Pulses are a major source of protein for majority of Indians, particularly the vegetarian population. India is the largest producer, consumer and importer of pulses in the world. The production trend in pulses in Fig. 6 indicates that the country produced only 12.0-14.0 million tonnes of pulses till 2010, which has reached 24.0-25.0 million tonnes at present.

Pulses such as chickpea, pigeonpea, lentils, beans and peas form important part of general food basket in India. Promoting cultivation of pulses can help India overcome problem of malnutrition, improve soil fertility by nitrogen fixation and provide income support to farmers. Though India has attained self-sufficiency in pulse production, India can be a potential exporter of pulses like pigeonpea, chickpea, mungbean etc.

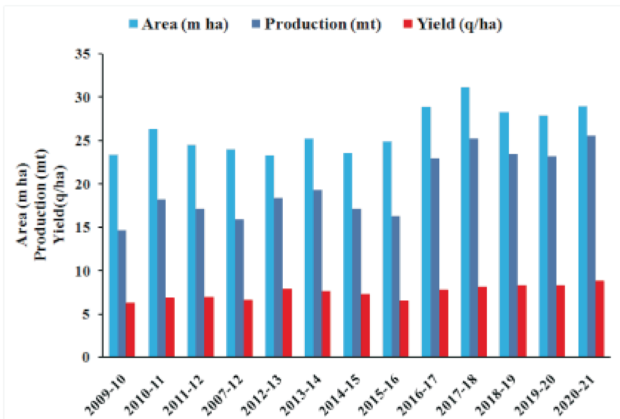


**Fig. 6. Area, production and yield trends of pulses in India**

Per cent share of different pulses in terms of production is given in Fig. 7 (with the highest of 45% for chickpea followed by 17% for pigeonpea) along with the future target for the commodity (Fig 8).

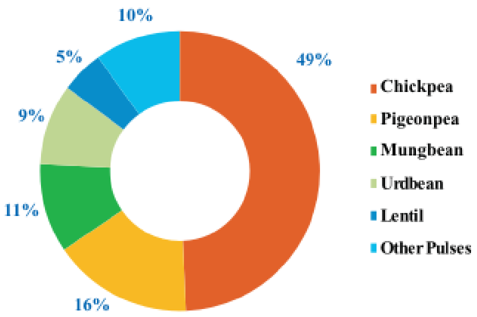



**Fig. 7. Share of different pulses in overall pulse production**

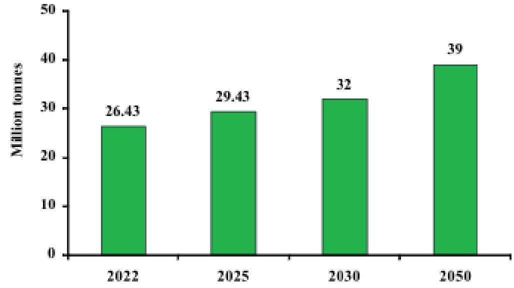



**Fig. 8. Trend of demand for pulses in India**

Pulses consume much lesser water than rice (Fig. 3). Pulses need to be promoted as it plays a crucial role in ensuring food security, public health, promoting environmental sustainability and climate change mitigation. Keeping in view of the benefits accrued through pulses, diversification of rice especially with pigeonpea in rice–wheat cropping system assumes greater significance with the following advantages.

a. *Biological Nitrogen fixation*: Pigeonpea crop fixes around 40 kg N/ha through biological nitrogen fixation (BNF) which is equivalent to 87 kg urea (Rs. 870 without subsidy) leading to direct saving following its cultivation. Besides the crop also has a leaf and flower fall (and root residues) of 2-3 t/ha which supplies around 8-16 kg N, 2.5-5 kg P and 13.5-24 kg of K per ha to the subsequent crop(s) in rotation. In addition, pigeonpea crop requires less fertilizer as compared to rice and is regarded as soil building crop.

*b.* *Water use efficiency*: Water use efficiency is more than double for pulses (3 kg grain/ha-mm for irrigated rice against 6-8kg/ha-mm for pigeonpea.

*c.* *Nutritional quality*: Nutritionally superiority of pigeonpea gives it an edge over rice. A 100 gram of rice (white, cooked) contains approximately 130 Cal energy, 28.7 g carbohydrate, 2.36 g protein and 0.19 g fat, while pigeonpea contains 335 Cal energy, 22.3% protein, 57.6% carbohydrate, 1.7% fat, 124 mg Ca, 304 mg P, 5.8 mg Fe, 133 mg Mg and a rich source of amino acids. Pulses are rich in lysine (67.1 mg compared to 30.5 mg of lysine /100 gram protein in cereals). Pulses are also rich in dietary fiber (fiber along with low fat and phytates causing lowering in blood cholesterol), hormone analogs (hypoglycemic effect i.e., lowering of blood sugar) and antioxidants (protection against cancer). Health benefits of pulses are thus huge as these are having high nutritional value. Besides these, pulses also prevent several chronic diseases such as cardiovascular ailments, diabetes, blood pressure, obesity and cancer. Pulses have low glycemic index (29-48) which is attributed to presence of slowly digestible starches and resistant starches. Therefore, these are considered as nutritionally important crops.

d. *Multiple uses*: Pulses, especially pigeonpea has multiple usages as *dal*, *dal*-mix and by-products for biscuits and other value added products. Traditionally, it has been used with proven diversity including lac production, fuel wood, soil conservation, fodder, food and medicine.

e. *Cost of production*: Pulses are having lower cost of production (Rs. 6000 to 9000/ha less) over that of rice as rice has a relatively complex process incurring higher expenses for growing it (nursery raising, transplanting etc). Besides these, relative average gross return for pigeonpea is higher (173% for pigeonpea compared to 100% for rice).

f. *Import bill*: There is possibility of lowering down of country's import bill through higher production of pulses. In fact, as a result of higher production of pulses, imports of pulses declined to about 1.8 million tonnes during April-Dec 2018, as against over 5 million tonnes during April-Dec 2017. Similarly, pulses especially pigeonpea has a great demand within the country and outside including SE Asia.

## C. Oilseeds

India meets 60% of the domestic edible oil requirements valued Rs. 78000 crores through imports. The country needs 25 million tonnes of edible oils to meet its present requirement at the current consumption level of 19 kg per person per annum. It has to increase 33.4 million tonnes edible oils from 47.7 million tons oilseed to feed 1.43 billion population by 2025. In this context, during *kharif* season soybean and during *rabi* season mustard can be potential crops to replace area under rice and wheat, respectively.

### C1. Soybean

Soybean is one of the main oil seed crop and is the only vegetable crop with high protein content. Soymilk is cheaper than other sources and has a promise for flavoured milk with varieties developed having less beany flavour. Tofu, prepared from soybean is highly nutritious and is complimentary to paneer. Soybean also has many therapeutic usages like overcoming problems related to menopause because of the presence of estrogen like compound and presence of flavones that protect from cancer. Soybean holds potential as vegetable to be grown between April to July when green peas are not locally available. Indian soybean deoiled cake too is in high demand and accrues foreign exchange to the worth of Rs.3349 crores during 2019-20, which is extensively used in feed industry along with maize.

a. *Crop demand in present and future*: Soybean processing industries are operated only to their 50% capacity and the huge demand for oil and feed exists in the country, which may be met by increasing soybean production. Soybean also has high potential in the secondary agriculture sector.

b. *Industrial usage*: Soybean has industrial usages apart from edible oil and the food usage such as soy milk, soy chunk etc. Soy isolate may have use as supplement and protein bars. Lecithin is a by-product used in the chocolate industry, fermented soybean, vegetable soybean and feed are other uses wherein soybean may find a niche market.

c. *Profitability*: The cost of cultivation for soybean is much lower (around Rs. 30,000) as compared to that of rice (Rs. 78,000).

d. *Fertilizer subsidy*: The estimated N contributed through residual biomass of soybean (RBNS) that include biological nitrogen fixation, leaf fall, root nodules and rhizo deposition accounts to around 50 kg N/ha which corresponds to roughly 110 kg urea. Moreover, soybean also provides other nutrients like P, K and micronutrients for the subsequent crops. The amount of N applied to soybean is only 25 kg N/ha as compared to rice (120 kg N/ha).

e. *Organic production*: With the increasing trend towards organic farming there is great potential of organic food and feed form soybean for domestic use as well as for exports.

f. *Vegetable protein benefits*: Soybean protein is the most economical source of protein and is considered as a complete protein like milk and egg.

g. *Multiple uses of the crop*: Soybean has multiple usages for oil, soy isolate, soy chunk, lecithin, vegetable soybean, fermented soybean, neutraceutical and feed.

h. *Water footprint*: The water use and efficiency concerning soybean cultivation is around 75-80 cm and 20-25 kg $ha\text{-}cm^{-1}$, respectively and these are much better than 90-250 cm for rice.

i. *Soil health and addressing environmental issues*: Soybean cultivation improves soil health through symbiotic nitrogen fixation. Soybean residues may be a substrate for mushroom industry and decompose very fast, not requiring burning unlike the paddy straw. In soybean, maximum values of GHG emissions amount to 59% to 85% are due to $N_2O$ and methane emissions represent less than 3%. In contrast to this maximum GHG emission in rice is from methane which has been estimated to 875 kg/ha/season (Bhat and Beri, 1996) at Ludhiana.

### C2. Mustard

Mustard is a potential *rabi* oilseed crop to replace area under wheat with substantial consumption potential in the industry. It has relatively lesser water requirement (300 mm) compared to wheat (600 mm). The crop has good production potential, where the cultivation is supported with suitable technology intervention and knowledge inputs. It can be grown under diverse agro-climatic zones in both irrigated and rainfed areas with ability of salt tolerance. It is suitable for sole and mixed cropping. This gives higher return with low cost of production. Mustard oil has lowest saturated fatty acids and seed meal has high content (36-38%) of quality of protein.

## 3. Recent area, production and yield of plausible diversifiable crops

Among the proposed crops for diversification of rice-wheat cropping system maize has highest percentage, while soybean has extremely limited area under cultivation in Punjab and none reported in Haryana. Among these crops, maize has the highest yield realization (35.8 q/ha and 28.3 q/ha in Punjab and Haryana, respectively). Though the area of maize has dropped substantially in Punjab over last several decades, mainly due to in roads of rice, in recent past it has recorded a positive growth trend (Fig 9, Annexure I). The area under other crops is relatively stagnant at around 2.45 thousand ha for pigenopea, 30.5 thousand ha for mustard. In case of Haryana the area under maize remains stagnant. The areas under other crops in Haryana, were around 3.0 thousand ha for pigeon pea and 579 thousand ha for mustard.

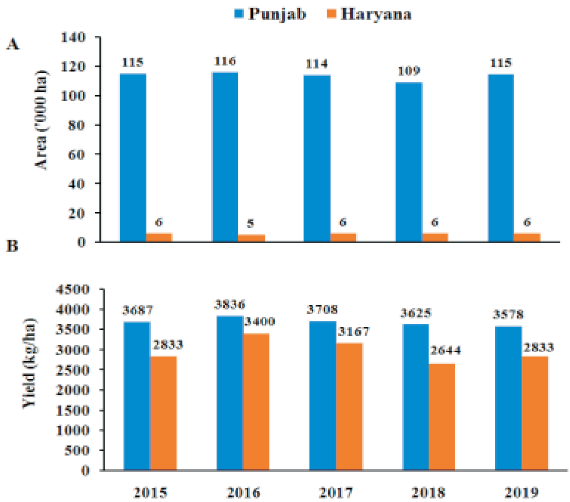



**Fig. 9. Change in maize area (A) and yield (B) in Punjab and Haryana from 2015**

## 4. Value chains of candidate crops

***Maize value chain*:** Maize-based value chain is quite extensive, which principally may be dealt as feed, starch, ethanol, processed food, processed specialty corns (baby corn and popcorn) and silage. While use of feed, starch and ethanol requires establishment of dedicated factories, processing of maize for food like snacks and breakfast cereals or pet food requires smaller processing plants. Baby corn and popcorn processing also can be done in a micro level through aggregation of Farmers Producer Organizations (FPOs), Farmers Producer Companies (FPCs) and Self Help Groups (SHGs).

***Pigeonpea value chain*:** The awareness generation regarding BNF, leaf fall and other carryover effects by pulses in addition to less water use can further convince the farmers to reduce the usage of fertilizers especially N fertilizers. To attain socially optimal level of pulse farming, the pulse growers should be provided additional support for their services to environment also. Encouragement could be provided in the form of equivalent subsidy on phosphorus fertilizers as P application in pulses increases nodulation and nitrogen fixation and balance nutrition besides increasing yield of these crops (ideal NPK ratio of 4:2:1). On ecology front, this could result in reducing GHG emission and prevent other issues associated with synthetic fertilizer based production, like health, eutrophication and pollution. Pigeonpea produced locally can be transported to consumer states for its processing and consumption. It can also be processed locally (*dal*) and transported to consumer states (with better transportability/storability due to split *dal*) for sale (under both PDS and open market). Some of the quality produce can be processed for export (bolder and perfect-colored ones). A part of the produce can be kept as seed for future use. Lot of scope exists for pigeonpea based value addition including its by-product use. Several homemade recipes *(barfi, ladoo, sev, kachri, sweet puries, kachauri masala)* are made from pigeonpea milling by-products. Biscuit is developed incorporating pigeon pea husk and cotyledon powder mixture in different proportions. Value added products from pigeonpea milling by-product are rich in protein, fiber and phenols, thus, have higher food value. Fractional separation of pigeonpea milling by-product yields 25% cotyledon powder for making *dal* analogue by unheated extrusion. Powder fraction can directly be poured into boiling water to make *dal*. Colour of *dal* is little brownish (due to husk in the mixture) while protein content is similar to dal. Alternatively by-products are useful for soup, gravy thickener and protein enhancer.

***Soybean value chain*:** Soybean is one of the major candidate for crop diversification in Punjab and Haryana with its value chain involving stakeholders at pre-production, production, post production and processing (quality seed, input supplier, mechanization, oil processors, soy food cottage industries for the manufacture of soy products like soy milk, soy paneer (tofu), vegetable soybean, soy protein concentrates, cold oil processing industries) and consumers.

***Mustard value chain*:** Rapeseed-mustard has a broad diversity of oil-types in addition to canola or high-oleic and low-linolenic cultivars. Moreover, its oil contains valuable minor compounds such as tocopherols (vitamin E) and phytosterols. Enhancing such components by breeding may result in value addition. The meal contains relatively high amounts of anti-nutritive fibres, phenolic acids, phytate and glucosinolates. Break down products of glucosinolates such as allyl isothiocyanates, which are present in the seed meal fraction of oilseed Brassica, have anti-cancerous properties. Isolation of these compounds would add value to this crop. The future thrust in quality improvement would be to improve the nutritional and storage quality of rapeseed-mustard seed meal contains high-quality protein that can be used as a valuable animal feed. Biscuits fortified with mustard flour are found acceptable in nutritional, sensory and textural characteristics. Defatted mustard flour can replace wheat flour at 5, 10, 15 and 20% incorporation levels in biscuit preparation. There is scope to establish different value chains from production to processing and supply for quality oil (single zero, double zero, high oleic oils etc.), quality mustard oilcake (primary and secondary products) and secondary oil products (medicinal and medicaments) in the region. Already, Canola mustard is under cultivation in Punjab, which may be increased further to cater the domestic need as well as export promotion.

## 5. Mapping of diversifiable crop specific processing industries in Punjab and Haryana

***Maize*:** Maize is principally used in the feed industry. There are more than 26 feed factories in Punjab and 28 in Haryana (Fig. 10). The feed, mainly poultry feeds produced by these firms are being locally consumed. There is one starch industry in Jalandhar and Yamunanagar each. However, all these factories predominantly import maize grains from outside the states, *viz*., Bihar, Madhya Pradesh, Maharashtra and others. There are 9 distilleries in Punjab and 12 in Haryana (Fig. 10). Though these distilleries absorb much of the locally produced grains, they are also dependent on supply of maize grains from outside the state. Thus, these industries assume much potential to process maize grains if produced locally. Maize-based food processing plants are not documented yet in these states. The food processors are apprehensive of aflatoxin contamination and soft grain traits in the local produce. Speciality corn processing has immense potential. In Ludhiana, there is a baby corn processing unit, which mainly caters the export market in Europe. The baby corn and sweet corn processing hubs in Sonepat district are living examples of the kind of revolution in rural economy these technologies may bring in.

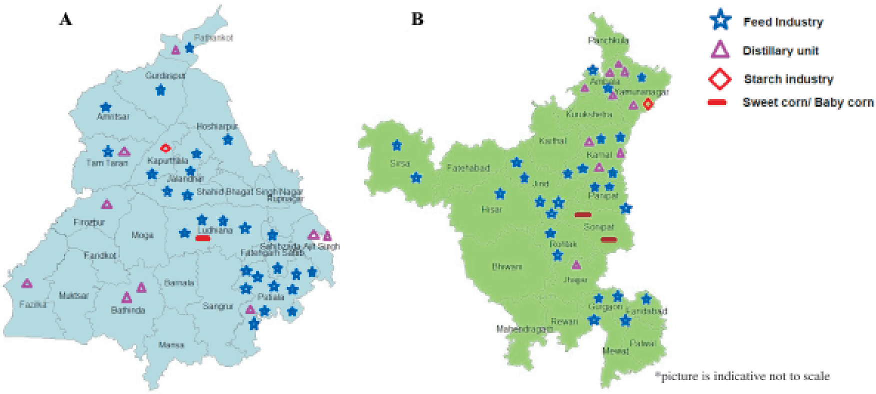



**Fig. 10. Mapping of maize based industries in Punjab (A) and Haryana (B)**

***Pigeonpea*:** With the rising per capita income and increasing population, demand for pulses has increased over the years. There is very little establishment of the processing and value addition industry for pigeon pea in the region owing to very less raw materials availability. The *dal* mills could be established for value addition and the present rice mills establishment could be explored with suitable modification.

***Soybean*:** Punjab is the number one state in utilizing soybean for food usages where about 200 small scale industries (tofu, soy-milk, soy chap, soy nuts etc.) spread over the state are operating presently. However, oil extraction is at a very low scale (~50 Kg/day) and limited to cottage industry since soybean production from these states is negligible.

***Mustard*:** Mustard is principally consumed as edible oil in human diet. The by-product, oil cake is used in animal feed due to high protein content. Oilcake is used for value added products like fortified biscuits and four. The mustard oil is rich in certain

## Table 1. SWOT analysis of plausible crops for diversification in Punjab & Haryana

| Parameters | Maize | Soybean | Pigeonpea | Rapeseed & Mustard |
|---|---|---|---|---|
| Strength | ❖ Mechanized cultivation - Seed to Seed<br>❖ Industrial uses - Feed, Starch and Ethanol<br>❖ High yield and highest growth rate among cereals<br>❖ Water and energy saving - 80% over rice<br>❖ Low GHG emission<br>❖ Diverse uses and types - Sweet corn, Pop corn, Baby corn and Silage<br>❖ Livestock promotion - complement well | ❖ Suitable for mechanized cultivation<br>❖ High protein crop suitable for food usage<br>❖ Industrial uses - high oil and soy meal for feed industry<br>❖ Water and energy saving over rice.<br>❖ Low GHG emission | ❖ Highly nutritive crops<br>❖ Fixes atmospheric nitrogen<br>❖ Industrial uses - Dal and by-product making<br>❖ Water and energy saving (80%) over rice<br>❖ Diverse uses and types like Food, Value addition and Fuel<br>❖ Tolerate partial drought and heat condition<br>❖ Low GHG emission | ❖ Mechanized production, processing and value addition<br>❖ Suited for diverse agro-ecological situations<br>❖ Water energy saving (less than half of wheat)<br>❖ Diverse usages - Quality oil (Canola), Medicaments, Lubricants, Super food etc.<br>❖ Quality oilcake for animal feed<br>❖ Tolerate moderate salinity and drought conditions |
| Weakness | ❖ Waterlogging susceptibility, more at early crop stage<br>❖ High moisture at harvest leading to aflatoxin contamination and lower realized market prices<br>❖ No policy support<br>❖ Lack of local market and linkages | ❖ Lack of market intelligence and linkages<br>❖ Vulnerable to unpredictable climatic variability<br>❖ Limited popularity as food<br>❖ No policy support<br>❖ Lack of awareness about the soybean crop benefits. | ❖ Susceptible to water logging at initial stage<br>❖ Vulnerable to unpredictable climatic variability<br>❖ Lack of market intelligence and linkages | ❖ Susceptible to water logging at initial stage |
| Opportunity | ❖ Market demand-domestic and export<br>❖ Value addition and employment generation<br>❖ Enhanced livestock productivity<br>❖ Demand for bioethanol<br>❖ Gluten free atta is gaining demand<br>❖ Climate change | ❖ Demand of processing industries in adjoining states<br>❖ Opportunity for establishment of high value soy protein isolate industry<br>❖ Value addition and employment generation | ❖ High demand for consumption due to taste<br>❖ Opportunity for establishment of processing industry<br>❖ Value addition and employment generation at block and village level | ❖ Demand in domestic and international market (Canola oil).<br>❖ Value addition and processing<br>❖ Quality animal feed |
| Threat | ❖ Damage by wild animals like blue cow, stray cattle<br>❖ Poor drying and storage facility<br>❖ Emerging insect-Fall Armyworm | ❖ Import of soy and its oil<br>❖ Unpredictable climate<br>❖ Appearance of new diseases | ❖ Problem of blue cows<br>❖ Pod borer infestation<br>❖ Climate change effect is high | ❖ Biotic stresses like aphid and stem rot<br>❖ Climate change (early and terminal heat and frost). |

secondary compounds, which may be separated for medicinal and medicaments usages. Thus, there is lot of potential for both primary and secondary industrial growth and employment generation in this region. In Punjab and Haryana, more than 100 mustard oil extraction units exist, and processing and branding the oil as organic, value-added, *Kachi Ghani* and refined FSSAI certified oils exist. However, most of these units run short of produce locally, and source either seed or *Kachi Ghani* oil from Rajasthan and Uttar Pradesh. There is no documented information about secondary value added products industries, however, these have great potential in near future. Mustard cake in animal feed may also play significant role in increasing milk production and related industries in this region.

## 6. Competitive analysis of various crops *vis-a-vis* rice-wheat cropping system

Any crop substitution should be looked in system perspective, rather than individual crop output. Table 2 makes a comparison of the system perspective of different *kharif* crop based system. It is clearly depicted that alternative cropping systems are much more sustainable than rice-wheat cropping system. Table 3 suggests various cropping systems, which have been compared with the rice-wheat cropping system. It may be observed that the system productivity and profitability from all the alternative cropping systems is higher than that of rice-wheat cropping system with substantial savings on energy/electricity. It is often said that though maize has demand, it has failed to play a key role in diversifying rice in Punjab and Haryana. The realized price difference between rice and maize is key factor in this regard, while rice is procured on assured minimum support price (MSP), maize farmers, on an average receive Rs. 900 per quintal of maize grains in Punjab and Haryana. However, an empirical calculation based on current average productivity of rice and maize shows that rice has marginal advantage over maize provided the MSP is realized in both the crops (Table 4). Thus, to procure maize from one lakh ha vis-a-vis rice there will be additional expenditure of Rs. 89.35 crores in Punjab and Rs. 24.56 crores in Haryana. This cross subsidy can easily be diverted due to the savings in water, electricity and the pollution costs due to rice residue burning. The government can also pay the differential pricing (MSP minus market price) to the farmers directly through direct benefit transfer (DBT) without direct buying and thus expenditure on storage can be reduced substantially. Though the net returns is equal for maize in Punjab, it is higher in Haryana compared to rice but the existing mindset and operating environment focuses more on gross returns. Thus, the initial cross subsidization for energy saving will accelerate the adoption of new system. The cost of cultivation, which is higher in maize can substantially be reduced through introduction of mechanization from seed to seed (Bombaria *et al.,* 2020). The above figures of cross subsidy are with existing productivity of maize in the states. However, extensive introduction of high yielding maize in a cluster manner can potentially increase the average productivity and thus, the cross subsidy may be slowly reduced. However, procurement of maize with this subsidized price needs to be ascertained through implementation of strict law. Considering demands for maize in this region, the price is not expected to be too low in open market.

## Table 2. Candidate crop based cropping system (CS) advantages over rice-wheat CS

| Parameters | Rice-wheat | Maize-based | Pigeonpea-based | Soybean-based |
|---|---|---|---|---|
| Water requ irement | Very high | Low (8-times lesser than rice) | Low | Low |
| Water productivity | Low | High | Very high | High |
| Residue burning | Very high | No such problem. | No such problem. | No such problem. |
| Ground water pollution | Nitrate and pesticide leaching. | No such problem | No such problem. | No such problem. |
| Duration | Long (120-130 days) | 100-110 days | 120-150 days | 120 days |
| Planting/crop establishment | Cumbersome and labour consuming | Easier, only direct seeding | Easier, only direct seeding | Easier, only direct seeding |
| Per day productivity | Less | Higher | Medium | Medium |
| Mechanization | Partially mechanized | Fully mechanized | Not possible | Fully mechanized |
| Soil physical health | Degrading crop | Restoring/improving crop | Restoring/improving crop health | Restoring/improving crop |
| Agrochemicals | More leaching | Less leaching | Less leaching | Less leaching |
| Cropping system optimization | Subsequent crop is affected, resulting in low system productivity & profitability. | Subsequent crops are benefitted and results in higher system productivity and profitability. | Subsequent crops are benefitted and results in higher system productivity and profitability. | Subsequent crops are benefitted and results in higher system productivity and profitability. |
| Climate resilience | A photo synthetically less efficient $C_3$ plant, results in higher emission of GHGs (methane, nitrous oxide) under increased temperature. | A photo synthetically efficient $C_4$ plant, there is no photorespiration under increased temperature results in lesser GHGs emission. | Lesser GHG emission and reduced urea consumption | Lesser GHG emission and reduced urea consumption |
| Policy intervention | Assured procurement at MSP. | Presently no such policy. | Assured procurement at MSP. | Incentivization to farmers as soybean is not an established crop in this region. |
| State requirement/demand | Surplus | Highly deficit | Highly deficit | Highly deficit |
| Use of biomass/residue | High silicon deters for use in livestock, problem of collection, burning due to less turnover time for wheat seeding. | Green fodder is used for animal fodder, easy dry fod der collection, easily decomposable, can be kept on the soil surface with zero-till planting or can be used for mushroom production. | Easily decomposable, can be kept on the soil surface with zero-till planting | Easily decomposable, can be kept on the soil s urface with zero-till planting |
| Livestock promotion | Not much scope as mostly used for food and straw is unsuitable for livestock. | Wider scope for livestock promotion as green fodder, silage and grain for feed. The fodder can be used for grazing/feeding to livestock at any stage of crop growth. It has no risk of any anti-nutritional compound. | Not much scope | Soybean meal in livestock feed |

| Parameters | Rice-wheat | Maize-based | Pigeonpea-based | Soybean-based |
|---|---|---|---|---|
| Poultry industry growth | Less suitable. | Most suitable as major feed ingredient. | - | Most suitable as a feed ingredient. |
| Value addition | Lesser opportunity due to more direct food consumption | More opportunity as thousands of the products can be made from different types of maize. | More opportunity as many products can be made by food processing. | More opportunity as many products can be made by food processing and for oil extraction. |
| Export opportunity | Only basmati has competitive market. | Grain, feed, starch and baby corn has great potential for the export in neighbouring countries as well as high value developed economy due to low cost of internal production and high external demand. | Yes | Yes |
| Conservation agriculture | Very less scope | Highly suitable for conservation agriculture. | Suitable for zero-till wheat growing. | Suitable for zero-till wheat growing. |
| Electricity and power/energy | Very high requirement for water pumping and urea | Very less requirement (82% lesser water than rice) | Very less requirement owing to lesser water and urea | Very less requirement owing to lesser water and urea |
| Transportation cost of commodity | Non-basmati rice used in PDS incurs huge transportation cost to make available in whole country. | Extra cost of transportation incurred in import of maize from other state that increases the cost of raw material for industry at present. | Less due to high demand in each state | Transportation of produce to oil processing industries is required. |
| Handling and post-harvest losses | High, extra infrastructure for storage of surplus rice is required. | Low, no carry stock due to shortage in the state and multiple industrial uses. Need drying and storage silos. | Very low compared to other pulses | Medium, seed viability loses fast and care is required for proper transportation |
| Silage | Not suitable | Best material for making silage which can be used in livestock and exported after meeting internal requirement. | Not suitable | Not suitable |
| Intercropping scope | Not suitable | Most suitable crop for growing pulses, vegetables and flowers due to wide spaced rows of the crop. | Can be intercropped with, bajra, jowar, mungbean & urdbean etc. | Can be intercropped with maize |
| Dietary diversification and nutritional security | Lesser opportunity | Quality protein maize can be integrated in diets of all group person for nutritional security. | Meets the protein requirement at household and National level | Meets the oil and protein requirement and reduced import bill for India. |
| Overall cropping system profitability | Less | More | More profitable @170% return | More |

## Table 3. Comparison of rice-wheat vs plausible futuristic cropping system for diversification in North-western IGP

| Cropping systems | Potential yield (t/ha) | Cost of cultivation (lakh/ha) | Net returns (lakh/ha) | Mechanization | GHG | Soil health | Residue burning problem | Water productivity (kg grain m$^3$) | Market demand | Energy/ electricity saving |
|---|---|---|---|---|---|---|---|---|---|---|
| Maize-wheat-mungbean with CA | 16.04 | 0.82 | 1.85 | Fully mechanized | 4 times lesser than rice | Improves | Residue is used in livestock and easily degradable | 2.37 (678 ha mm) | Very high and increasing | 82% |
| Maize-wheat-mungbean conventional | 14.64 | 0.87 | 1.62 | Fully mechanized | 4 times lesser than rice | Improves | Residue is used in livestock and easily degradable | 2.07 | Very high and increasing | 80% |
| Pigeonpea-wheat-mungbean | 10.25 | 0.32 | 1.04 | Partial mechanized | 4 times lesser than rice | Improves | Residue is used in livestock and easily degradable | 5.10 | Very high and increasing | 80% |
| Soybean-wheat-mungbean | 20.94 | 0.98 | 2.09 | Fully mechanized | Lesser than rice | Improves | Residue is used in livestock and easily degradable | 4.35 | Very high and increasing | 75% as compared to rice |
| Maize-mustard-mungbean | 14.84 | 0.78 | 1.80 | Fully mechanized | Less | Improve | Residue is used in livestock and easily degradable | 7.00 | Very high and increasing | 90% |
| Maize-potato-water melon | 57.0 | 3.50 | 2.50 | Partially mechanized | Less | Improves | Residue is used in livestock and easily degradable | Very high | Very high and increasing | 80% |
| Rice-wheat-mungbean | 16.19 | 0.93 | 1.69 | Partially mechanized | Very high | Physical health degrades | Problematic | 0.73 (2290 ha mm) | Decreasing | High energy intensive system |
| Rice-wheat | 13.33 | 0.91 | 1.28 | Partially mechanized | Very high | Deleterious effect | Problematic | 0.59 (2340 ha mm) | Decreasing | High energy intensive system |

**Source: Compiled from Parihar *et al.*, 2016; IIMR, 2019a; Jat *et al.*, 2019a, 2019b.**

**Table 4. Comparative return from rice and maize and compensation requirement for maize in Punjab and Haryana**

| Crop | Average state grain productivity (kg/ha) | | Gross returns from grain yield per ha @ MSP (Rs. in thousand) | | Net returns form grain yield (Rs. in thousands) | | Additional compensation for maize to equate gross returns comparable to rice on account of savings on ecology, energy and health (in Rs./quintals) | |
|---|---|---|---|---|---|---|---|---|
| | **Punjab** | **Haryana** | **Punjab** | **Haryana** | **Punjab** | **Haryana** | **Punjab** | **Haryana** |
| Rice | 4165 | 3172 | 77.80 | 59.25 | 23.10 | 4.55 | 240 | 80 |
| Maize | 3723 | 3070 | 68.90 | 56.79 | 22.40 | 10.29 | | |

* The cost of cultivation is Rs. 54.7 and 46.5 thousands/ha for rice and maize, respectively.

It may also be bore in mind that maize being more an industrial crop even if government procures and stores, with assured supply the grains will be readily procured by the industries. During peak supply, of maize grains, the government can procure maize under MSP and sell during low supply period, when the price rises. Thus, government can sell the procured grains even at higher prices leading to earning to the government. Overall savings to the government with initial spending on infrastructures like dryers, silos etc. will be much higher than current investment on rice-wheat procurement.

## 7. Suggested intervention

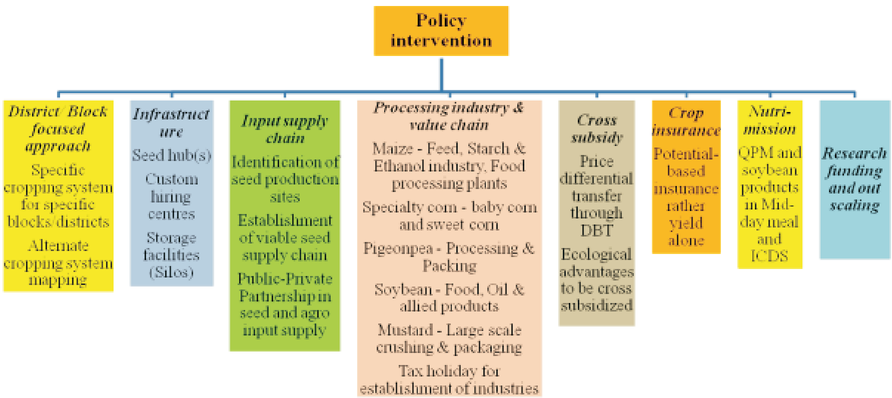
### *A. Policy intervention*

Prevailing policy support favours the rice-wheat cropping system. In recent past, much policy support is being given to prevent burning of rice straw with limited success. Time has come to divert policy support to those cropping systems, which address the challenges of depleting water table, fragile ecology and energy with substantial economic return in a sustainable manner. In this regard, the alternative cropping systems need policy support as follows:

a. ***Adoption of district/block approach*****:** Any alternate crop-based diversification should be intensely focused in selected districts with lighter soil facing stiff challenge of ground water depletion in one hand and availability of processing plants/factory on the other. In Punjab, Hoshiyarpur, Ludhiana, Kapurthala and Jalandhar, and in Haryana Hisar, Fatehabad, Sirsa and Karnal may be focused in first phase. Mapping of alternate cropping systems is given in Annexure II in current One District-One Product map maize has little place, which needs to be relooked.

b. ***Creation of infrastructure:*** Each crop has enabling technologies in terms of high yielding cultivars (Annexure III-VI) and crop production technologies for Punjab and Haryana. Steady supply of quality seed is foremost important. This calls for *creation of seed hub* with adequate linkages with the seed production agencies at various sites. The seed bub may be created in the campus of ICAR-IIMR, Ludhiana to cater the need of all the crops (maize, pigeonpea, soybean and mustard). Seed-to-seed mechanization is well established in maize and soybean, and partially in pigeonpea and mustard. Crop-wise requisite machineries are to be made available to the selected clusters in a subsidized rate. In this context *farm machinery banks or custom-hire centres* need to be established in cluster mode. Rural youths, FPOs, FPCs and SHGs are to be encouraged in this regard. Post harvest handling and storage is of particular concern in case of maize. Dryers of moderate capacity (2-4 t per batch) need to be made available at custom-hire centres (CHC). Post-harvest *storage facilities in the form of silos* may be provided at block level on hiring so that the produce (maize grains) may be stored safely and to avoid distress selling. Towards establishment of CHCs, Sub-Mission on Agricultural Mechanization needs to be roped in. Financial support under MUDRA Bank may be an unique opportunity to support such CHCs, FPOs, FPCs and SHGs.

*Enabling seed supply chain*: Since maize, pigeonpea, soybean and mustard are not a major crop in this region less focus is being given on cultivation of high yielding cultivars by farmers and the availability of seed is less in the region. For example, in the main maize growing belts of Punjab open pollinated varieties (OPVs) are frequently cultivated to meet the domestic needs. Hence, special attention is to be given to produce and supply quality seeds timely. National Seed Corporation (NSC) and State Seed Corporations (SSC) need to be more actively engaged in seed production of maize and pigeonpea hybrids and varietal seeds of soybean and mustard, which is not receiving much attention of the NSC and SSC at present. Seed production of these crops should be incentivized.




**c.** ***Establishment of processing industries and facilitation of new value chain*:** Farmers will never be encouraged unless proper market is created for sale of their produce. Value chain development will play a crucial role in this regard. Maize is extensively used in feed, starch, processed food and in recent past in ethanol industries. Similarly, pigeonpea needs processing and packaging. Soybean is processed in various forms for food, oil and other products. Mustard processing also needs extensive industrial interventions. Since these crops are not of much relevance in the region in the current scenario, such industries are lacking or running below the capacities. *Tax holidays* to such industries will encourage their establishment and creation of market for these crops. Government-Industry Summits need to highlight these possibilities to encourage private/corporate investment in establishment of such industries in the states. Specialty corn based value chain can create substantial job opportunities and earnings to the farmers. Similarly, apiculture can be integrated with mustard cultivation. FPOs, FPCs and SHGs need to be incentivized to create maize-based processing plants. Initiatives under Skill India with support from MUDRA Bank can be of great help in establishing rural entrepreneurship in this area.

d. ***Cross subsidization of alternate cropping system in lieu of ecological benefits*:** Current policy support is in favour of rice-wheat cropping system with a huge impact on ecology, health and public procurement, storage and distribution. Existing market scenario also supports rice and wheat. Shifting to any other cropping system needs some added tangible benefits to the farmers. Realized market prices of majority of the crops other than rice and wheat are mostly much lower than the MSP. Transfer of price differential directly to the farmers through DBT scheme will provide a level field for the alternate crops. Taking into consideration of the savings on water, energy, ecology and health in one hand and public procurement, storage and distribution on the other, this cross subsidization will cause lesser dent on government overall spending.

e. ***Crop insurance for alternate crops:*** The crop insurance policy to be revised for maize, pigeonpea, soybean and mustard based on existing potential of the cultivars.

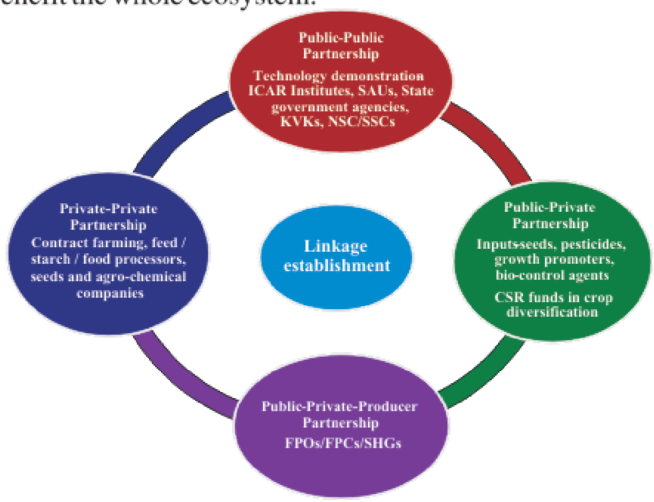
f. ***Introduction of QPM and Soybean in nutri-mission:*** Nutri-mission of government is contributing immensely addressing malnutrition of the country. Quality Protein Maize (QPM) has proven benefit in terms of nutrition. It has biological value close to milk. ICAR has QPM hybrids with experimental yield potential of 6-7 t/ha for Punjab and Haryana (Annexure III). However, due to lack of market demand QPM hybrids are not gaining popularity among farmers. Introduction of QPM-based products like grits, porridge etc. in the mid-day meal and other mass nutrition programme like Integrated Child Development Services (ICDS) will help in creation of market for QPM. Similarly, soybean products also may be included in nutri-mission to increase the demand of soybean.

g. ***Enabling policy to support bio-ethanol production from maize:*** Bio-ethanol production from maize has immense potential to create huge demand for maize to commensurate the ethanol-blending target envisaged by the government. The bio-ethanol industry is to be delinked from physical intervention of excise department.

*h.* ***Funding for research and out-scaling projects of diversification:*** Though diversification efforts are being made for long, it has made limited success in the states till now. In the state of Punjab, the area under maize has marginally increased from 109 thousand ha in 2018 to 114.6 thousand ha in 2019. In Haryana, the area under maize remained stagnant in recent years at around 6 thousand ha. This indicates that the efforts by the states and ICAR to diversify rice cultivation with maize are giving limited yield which needs to be intensified through policy driven measures. Government funding in research on maize and other proposed crops needs to be augmented to meet the changed scenario. Large-scale demonstration of various cropping system will play an integral role in this regard.

## B. Establishment of linkages

Awareness and popularization of alternate cropping system will play an important role. Technology demonstration through *Public-Public Partnership* involving ICAR institutes, SAUs, state government agencies and KVKs will play a key role in this regard. Linkage of NSC/SSCs with the government departments in terms of technology transfer will play a key role in this regard. *Public-Private Partnership* in terms of input (seeds, pesticides, growth promoters and biocontrol agents) providers can play a catalytic role in this regard. NGOs working at grass root level will also be an important component in the process. Tapping of CSR funds in crop diversification may also play a key role. *Public-Private-Producer Partnership* to handhold the FPOs, FPCs and SHGs in alternate value chain can create avenue for entrepreneurship development. *Private-Private Partnership* enabling contract farming with assured input supply and purchases will catalyze the process of diversification. In the process feed/starch/food processors can join hands with the seed companies to supply right quality seeds, agro-chemical companies for supply of agro-inputs and can directly purchase the farm produce from the farmers field for local consumption. Partnership between starch and feed industry to utilize starch industry byproduct, DDGS will be mutually beneficial. Even cross commodity linkages like soya processor with maize-based feed processor can significantly benefit the whole ecosystem.



## 8. Road map for diversification

| Action point | Responsibilities | Timeline |
|---|---|---|
| Publicity of advantages of alternate cropping systems over rice-based cropping system | State governments, KVKs, ICAR-IIMR, ICAR-IIPR, ICAR-IISR | First fortnight of May |
| Inclusion of machinery in maize, soybean and pigeonpea cultivation under subsidy net | State governments, DAC&FW | First fortnight of May |
| Maize/Soybean/Pigeonpea Divas | State governments with participation of SAU, ICAR-IIMR, ICAR-IIMR, ICAR-IIPR, ICAR-IISR, Farmer, Seed and input companies/dealers/traders, maize using industries (feed, poultry, starch) | By 15th May |
| Training to master trainers of state departments | State governments, SAU, ICAR-IIMR, ICAR-IIPR, ICAR-IISR | By 15th May |
| Arrangement of seeds (hybrids for maize and pigeonpea, and varieties for soybean) | State governments or as per directives of the government to farmers for direct purchase from market | By 25th May |
| Handover of diversification kit (seed, agrochemical and literature) to farmers | State departments | By 30th May |
| Arrangement of machinery for sowing for maize | State governments | By 30th May |
| Training to block level officials | State governments | By 30th May |
| Training to farmers with lecture, literature and input | State departments in association with SAUs and ICAR-IIMR, ICAR-IIPR, ICAR-IISR | By 05th June |
| Reimbursement of seed and agrochemicals for maize, pigeonpea and soybean production through DBT | Dedicated online portal of state government | 10 days after sowing of crop |
| Incentives for adoption of alternate cropping system through DBT | Dedicated online portal of state government | By 30th July |
| Provision of harvesting equipment for maize and pigeonpea to CHCs | State departments | By 15 August |
| Seed availability of early season vegetables in peri-urban interface in maize system | State government | By 15th September |
| Procurement of maize, pigeonpea and soybean from farmers | State Government or tax rebate to industry | After harvesting |
| Publicity of advantages of mustard cropping | State governments, KVKs, ICAR-DRMR | Second fortnight of September |

| Action point | Responsibilities | Timeline |
|---|---|---|
| Mustard Divas and training to farmers with lecture, literature and input | State governments with participation of SAU, ICAR-DRMR, Farmer, Seed and input companies/dealers/traders, maize using industries (feed, poultry, starch) | By 15$^{th}$ October |
| Training to master trainers of state departments | State governments, SAU, ICAR-DRMR | By 15$^{th}$ October |
| Arrangement of seeds | State governments or as per directives of the government to farmers for direct purchase from market | By 20$^{th}$ October |
| Handover of diversification kit (seed, agrochemical and literature) to farmers | State departments | By 20$^{th}$ October |
| Training to block level officials | State governments | By 20$^{th}$ October |
| Reimbursement of seed and agrochemicals for mustard production through DBT | Dedicated online portal of state government | 10 days after sowing of crop |
| Incentives for adoption of alternate cropping system through DBT | Dedicated online portal of state government | By 30$^{th}$ November |
| Felicitation of the farmer/village adopting or official efforts towards successful diversification | State government in District/State level function | Continuous |
| Establishment of corn/pigeonpea/soybean/mustard villages (in put and marketing support) | CSR funds of the industries working in the states duly facilitated and documented by State Government | Continuous |
| Establishment of maize/pigeonpea/soybean/mustard farmer producer organization/SHGs establishment | State government | Continuous |
| Establishment of quality protein maize villages for nutritious food, feed and silage | Processing industries with incentives by state government | Continuous |
| Establishment of baby corn, sweet corn and pop corn villages establishment | Processor, exporter and FPOs with incentives by state government | Continuous |
| Promotion of silage from maize for dairy and export | State government through subsidy/incentive on machinery | On demand of farmer/FPO/SHG |

## Intermediate measures:

Beside these as immediate steps for sustainability of diversifications following intermediate measures should also be adopted.

1. Promotion of contract farming by poultry, feed, seed, starch, oil, *dal* etc. industries
2. CSR fund of industry towards protection of natural resources by alternative crop cultivation
3. Reduction of subsidy on water pumping
4. Rebate on the taxes for diversified crop purchasing by industry
5. Rebate on transport of diversifying crop produces from the production site to utilization plants.
6. Imposition of safeguard duty on import of soybean as done for oil palm.
7. Cold chain for specialty corn and vegetables
8. Export facilitation by establishment of maize, soybean, pigeon pea and mustard export zone
9. Tax rebate/subsidized electricity for establishment of maize, soybean, pigeon pea and mustard based agro-industry

## Long-term measure

1. Steps for phasing out subsidy on water pumping for sustainability
2. Phasing out of the incentives towards promotion/purchase of the established diversified crops

## 9. Mapping of institutes to contribute in cropping system diversification

***Maize*:** Maize research and development in India is being spearheaded by the ICAR-Indian Institute of Maize Research (ICAR-IIMR), which is located at Ludhiana. It has two of its regional stations in Hyderabad (Winter Nursery Centre) and Begusarai, Bihar (Regional Maize Research & Seed Production Centre). ICAR-IIMR is nodal point for All India Coordinated Research Project (AICRP) on Maize, which has 30 regular and two co-opted centres across the country (Fig. 11). The maize research under AICRP on Maize is being conducted under five zones, *viz*., Northern Himalayan Zone (Zone I), North Western Zone (Zone II), North Eastern Plain Zone (Zone III), Peninsular Zone (Zone IV) and Central Western Zone (Zone V). Public bred

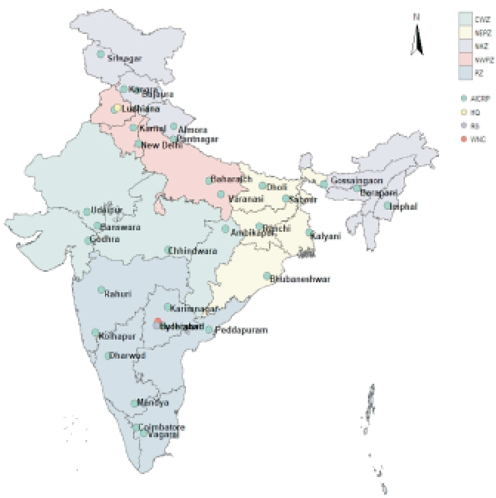



Fig. 11. Maize research network

hybrids developed and released through AICRP can be obtained from this institute or its AICRP partners (details are given in Annexure III). Punjab Agricultural University, Ludhiana and Regional Research Station of CCS Haryana Agricultural University at Karnal are the two AICRP centres dedicated on maize research and technology dissemination in Punjab and Haryana, respectively.

The most convincing maize-based cropping system based on experimental findings are maize-wheat-mungbean (M-W-Mb) cropping system. Fig. 12 depicts an integrated model linking M-W-Mb cropping system to the institutional support in input supply and training cum awareness and market linkages through various intermediaries. Three most important input supplies will be key in this network – seeds, agro-chemicals and machineries for mechanization of the cropping system. A well established seed hum deep inside the region being supported and coordinated by respective state governments duly complemented with private companies to supply seeds, agro-chemicals and agro-machineries will be key to the success of the model. Custom hiring centres (CHCs) can play a crucial role to provide key implements like bed planter, combined harvesters, shellers dryers etc. in a affordable rates. Governmental schemes on mechanization may support the CHCs in procuring the implements. Input subsidies for seeds and agro-chemicals may be transferred to the farmers adopting the system through direct benefit transfer (DBT) along with incentives to adopt the cropping system. Famers Producer Companies (FPCs), Famers Producer Organizations (FPOs), Self Help Groups (SHGs) and others may act as aggregator to link the farmers to the maize processing companies. Such aggregators may be provided with higher capacity dryers and silos for long-term storage of maize grains. National Rural Livelihood Mission (NRLM) can play a key role in forming FPCs/FPOs/SHGs and supporting the CHCs. Money directly paid to the farmers based on grain moisture standard online by the FPCs/FPOs/SHGs will energise the farmers. The maize processing industries buying quality maize from the FPCs/FPOs/SHGs will pay them premium price as the grains will be

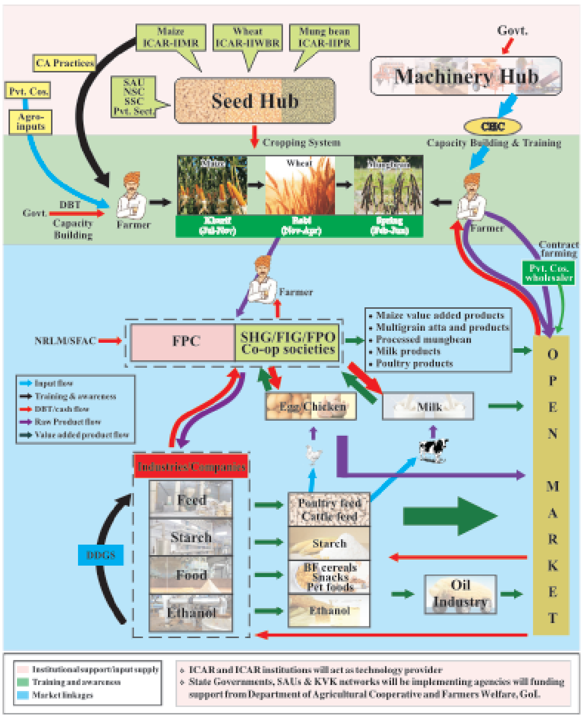



**Fig. 12. M-W-Mb cropping system based value chain network**

of good quality. The diverse value added products from such processing companies can find place in open market or the FPCs/FPOs/SHGs may buy back the value added products to sell in open market. Say feed industry can supply inputs to dairy and poultry farmers, while the products i.e. milk and egg/chicken may find place in open market or may go back to the FPCs/FPOs/SHGs, who may again act as an aggregator for dairy/poultry farmers and market the value added products. The feed industries can also be linked to the ethanol industry through supply of Dried Distilleries and Grain Soluble (DDGS), a by-product of ethanol production and an ingredient for feed. Such models can bring a much waited revolution in the rural economy, simultaneously addressing the serious problem of ground water depletion, residue burning and other ecological/health consequences.

***Pigeonpea*:** ICAR-Indian Institute of Pulses Research (ICAR-IIPR) is a premier Institute in the country dedicated on pulse research. The institute harbours three AICRPs, *viz.,* AICRP on Chickpea, AICRP on Pigeonpea and AICRP on MULLaRP (Mungbean, Urdbean, Lentil, Lathyrus, Rajmash and Fieldpea). The pulses research network across the country through its headquarter and AICRP centres is given in Fig. 13.

The Institute is mandated with basic, strategic and applied research on major pulse crops. It has now six specialized divisions (Crop Improvement, Plant Biotechnology, Crop Production, Crop Protection, Basic Sciences and Social Sciences) and four Regional Research Centres/Stations (Dharwad, Bhopal, Bikaner and Khordha) to meet the mandates of the institute. Its key role includes developing technologies and materials towards pulses improvement, production and protection, and giving its fruits to our clientele, *the farmers,* besides tactical linkages and strategic coordination with the network on pulses research programs across the country and the globe. The varietal trials of pigeonpea are carried out by 26 regular and 5 voluntary centers spread over five Agro-climatic Zones of India as given below.

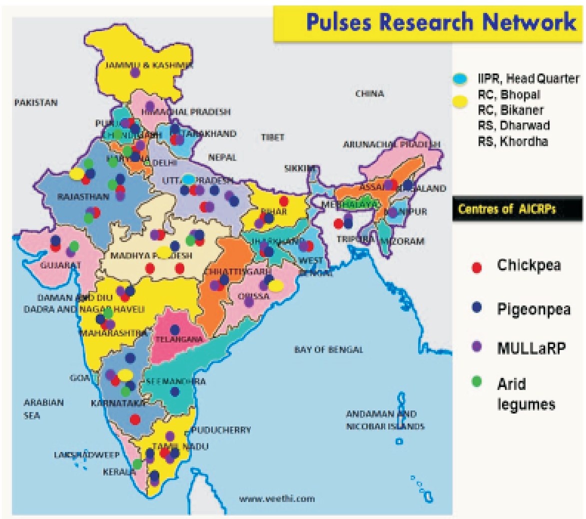


Fig. 13. Pulses research network in the country

1. NWPZ: North West Rajasthan, Punjab, Haryana, Delhi, Western Uttar Pradesh.
2. NEPZ: Eastern and Central Uttar Pradesh, Bihar, West Bengal, Assam, Jharkhand
3. Hilly Zone: Uttarakhand, Nagaland, Tripura

4. Central Zone: Gujarat, Maharashtra, Madhya Pradesh, Rajasthan, Chhattisgarh.
5. South Zone: Andhra Pradesh, Telangana, Karnataka, Orissa,Tamil Nadu.

The total cadre strength of 107 including a project coordinator, 70 scientists and 36 technical staffs are working under the scheme. The Institution and AICRP on Pigeonpea bred varieties and hybrids which can be obtained from this institute or its AICRP partners (details are given in Annexure IV). Punjab Agricultural University, Ludhiana and CCSHAU, Hisar are the two AICRP centres dedicated on pigeonpea research and technology dissemination in Punjab and Haryana, respectively. The most convincing pulses based cropping system is pigeonpea-wheat-mungbean (P-W-Mb) cropping system. It is similar to M-W-Mb or R-W-Mb except the fact that short duration pigeonpea will replace maize or rice during the *kharif* season. It thus, brings in all the beneficial effect of both the pulses, *viz*., pigeonpea and mungbean. The Institution and AICRP will support in input supply and training cum awareness and market linkages through various intermediaries. Three most important inputs are needed which include seeds, agro-chemicals and machineries for mechanization of the cropping system. For fulfilling seed need, well established seed hubs at Ludhiana in Punjab, CCSHAU, Hisar, KVK-Bhiwani and KVK-Sirsa are functioning well in addition to breeder seed programme (BSP) on pigeonpea and other pulses. This is supported and coordinated by ICAR-IIPR, Kanpur, its AICRP on Pigeonpea and other crop-based institutes to supply agro-chemicals and agro-machineries will be key to the success of this cropping system. Moreover, custom hiring centres (CHCs) are fully equipped to play a crucial role to provide key implements like bed planter, combined harvesters, pigeonpea strippers, etc. in a affordable rates. Governmental schemes may also support the CHCs in procuring the implements.

In addition, input subsidies for seeds and agro-chemicals may be transferred to the farmers adopting the system through DBT along with incentives to adopt the cropping system. FPCs, FPOs, SHGs and others (Cooperative societies) may act as aggregator to link the farmers to pulses processors. On this account, small scale *dal* mills or IIPR Mini *Dal* Mills can be of immense help to small and marginal farmers including FPCs/FPOs/SHGs supporting the CHCs. Pigeonpea *dal* is not used in the locality. Therefore, the value chain must include fulfilling the demand for the commodity elsewhere in the country. Diverse value added products from such processing locations can find place in open market or the FPCs/FPOs/SHGs may buy back the value added products to market. Such activities can bring additional income in the existing rural economy which could address the serious problem accrued as of now (ground water depletion, residue burning and other ecological/health consequences).

***Soybean*:** ICAR-Indian Institute of Soybean Research (ICAR-IISR) at Indore is conducting and coordinating the soybean research in India and coordinating the soybean research in India through All India Coordinated Research Project on Soybean (AICRPS). In AICRPS, the country has been divided into 6 zones (Fig 14), *viz.*, Northern Hill Zone, Northern Plain Zone, North Eastern Hill Zone, Eastern Zone, Central Zone and Southern Zone. Twenty one state agricultural universities are main centres and 12 universities / institutes / KVK / NGO / private companies are need based centres for multi-location AICRPS trials. Punjab is included in Northern Plain Zone and in addition to Punjab Agricultural University (PAU), Ludhiana, ICAR-Indian Agricultural Research Institute and G.B. Pant University of Agriculture and Technology, Pantnagar are other centres located in this zone. Although the potential of soybean crop in Punjab and Haryana has been successfully demonstrated through AICRPS it is still grown in small pockets. Soybean crop can easily fit in soybean-wheat-mungbean cropping system but requires availability of quality seeds, agro-chemicals, machines and support for the sale of crop. List of improved soybean cultivars is given in Annexure V. In one of the projects handled by PAU, Ludhiana for two years soybean crop became popular when its assured procurement by university @ Rs 5000 per quintal was ensured. Seed hub for the crop; custom hiring centres for BBF, FIRBS, combined harvester; FPOs, FPCs and SHGs for seed availability and popularizing soybean food usages are some of the areas for diversifying cropping system in Punjab and Haryana.

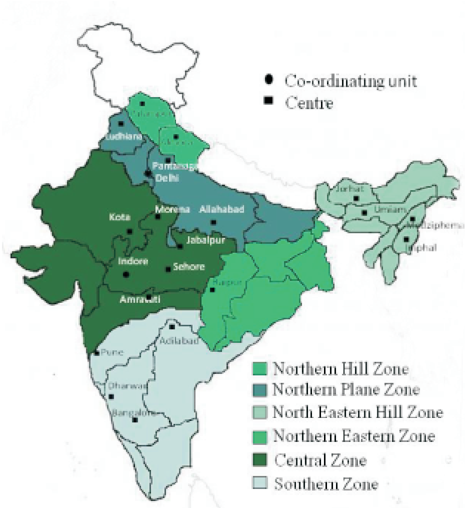



**Fig. 14. Soybean research network in the country**

***Rapeseed-Mustard***: Research and development of rapeseed-mustard in India is spurred by ICAR-Directorate of Rapeseed-Mustard Research, which is located at Bharatpur (Rajasthan). It has one Krishi Vigyan Kendra in Alwar district of Rajasthan. ICAR-DRMR is nodal point for All India Coordinating Research Project on Rapeseed-Mustard (AICRP-RM) which has 22 regular and 13 verification center across 17 states of the country (Fig.15). The

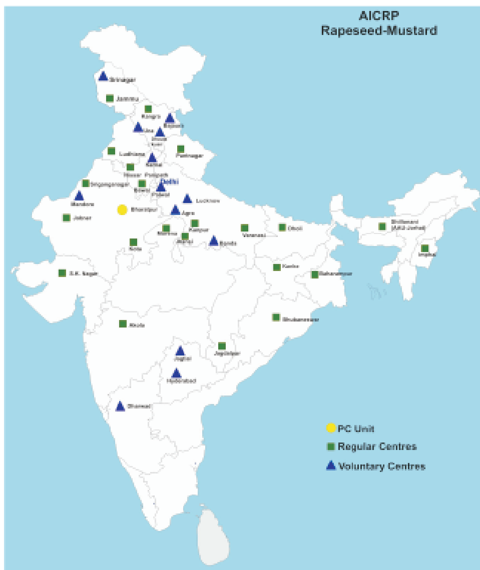



**Fig. 15. Rapeseed and mustard research network in the country**

rapeseed-mustard research under AICRP is being conducted in 6 zones, *viz.,* Zone-I (Kashmir, Himachal Pradesh), Zone-II (Jammu, Punjab, Haryana, Delhi, some parts of Rajasthan and some parts of U.P.), Zone-III (some parts of Rajasthan, Madhya Pradesh, Bihar, UP, Uttarakhand), Zone-IV (Gujarat, Maharashtra, some parts of Rajasthan), Zone-V (Odisha, West Bengal, Jharkhand, Chhattisgarh, Manipur), Zone-VI (Telangana, Andhra Pradesh, Karnataka). Public sector varieties and hybrids developed and released from AICRP can be obtained from its AICRP partners (details are given in Annexure-VI). PAU, Ludhiana, CCSHAU, Hisar and RRS, Bawal (Rewari) are the three AICRP centres dedicated on rapeseed-mustard research and technology dissemination in Punjab and Haryana. The rapeseed-mustard group of crops can be more remunerative in maize based cropping systems. Two most important input supplies will be quality seeds of varieties/hybrids and machineries, both for sowing and harvesting, for mechanization of the cropping system including R-M as one crop. A mustard seed-hub at RRS, Bawal (Rewari, Haryana) being supported and coordinated by ICAR-DRMR in the region and other crop based institutes duly complemented with private companies to supply agro-chemicals and machineries will be key to the success of the model. CHCs can play a very important role to provide key implements like ferti-seed-drill, Combine harvester etc. at affordable rates. Government schemes likes RKVY, SMAM (Sub-Mission on Agricultural Mechanization) etc. may support the CHCs in procuring the implements. Input subsidies for seeds and agro-chemicals may be transferred to the farmers adopting the cropping system through DBT along with incentives to adopt the cropping system. FPCs, FPOs, SHGs and others may act as aggregator to link the farmers to rapeseed-mustard processing industries. The rapeseed-mustard processing industries, buying rapeseed-mustard from FPCs/FPOs/SHGs, will pay them premium prices for quality mustard (single low/double low). The oil and seed-meal from such processing companies can find place in open market or the FPCs/FPOs/SHGs may buy back the product and sell in the open market and can fetch premium price since India is deficit in edible oil production by more than 50%. The animal feed industry can be linked to this for rapeseed-mustard seed meal which is very high in good quality protein (30-35%). Such models can bring a much awaited revolution in the rural economy simultaneously addressing the serious problem of ground water depletion, residue burning and nutritional security since rapeseed-mustard is high energy crop.

## 10. Epilogue

Strong policy intervention coupled with public-private partnership can bring perceivable changes in the predominant rice-wheat cropping system in the states of Punjab and Haryana and address the challenge of water crisis in one hand and residue burning on the other. Spread of maize, soybean, pigeonpea and mustard can ensure steady supply of the raw materials to the industry ensuring employment and entrepreneurship development in the region. Similarly, specialty type and quality produce of these crops also can create enough job opportunities and alternate source of income to the farmers and the rural youth. Policy intervention supporting rice and wheat has brought dramatic changes in the cropping pattern in the states. When the country was in need of food such policies certainly brought the country out of the 'ship-to-mouth' situation to self-sufficiency. However, this has caused some near irreversible damage to the whole ecosystem and the economy. The states have become net exporter of precious ground water. Now it is time to look back and take stringent policy decision to support the alternate crops, which can be very potent crops not only to address the economical and environmental issues but overall profitability of the system. In the process, no crop should be seen in isolation but should be viewed from cropping system perspective and system productivity and profitability, where all aspects encompassing water and energy conservation and conservation of nature should be viewed in a holistic manner. In the process ICAR institutes, *viz*., Indian Institute of Maize Research, Indian Institute of Pulses Research, Indian Institute of Soybean Research and Directorate of Rapeseed and Mustard can provide proven technologies, while the implementation part will have to be in the hands of state governments supported by Department of Agricultural Cooperation and Farmers Welfare, Government of India. The networks of scientists in the state agricultural universities and the Krishi Vigyan Kendras can play a key role in implementing the schemes.

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## Annexure I. Area and yield of rice, wheat, maize, pigeonpea, soybean and mustard in Punjab and Haryana

| Year | Area ('000 ha) | | | Yield (kg/ ha) | | |
|---|---|---|---|---|---|---|
| | Maize | Pigeonpea | Mustard | Maize | Pigeonpea | Mustard |
| | | | Punjab | | | |
| 2014 | 126.0 | 2.6 | 31.0 | 3651 | 923 | 1248 |
| 2015 | 115.0 | 2.6 | 31.0 | 3687 | 1000 | 1348 |
| 2016 | 116.0 | 5.7 | 31.7 | 3836 | 860 | 1413 |
| 2017 | 114.0 | 2.6 | 30.5 | 3708 | 1030 | 1498 |
| 2018 | 109.0 | 2.3 | 30.5 | 3625 | 1047 | 1524 |
| 2019 | 114.6 | 2.0 | 31.2 | 3577.7 | 1082 | 1492 |
| | | | Haryana | | | |
| 2014 | 8.0 | 6.1 | 493.0 | 2250 | 1098 | 1432 |
| 2015 | 6.0 | 5.0 | 505.0 | 2833 | 1000 | 1594 |
| 2016 | 5.0 | 14.2 | 510.0 | 3400 | 915 | 1853 |
| 2017 | 6.0 | 4.1 | 549.0 | 3167 | 1097 | 2018 |
| 2018 | 5.9 | 1.9 | 609.2 | 2644 | 1211 | 2058 |
| 2019 | 6.0 | | | 2883 | | |

Source: DACNET

## Annexure II. Mapping of alternate cropping systems

| Cropping system | Districts | | Specific interventions |
|---|---|---|---|
| | Punjab | Haryana | |
| Maize-wheat-mungbean with CA | Hoshiyarpur, Ludhiana, Kapurthala and Jalandhar | Hisar, Fatehabad, Sirsa and Karnal | IEC, machineries for crop production and medium capacity dryer through CHC, establishment of storage & processing industry |
| Maize-wheat-mungbean conventional | Gurdaspur, Pathankot, Hosiarpur, SBS Nagar, Roopnagar | Hisar, Fatehabad, Sirsa and Karnal | IEC, machineries for crop production and medium capacity dryer through CHC, establishment of storage & processing industry |
| Pigeonpea-wheat-mungbean | Gurdaspur, Pathankot, Hosiarpur, SBS Nagar, Roopnagar | Hisar, Fatehabad, Sirsa and Karnal | IEC, establishment of storage & processing industry |
| Soybean-wheat-mungbean | Ropar, Hoshiarpur, Ludhiana, Jalandhar | Karnal, Kuruksetra, Jind, Ambala | IEC, establishment of storage & processing industry, Sowing Machine |
| Maize-mustard-mungbean | Kandi belt | Hisar, Kaithal, Jind, Sonipat, Rohtak, Bhimani, Sirsa and Fatehabad | IEC, machineries for crop production and medium capacity dryer through CHC, establishment of storage & processing industry |
| Maize-Potato-Water melon | Jalandhar and Bhabhar areas | Kurukshtera, Yamunanagar, Karnal, Sonipat, Ambala, Panchkula, Panipat, Rohtak, Jind and Sirsa | IEC, machineries for crop production and medium capacity dryer through CHC, establishment of storage & processing industry |

Note: Provision of Seed Hubs for promising cultivars need to be established for all cropping systems.

## Annexure III. List of maize hybrids released for the states of Punjab and Haryana through AICRP on Maize

| S. No. | Cultivar | Nature of cultivar | Developer of the cultivar | Public/ Private | Release Year | Maturity | Average Yield (t/ha) | Season |
|---|---|---|---|---|---|---|---|---|
| **Normal Field Corn** | | | | | | | | |
| 1 | CP 858 | SCH | Charsen Pokphand Seed (India) Pvt. Ltd., Bangalore | Private | 2020 | Late | 9.50 | *Kharif* |
| 2 | HT17169 | SCH | Hytech Seed India Pvt. Ltd. | Private | 2020 | Late | 10.00 | *Kharif* |
| 3 | PMH13 | SCH | PAU, Ludhiana | Public | 2020 | Late | 7.00 | *Kharif* |
| 4 | CP. 838 | SCH | Charsen PokphandSeed (India) Pvt. Ltd., Bangalore | Private | 2018 | Late | 11.20 | *Rabi* |
| 5 | PMH11 | SCH | PAU, Ludhiana | Public | 2018 | Late | 6.50 | *Kharif* |
| 6 | GK 3150 | TWC | Ganga Kaveri Seeds Pvt Limited | Private | 2017 | Late | 11.90 | *Rabi* |
| 7 | DRONA (KMH-2589) | SCH | Kaveri seed company limited | Private | 2017 | Late | 10.80 | *Kharif* |
| 8 | P3544 | SCH | Pioneer Hi-Bred Private Ltd. | Private | 2017 | Late | 10.80 | *Kharif* |
| 9 | DKC 9126 (MCH 46) | SCH | Monsanto India Ltd., Bangalore | Private | 2016 | Late | 8.90 | *Kharif* |
| 10 | Dragon (NMH-1247) | SCH | Nuziveedu Seeds Limited, Hyderabad | Private | 2016 | Late | 9.90 | *Rabi* |
| 11 | KMH-7148 | SCH | Kaveri Seed Company Limited, Secundrabad | Private | 2015 | Late | 10.10 | *Rabi* |
| 12 | KMH-25K45 (BUMPER) | SCH | Kaveri Seed Company Ltd., Andhra Pradesh | Private | 2015 | Late | 9.00 | *Rabi* |
| 13 | NMH-1242 | SCH | Nuziveedu Seeds Limited | Private | 2015 | Medium | 7.30 | *Kharif* |
| 14 | CoH (M)8 (CMH 08-292) | SCH | TamilnaduAU, Coimbatore | Public | 2014 | Medium | 7.10 | *Kharif* |
| 15 | KMH-25K45 (2700) (BUMPER) | SCH | Kaveri Seed Company Ltd., Andhra Pradesh | Private | 2014 | Late | 9.00 | *Rabi* |
| 16 | P3522 (X35A019) | SCH | Pioneer Overseas Corporation, Karnatka | Private | 2014 | Late | 9.10 | *Rabi* |
| 17 | P 1864 (X8F984) | SCH | Pioneer Overseas Corporation, Karnatka | Private | 2014 | Early | 7.60 | *Kharif* |
| **Quality Protein Maize (QPM)** | | | | | | | | |
| 18 | LQMH-202(LQMH-2) | SCH | ICAR-IIMR, Ludhiana | Public | 2020 | Medium | 7.50 | *Kharif* |
| 19 | Pusa HM-4 Improved (AQH-4) | SCH | ICAR-IARI, New Delhi | Public | 2017 | Medium | 6.40 | *Kharif* |
| **Popcorn** | | | | | | | | |
| 20 | GAPCH-21 Mahashweta | SCH | Anand Agricultural University, Anand | Public | 2020 | | 3.70 | *Kharif* |
| 21 | BPCH-6 | SCH | ANGRAU, Hyderabad | Public | 2015 | Medium | 3.20 | *Kharif* |
| 22 | DMRHP 1402 | SCH | ICAR-Indian Institute of Maize Research, Ludhiana | Public | 2018 | Early | 3.90 | *Kharif* |
| **Sweet Corn** | | | | | | | | |
| 23 | NUZI 260 | SCH | Nuziveedu Seeds Limited, Hyderabad | Private | 2020 | Medium | 13.90 | *Kharif* |
| 24 | Hi-brix-39 (ADVSW-1) | SCH | Advanta Limited, Hyderabad | Private | 2017 | Medium | 13.80 | *Kharif* |
| 25 | Hy-brix 53 (ADVSW-2) | SCH | Advanta Limited, Hyderabad | Private | 2017 | Medium | 13.70 | *Kharif* |
| 26 | Central Maize VL Sweet Corn 1 | SCH | VPKAS, Almora, Uttarakhand | Public | 2016 | Medium | 10.80 | *Kharif* |
| 27 | CANDY (KSCH-333) | SCH | Kaveri Seed Company Limited, Secundrabad | Private | 2015 | Early | 11.90 | *Kharif* |
| **Baby Corn** | | | | | | | | |
| 28 | IMHB 1532 | SCH | ICAR-IIMR, Ludhiana | Public | 2018 | Medium | 2.00 | *Kharif* |

## Annexure IV. List of Pigeonpea varieties/hybrids released for the states of Punjab and Haryana through AICRP on Pigeonpea (2010-2020)

| S. No. | Variety | Pedigree | Developer of the cultivar | Zone | Release year | Traits |
|---|---|---|---|---|---|---|
| 1 | Pusa 992 | Sel. Of 90306 | IARI, New Delhi | NWPZ | 2002 (CVRC) | Indeterminate, semi-spreading, early maturing (135-140 days), yields about 12-15 q/ha, suitable for pigeonpea-wheat cropping system |
| 2 | VLA 1 | ICP6 x Pant 2 | ICRISAT | Uttarakhand | 2006 (SVRC) | Indeterminate, Early maturing and semi spreading |
| 3 | PAU 881 | H89-5XICPL 85024 | PAU,Ludhia na | Punjab | 2007 (SVRC) | Indeterminate, early maturing, semi spreading, suitable for pigeonpea-wheat cropping system |
| 4 | Pusa 2002 | Sel. 90310 x H 88-45 | IARI, New Delhi | Delhi | 2007 (SVRC) | Indeterminate, semi spreading, early maturing, suitable for pigeonpea-wheat cropping system |
| 5 | PA291 | UPAS120XKPBR 80-2-1 | G.B.P.U.A.&T, | NWPZ (State) | 2008 (SVRC) | Tolerant to *Phytophthora* stem |
| 6 | Pusa Arhar 16 (PADT 16) | Population improvement approach involving diverse genotypes viz., ICP 85059, ICPL 390, ICPL 267, Manak, H-92-39 and ICP 85024 | IARI, Pusa, New Delhi | Delhi | 2018 (SVRC) | Determinate, erect and compact, extra early, matures in about 120 days, yields about >10q/ha |
| 7 | Pant Arhar 6 (PA 421) | ICPL 84023 x ICPL 88039 | GBPUA&T Pantnagar | NWPZ | 2019 (CVRC) | Indeterminate, semi spreading, matures in about 145-150 days, possesses resistant to wilt and sterility mosaic disease. Gives an yield about 15-16 q/ha. |
| 8 | IPH 15-03 (Hybrid) | CMS PA 163A x AK 250189R | IIPR Kanpur | NWPZ | 2019 (CVRC) | It is an early CGMS based hybrid having the cytoplasm of *C. scarabaeoides*. It is indeterminate, semi spreading, matures in about 150-155 days. Possesses resistance to Fusarium wilt and has a yield potential of 2.5 t/ha |
| 9 | IPH 09-5 (Hybrid) | CMS PA 163A x AK 261322R | IIPR Kanpur | NWPZ | 2020 (CVRC) | It is indeterminate, semi spreading, matures in about 150 days. Possesses resistance to Fusarium wilt and has a yield potential of 2-2.5 t/ha |

## Annexure V. List of soybean varieties/hybrids released for the states of Punjab and Haryana through AICRP on Soybean (2010-2020).

| S. No. | Name of variety | Developer of the cultivar | Public/ Private | Release Year | Maturity | Average Yield | Season |
|---|---|---|---|---|---|---|---|
| 1. | SL 525 | PAU, Ludhiana | Public | 2007 | 121 days | 2727 | *Kharif* |
| 2. | PS 1347 | GBPUA&T, Pant Nagar | Public | 2008 | 123 days | 2542 | *Kharif* |
| 3. | SL 688 | PAU, Ludhiana | Public | 2008 | 125 days | 2435 | *Kharif* |
| 4. | SL 744 | PAU, Ludhiana | Public | 2012 | 139 days | 2142 | *Kharif* |
| 5. | Pusa 12 | IARI, New Delhi | Public | 2015 | 124-131 days | 2286 | *Kharif* |
| 6. | SL 958 | PAU, Ludhiana | Public | 2016 | 142 days | 2282 | *Kharif* |
| 7. | Pant Soya 24 | GBPUA&T, Pant Nagar | Public | 2017 | 113 days | 2560 | *Kharif* |
| 8. | SL 955 | PAU, Ludhiana | Public | 2020 | 126 days | 2201 | *Kharif* |
| 9. | SL 979 | PAU, Ludhiana | Public | 2020 | 127 days | 2335 | *Kharif* |
| 10. | PS 1572 | GBPUA&T, Pant Nagar | Public | 2020 | 120 days | 1925 | *Kharif* |

## Annexure VI. List of mustard varieties/hybrids released for the states of Punjab and Haryana through AICRP on Mustard (2010-2020).

| S. No. | Variety/hybrid | Nature of variety/hybrid | Developer of the cultivar | Public/ Private | Release Year | Maturity | Average Yield (t/ha) | Season |
|---|---|---|---|---|---|---|---|---|
| **Indian mustard** | | | | | | | | |
| 1 | Pusa mustard -26 (NPJ-113) | Late sown irrigated, tolerant to high temperature at seedling and maturity stage | ICAR-IARI, New Delhi | Public | 2010 | 115-137 | 1.5-1.9 | *Rabi* |
| 2 | RH 0119 | Thermo-tolerance | CCSHAU, Hisar | Public | 2010 | 145-150 | 1.8-2.0 | *Rabi* |
| 3 | Pusa Mustard 28 (NPJ 124) | Early sown, irrigated, tolerant to high temperature at seedling and salinity | ICAR-IARI, New Delhi | Public | 2011 | 97-131 | 1.9-2.1 | *Rabi* |
| 4 | Coral PAC 437 (Hybrid) | Hybrid, tolerant to white rust | Advanta India Limited | Private | 2011 | 130-140 | 2.0-2.8 | *Rabi* |
| 5 | RLC 2 | Timely sown irrigated, low erucic acid (< 2%) | PAU, Ludhiana | Public | 2011 | 132- 155 | 2.0-2.3 | *Rabi* |
| 6 | PBR-357 | Timely sown irrigated | PAU, Ludhiana | Public | 2011 | 142-149 | 2.5-2.8 | *Rabi* |
| 7 | RGN-229 | Tolerant to high temperature and salinity at seedling stage, timely sown rainfed | ARS, Ganganagar (SKRAU, Bikaner) | Public | 2011 | 140-150 | 2.2-2.6 | *Rabi* |
| 8 | RH 0406 | Tolerant to high temperature and salinity at seedling stage | CCSHAU, Hisar | Public | 2011 | 136-149 | 2.1-2.4 | *Rabi* |
| 9 | RGN-236 | Tolerant to high temperature and salinity at seedling stage, late sown irrigated | ARS, Ganganagar (SKRAU, Bikaner) | Public | 2011 | 126-128 | 1.5-1.8 | *Rabi* |
| 10 | Pant Rai-19 (PR 2006-1) | Tolerant to high temperature during early stages, suitable for early sowing. | GBPUA&T, Pantnagar | Public | 2012 | 117 | 2.1 | *Rabi* |
| 11 | Pusa Mustard- 29 (LET-36) | Low erucic acid (<2%) | ICAR-IARI, New Delhi | Public | 2013 | 143 | 2.2 | *Rabi* |
| 12 | RVM-2 | Rainfed as well as irrigated | ZRS, Morena RVSKVV, Gwalior | Public | 2013 | 194-209 | 1.7 | *Rabi* |
| 13 | Giriraj (DRMRIJ 31) | Timely sown irrigated | ICAR-DRMR, Bharatpur | Public | 2013 | 137-153 | .. . .. | *Rabi* |
| 14 | RH 0725 | Timely sown rainfed | CCSHAU, Hisar | Public | 2017 | 141 | 2.4-2.8 | *Rabi* |
| 15 | CS 2800-1-2-3-5-1 (CS 60) | Tolerant to salinity/alkalinity | ICAR-CSSRI, Karnal | Public | 2017 | 134 | 1.7-2.2 | *Rabi* |
| 16 | PDZ-1 | Quality mustard (00) | ICAR-IARI, New Delhi | Public | 2017 | 142 | 2.0-2.5 | *Rabi* |
| 17 | DRMR 2017-15 (Radhika) | Late sown, irrigated | ICAR-DRMR, Bharatpur | Public | 2020 | 122-139 | 1.7-1.8 | *Rabi* |
| 18 | DRMRIC 16-38 (Brijraj) | Late sown, irrigated | ICAR-DRMR, Bharatpur | Public | 2020 | 122-139 | 1.7-1.8 | *Rabi* |
| 19 | LES 54 (Pusa Mustard 32) | Timely sown irrigated, low erucic acid | ICAR-IARI, New Delhi | Public | 2020 | 142-147 | 2.6-2.8 | *Rabi* |
| **Gobhi Sarson** | | | | | | | | |
| 1 | GSC 7 | Canola quality | PAU, Ludhiana | Public | 2015 | 154 | 2.2 | *Rabi* |
| 2 | AKMS 8141(Him Palam Gobhi Sarson 1 | Canola quality, timely sown irrigated | CSKHPKVV, Palmpur, Himachal | Public | 2020 | 155-177 | 1.8-2.1 | *Rabi* |

# Glimpses of Alternative Crops

Maize

Maize + Pigeonpea

Pigeonpea


Mungbean

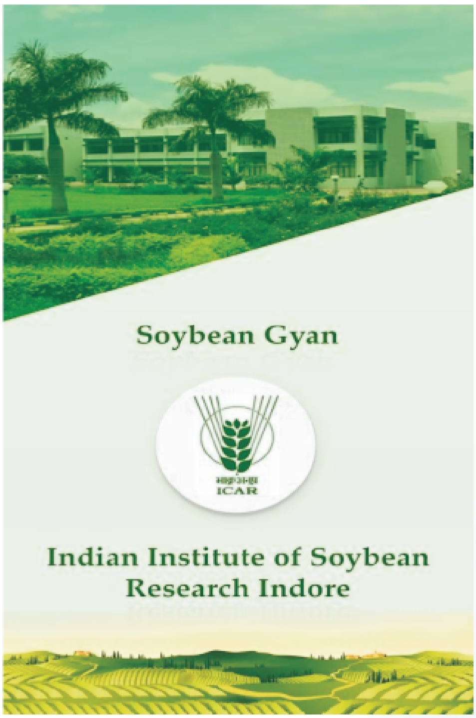
Soybean

Mustard

# MOBILE APPS FOR DIVERSIFIABLE CROPS


Bharti Makka


Mung Advisor




Soybean Gyan


Mustard Farming

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