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12. Pulse-Based Crop Diversification in Indo-Gangetic Conditions

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Abstract:

In India's Gangetic Plain, 44 million hectares are predominantly cereal crops. Rice-wheat and rice-crop systems are the main cropping systems, with rice-wheat rotations accounting for about 10 million ha. Legumes are grown on about 5 million ha, accounting for about 14% of the country's total area. This region has wide spatial variation in rainfall patterns (268 mm in the far north to 1600 mm in the far east) and is largely dominated by Inceptisol soils. There are also large differences in other agroclimatic characteristics such as temperature regime, length of growing season, and evapotranspiration. Despite these major differences, chickpea, lentils, and pigeon pea are the main legumes grown throughout the region. Their production is severely affected by many diseases, pests, and abiotic stresses in this diverse part of the country. Socioeconomic constraints are also a major reason hindering cultivation. The Indian government has increased research spending to develop improved technologies to increase legume production in the country. The results of government investments have been promising, and some improved varieties and technological options have been developed to mitigate biotic and abiotic constraints. The government also initiated several policy measures to alleviate socioeconomic constraints to increase legume production. Available trends show that the area under legumes is gradually increasing in some regions. The region has tremendous potential for legume production (either as an intercrop, summer crop, or sole crop in a variety of cropping systems), provided that appropriate crop varieties/technologies reach farmers' fields.

Keywords:

cropping system, food security, Indo-gangetic plains, intercropping, Pulse.

12.1 Introduction:

The backbone of our Indian economy is Agriculture. The first prime minister of India Pandit Jawaharlal Nehru said, "If agriculture in this country fails, we fail, the government fails and the nation fails, there is no help for us but to succeed in agriculture". Our world faces the

tough challenges of climate change, which makes life difficult on our planet. Millions of people are suffering from severe hunger and malnutrition. The economic systems of many developed countries where agriculture contributes a considerable share of the economy are directly influenced by climate change, population explosion, and food insecurity. The world is longing for a solution that can tackle the situation. The solution should be inexpensive, easy to access, requires minimum input and management practices that have a high amount of nutritive valuable food. Pulses are the best source of all these requirements. Pulses have a prominent and very good source of protein in human beings. It has qualities like a low glycemic index (FAO, 2016), is gluten-free, and even acts as a functional food (Rao, 2002). The diet of Type 2 diabetes patients can be included pulses in their regular diet because of having a low glycemic index and pulses are gluten-free so including it in the diet will not cause chances of Celiac disease. Pulses have important and cheap sources of plant dietary proteins having various amino acids. These are consumed in split form and prepared as a curry called 'dhal' or 'dal' which is an important source of dietary proteins for Indian masses. These superfoods have double the protein in wheat and three-fold in rice. Besides, they are also rich in complex carbohydrates, micro-nutrients, protein, and vitamins B and minerals like calcium, iron, magnesium, zinc potassium, and folate. Long shelf life without loss of nutritional value, low prices coupled with wider availability make pulses an affordable source of protein and minerals and contribute to food security at all levels of society in India. Besides adding to human nutrition, pulse crops serve as a source of fodder and fuel for farm families.

Several pulse crops are grown in India and all over the world. Among the crops, the major ones are Gram, Pigeonpea, Lentil, Fieldpeas, etc. According to history, the origin of Gram is in South West Asia probably Afghanistan and Persia, Pigeonpea in Africa, Lentil in Turkey to South Iran and Field peas in the Mediterranean Region of Southern Europe and Western Asia. Pulse crops are cultivated in the Kharif, Rabi and Zaid seasons of the Agricultural year. Rabi crops require a mild cold climate during the sowing period, the vegetative stage to pod development stage requires a cold climate and the maturity stage requires a warm climate. Similarly, Kharif pulse crops require a warm climate throughout their cropping seasons from the sowing to the harvesting stage. Summer pulses crops are habitants of hot climate. Seed is required to pass many stages to produce seed like germination, seedling, vegetative, flowering, fruit setting, pod development and grain maturity or harvesting.

The Indo-Gangetic Plains of India, spreading about 44 million ha area, is over 185 districts in the states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. The IGP in India can be divided into four major sub-regions, viz. Trans-Gangetic Plains (Punjab, Haryana, Chandigarh and Delhi), Upper-Gangetic Plains (Western and Central Uttar Pradesh) Middle-Gangetic Plains (Eastern Uttar Pradesh and Bihar) Lower-Gangetic Plains (West Bengal).

The Indo-Gangetic Plains also known as the North Indian River Plain is a 700-thousand km2 (172-million-acre) fertile plain encompassing northern regions of the Indian subcontinent, including most of northern and eastern India, around half of Pakistan, virtually all of Bangladesh and southern plains of Nepal. The region is named after the Indus and the Ganges rivers and encompasses several large urban areas. The plain is bound on the north by the Himalayas, which feed its numerous rivers and are the source of the fertile

alluvium deposited across the region by the two river systems. The southern edge of the plain is marked by the Deccan Plateau. On the west rises the Iranian Plateau. Many developed cities like Delhi, Dhaka, Kolkata, Lahore and Karachi are located in the Indo-Gangetic Plains. Pulse crops are part of the legume family, with common varieties including a diversity of species such as fava beans, lentils, field peas and common bean. Corteva Agriscience is seeking new cropping systems that incorporate a pulse crop to increase the amount of protein-rich food grown on existing farmland while reducing agricultural inputs. Crop Diversification refers to a shift from the regional dominance of one crop to the regional production of many crops, to meet the ever-increasing demand for cereals, pulses, vegetables, fruits, oilseeds, fibers, fodder, grasses etc. The importance of crop diversification lies in the fact that it effectively increases soil fertility and controls pest incidences. The boost in rural employment impacts the overall economy of the nation, as agriculture in India falls into the primary sector of the country. A shift in crop preferences is visible since the 1990s. The farmers of the Indo-Gangetic belt who grew pulses earlier, have shifted to wheat where yields range from 3,000 to 4,000 kg per hectare compared to only about 800 kg in the case of pulses. Over the past two decades the production of pulses has largely shifted from northern India to central and southern parts. Today, >90% of total pulses production is realized in 10 states namely, MP, MS, Rajasthan, UP, Karnataka, AP, Gujarat, Jharkhand, CG and Telangana. Both area and productivity of chickpea significantly increased over decades.

12.2 Area and Distribution of Pulse Crops in India:

From 1980–1981 to 2020–2021, the total cropped area under pulses in India increased from 22.46 to 28.83 m ha with a peak of 26.40 m ha in 2010–2011. Due to stagnant production and an increase in population, the per capita availability of pulses has declined in the range of 35.4 g to 47.2 g/capita/day during 2009–2020. The total world acreage under pulses is about 93.18 (Mha) with the production of 89.82 (Mt) at a 964 kg/ha yield level. India, with >28 Mha pulses cultivation area, is the largest pulse producing country in the world. It ranks first in area and production with 31 percent and 28 percent respectively. In India pulses covers an area of 28.78 m ha with production of 25.46 m t. Among the pulses, chickpea contributed 48 percent and then comes pigeon pea, black gram, green gram and other pulses (GOI, 2016). During 2020-21 our productivity at 885 kg/ha, has also increased significantly over the last five years. Under the pro-active pulse program implementation strategies and robust monitoring mechanism of the government of India, significant growth in the area, production and productivity of pulses has been recorded. More visible and significant increasing trends during 2016-17, 2017-18 and 2020-21, whereby the pulses production reached 23.13 Mt, 25.42 and 25.46 Mt respectively, is a grand success story in itself. The productivity of pulses has increased by 13 percent at 885 kg/ha during 2020-21 and 9 percent at 853 kg/ha during 2017-18 from the level of 786 kg/ha during 2016-17. The production growth has been 10 percent highest over 2016-17. Major pulses producing states in India are Rajasthan, Madhya Pradesh, Maharashtra, Uttar Pradesh and Karnataka. Rajasthan was a leading producer of pulse in India with a production of 4821.84 tonnes in 2020-21. India is the grower of pulses in huge quantities. Some government programs like National Food Security Mission (NFSM) - Pulses program are highly useful to make it ever-increasing. The government of India has initiated an NFSM-Pulses program to support the production of different types of pulses in India. The program is being initiated in around 644 districts across 28 States and the Union Territories of Jammu & Kashmir and Ladakh.

Under the NFSM-Pulses program, the government focuses on:

- Distribution of incentives to farmers.
- Distribution of high-yielding varieties of seeds (HYVs).
- And, Production of certified seeds.
- Distribution of efficient farm machinery/tools.
- Distribution of water-saving devices, plant protection chemicals, and soil ameliorants (substances that helps improve/grow the physical condition of the soil).
- Training is also given to farmers to improve crop production and yield.
- And Central seed agencies get assistance to produce certified and latest seed varieties.
- Free of cost, mini kits of various pulses are distributed to farmers.

12.3 Importance of Pulses in India:

The Pulses crops belong to the family Fabaceae or Leguminosae, which is the world's third largest group of plant life after Orchidaceae and Asteraceae. The word ‘pulse’ has its origin from the Latin word ‘Puls’ meaning thick soup or potage (FAO, 2016). According to FAO, pulses are annual leguminous crops yielding, one to twelve grains or seeds of variable size, shape and color within a pod. Only legumes harvested for dry grain are classified as pulses. Legume species used for oil extraction (e.g. soybean and groundnut) and sowing purposes (e.g. clover and alfalfa) are not considered as pulses. Likewise, legume species are not considered pulses when they are used as vegetables (e.g. green peas and green beans) (FAO, 1994). Therefore, all pulses are legumes, but not all legumes are pulses.

Pulses are part of traditional offerings in many temples e.g. Green gram powder as Prasada in Mookambika Temple, boiled cowpea in Parassini Muthappan Temple and ‘Chana sundal’, a special preparation during Ganesh Puja. Pulses are an important component of diets in many countries and can help to provide balanced nutrition. They can also be grown as a palatable and nutritious feed for animals, as a green manure crop, as a fuel source, or even for medicinal use. Pulses are sources of high-quality protein. They act as a good fodder crop. Due to its drought-tolerant properties, it can be grown on marginal and wastelands. It even finds a suitable crop of summer fallows of cereals and areas where rain-fed agriculture is practiced. It has a comparatively short duration than other crops, so it can fit into the gap between the two main crops. It fixes atmospheric nitrogen efficiently through its root nodules. Thus, it not only reduces the fertilizer input of it but also reduces the fertilizer input of the succeeding crop to an extent of 25 to 30 percent. It is also a good green manuring crop. Thus, it enhances the physical, chemical and biological properties of the soil. As it requires less input, less management practices and less labor requirements the cost of cultivation of pulses is very less. Pulses also play a key role in soil and water conservation. They are important crops for food security, combating malnutrition, alleviating poverty, improving human health and enhancing agricultural sustainability. Despite its importance to man, pulses are usually regarded as 'orphan crops'. 'Orphan crops' are crops that are not part of the main crops that are traded internationally and are often considered staple crops, such as rice, wheat or maize. However, the Food and Agriculture Organization of UN (FAO) identified these orphan crops as a solution to global food system risks and an investment opportunity for future agricultural research (GPC, 2016).

12.4 Different Cropping Systems in Indo-Gangetic Regions:

Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. The major cropping systems in western IGP are rice-wheat, maize-wheat, sugarcane-wheat, pearl millet-mustard, rice-chickpea, cotton-wheat, pigeon pea-wheat, rice/maize-potato/mustard-urban/mungbean and rice wheat-mungbean. In the eastern IGP, rice-wheat, rice-chickpea/lentil, rice rice, maize-wheat, sugarcane-wheat, rice-mustard, groundnut-wheat, rice-mustard/potato-urdbean/mungbean and rice-mustard-jute/vegetables are important cropping systems. However, rice-wheat is the predominant cropping system occupying about 10.5 million ha. The main crops are grown in IGP cereals - rice, maize, pearl millet, sorghum, wheat and barley, pulses- chickpea, lentil, fieldpea, pigeonpea, urdbean and mungbean, oilseeds- rapeseed and mustard, soybean, groundnut, sunflower and linseed and cash crops like cotton, sugarcane and potato among. Crop rotations with pulses enhance the productivity of systems. We should focus on the cropping system approach for increasing pulse production by giving more emphasis to increased production per unit of time and space. Reddy and Reddy (2013), the Cropping system consists of a "pattern of crops taken up for a given piece of land or order in which the crops are cultivated on a piece of land over a fixed period and their interaction with farm resources". The advantages of cropping systems include using resources more efficiently, enhancing crop growth, increasing the soil cover of the cultivated area, maintaining and enhancing soil fertility, minimizing the spread of pests and diseases, controlling weeds and reducing the risk of crop failure.

12.5 Deterioration of Natural Resources in Indo-Gangetic Regions:

Pulses in crop rotations increase the systems' production. Continuous use of the rice-wheat or rice-rice cropping systems in IGP resulted in a noticeable depletion of natural resources. According to the National Bureau of Soil Survey and Land Use Planning, the IGP contains 22,84 million ha of degraded land. The main concerns for improved and sustainable agricultural production are growing salt dangers, lowering water table due to over-exploitation of groundwater, particularly in the western region, poor soil health, pest outbreaks, weed threat, and diminishing Total Factor Productivity. Ramesh Chand and T. Haque (1998) expressed that the apprehension emergence of rice-wheat rotation crop system in Indo- Gangetic plains as a post-green revolution phenomenon has resulted in waterlogging, soil salinity and over-exploitation of the natural resource base. Moreover, it is argued that the short time duration between rice-wheat crop rotation has led to sub-optimal land preparation and sub-optimal use of other inputs, causing a reduction in the yield of rice and wheat.

12.5.1 Crop management:

Generally, pulses are grown under low input management and therefore, the yield is realized only 60-65 %. The yield of the pulse crop is a 30-35 % increase with better management practices attainable. Some of the major practices for increasing the pulse crops yields under IGP's are given below:

A. Plant population: For ensuring optimum plant stand, the seed rate should be worked out with due consideration to seed viability and purity, seed size, no. of plants required per sq m

area, soil moisture status, planting time and planting method. Raise bed/ ridge-furrow planting is a must for kharif pulses, especially in eastern IGP where water stagnation/poor drainage often leads to the mortality of plants. Seed treatment with fungicides like carbendazim protects young plants against seed-borne diseases and therefore should invariably be followed.

B. Nutrient management: Pulses have an intrinsic ability to trap atmospheric nitrogen to meet their requirements and also leave some amount for succeeding crops. To augment the process, seed inoculation with appropriate Rhizobium culture should be done. Similarly, PSB inoculation enhances the availability of soil phosphorus. Besides biofertilizers, soil placement of N, P, K, S, and Zn as per soil nutrient status should be done. Foliar application of 2 % urea at flower bud formation and 15 days thereafter is quite beneficial for late-planted and rainfed crops.

C. Integrated pest management: For containing diseases, resistant/ tolerant varieties should be chosen. Seed dressing with appropriate fungicides, crop rotation, soil solarization and soil application of Trichoderma contributes to reducing the spread of disease. IPM, which uses a combination of plant-based insecticides, biopesticides, cultural methods, and a little quantity of chemical insecticides, should be used to control insect pests. Spraying pre-emergence herbicides like pendimethalin and postemergence herbicides like imazethapyr, as well as cultural measures, can effectively manage weeds that may reduce crop output by 15–30%. Nematodes also significantly reduce yield in light-textured soils. Neem cake or phorate granules applied to the soil efficiently reduce plant nematodes connected to pulse crops.

D. Soil and water management: Pulses are typically farmed in rainfed environments, where insufficient soil moisture and unpredictable rainfall frequently cause intermittent droughts that cause significant crop loss. The soil moisture status is improved via laser leveling, field bundling, in-situ moisture conservation, mulching, etc. It is advised to collect water in agricultural ponds and community reservoirs for come-up irrigation and life-saving purposes. Pulses are chronically lacking in the Indo-Gangetic Plains, which contribute more than 50% of the food grains to the national food basket. IGP only produces 3.30 million tonnes of pulse compared to the 10.62 million tonnes total required. Pulses' area under cultivation shrank dramatically from 7.10 million ha in 1970–1975 to 3.37 million ha in 2010–14, posing a severe danger to the region's ability to produce crops sustainably.

12.6 Conclusion:

Pulses are sources of high-quality protein. India is the largest pulses producer globally, accounting for 27-28% of the world's total production. Moreover, India imports 14% of pulses globally. In India, total food grain production only accounts for pulses 7-10%. Pulses are well suited to grow well in both Rabi and Kharif seasons. The problem of malnutrition and inadequate supply of protein poses an enormous task to increase pulse production in many countries. This comprehensive book chapter has been designed to provide sequential development and generation of information in the science and technology of growing pulse crops. It aims to equip the students and researchers with the knowledge of research results to put those into practice for higher crop production in Indo-Gangetic Plains.

Sustainable efforts are needed to end hunger and provide food security. However, one concrete, promising, sustainable and cost-effective opportunity lies within the tiniest of seeds found in a multitude of plants: Pulses-Seeds for a sustainable future (FAO, 2016).

Pulses are the most efficient primary producers of proteins harnessing natural elements like sunlight, soil nutrients and water. While pulses are already relatively climate-hardy, they are being developed. These specific roles of pulses in the cropping system are of greater importance and thus contribute to the cropping system's productivity. to be more tolerant to these conditions. Pulses contribute towards sustainability by mitigating and adapting climate change, reducing poverty and hunger, improving health by providing nutrition and helping to promote economic stability. Pulses are an important component to sustain agriculture production as the pulse crops possess wide adaptability to fit into various cropping systems, improve the soil fertility being leguminous in nature and physical health of soil while making the soil more porous due to the tap root system. Introducing pulses into farm production can be a key to increasing resilience to climate change. It is clear that pulses are an incredible food and deserve greater attention in both our consumption and production. Thus, due attention is required to enhance the production of pulses not only to meet the dietary requirement of protein but also to raise awareness about pulses for achieving nutritional, food security and environmental sustainability. Pulses are good for people, good for soils and good for the planet.

During the Green Revolution period, Indo-Gangetic Plains witnessed a sea change in cropping pattern, with rice-wheat covering over 10 million ha As a consequence of this, pulses were marginalized. Whereas wheat area increased by 58.6 % during 1970-75 to 2010-14, the pulse area decreased by 52.4% during the same period. The share of pulses in food grain acreage of IGP decreased from 16.7% to 7.0 %. This is posing a serious threat to nutritional security and sustainable crop production. The low yield of pulses coupled with high instability in production led to the gradual decline in its area which is alarming and needs to be reversed. Three-pronged strategies (a) expanding area under pulses through intercropping, catch cropping and introduction in rice fallows, (b) improving genetic yield potential through widening the genetic base and employing transgenic technology and (c) improving crop management practices need to be adopted to address the emerging challenges.

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