Chapter

Sustainable Production of Pulses under Saline Lands in India

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Abstract

The decreasing agricultural lands along with waste lands and poor water resources are the main constraints for sustainable agricultural production. The need of time is to produce maximum with minimum inputs. Depleting levels of major and micro-nutrients in Indian soils have been on the rise, and situation may be more harmful if corrective measures are not followed in time. The soil nutrient deficiencies significantly reduce the crop yields in addition to the soil fertility. In preview of this, the need of the hour is to conserve agricultural sustainability, soil health enhancement, and water management. Farmers are forced to use saline water for irrigation in areas with poor quality water or less available water for irrigation, specifically in arid or semi-arid regions. Every crop plants have threshold limit of tolerance beyond which salinity decreases the crop yield. Legumes are very sensitive crops towards soil salinity, and secondary salinization mainly through irrigation water is the hardest challenge for survival of legume crops in arid regions. In view of this, the sustainability of legumes in salt affected areas is a big challenge for crop productivity being sessile to salinity. Hence, the possible strategies for sustainability of salt sensitive legumes have been briefly reviewed in this chapter.

Keywords: soil salinity, pulses, abiotic stress, tolerance, sustainability

1. Introduction

Pulses are one of the food crops that address the challenge of global food security and climate changes, as well as contribute to healthy diets. In recognition of the importance of pulses for human well-being, year 2016 was declared as the International Year of Pulses by the UN General Assembly. Pulses are a subgroup of legumes belonging to Leguminosae family and its seeds are edible FAO [1]. All legumes are sometimes not categorized as pulses e.g., oil producing soybean (*Glycine max* [L.] Merr.) does not come under pulses but grouped as oil-seed crop. Similarly, some other legumes which are consumed as green vegetables e.g., *Medicago sativa* L. are also excluded from pulses. Pulses can be defined as protein rich plants that contribute to healthy diet for people across the globe. Nutritionally, pulses are rich source of dietary fiber, minerals and vitamins with low levels of cholesterol and fat. The protein content in pulses is more than double in comparison to cereals and hence are the important source for nutritional and balanced diet for humans. Pulses are included in all "food baskets" and dietary guidelines. The World Food Program (WFP), for instance, includes 60 g of pulses in its typical food basket, alongside cereals, oils and sugar and salt. India is the largest producer of pulses in the world, with 25% share in the global production. In India, mainly mung bean or green gram (*Vigna radiata*), chickpea or Bengal gram (*Cicer arietinum*), urad bean or black gram (*Vigna mungo*), moth bean (*Vigna aconitifolia*), pigeonpea or red gram (*Cajanus cajan*), lablab bean (*Lablab purpureus*), broad bean or faba bean (*Vicia faba*), horse gram (*Dolichos uniflorus*), lentil (*Lens culinaris*), pea (*Pisum sativum var. arvense*), grass pea or khesari (*Lathyrus sativus*), cowpea (*Vigna unguiculata*) etc. are grown as pulses. Generally, two growing seasons are available for pulses kharif and rabi. Rabi season legumes chickpea, lentil, and dry peas are the cool, dry season pulses grown during October–April while pigeonpea, urad bean, mung bean, and cowpea are grown preferably during the warmer, rainy season or kharif from June to October [2, 3]. The global legume/pulse production, area and yield during 2013 was ~73 million tons (MT), ~80.8 million ha (M ha) and ~904 kg ha-1respectively [4]. Further, Africa and Asia together contribute ~49 MT, i.e., 67% of the global pulse production. In India, production of pulses is around 25.23 million tons during 2017–2018 (DAC, 2018) with maximum production of soybean (11.95 MT) followed by chickpea (~11.23 MT), groundnut with shell (9.4 MT), pigeonpea (~4.25 MT), lentils (~1.61 MT) and dry peas (0.6 MT). During the last 50 years from 1961 to 2011, overall, an average of ~1.7 times legume production has increased globally with ~3 times more cereal production in the same period. Increase in yield per hectare of legumes was observed only ~1.4 times with ~3.0 times increase in cereals. These data show that there is an acute shortage of pulses in India to meet the daily recommended diet. The area, production, growing states with distribution of pluses in India is being given in **Figure 1**.

The Legume family consists of important food grain, oilseed, forage, and agro forestry species. The domestication of legumes by humans dates back to Neolithic times. Chickpea is one of the seven Neolithic founder crops of the near East [5].

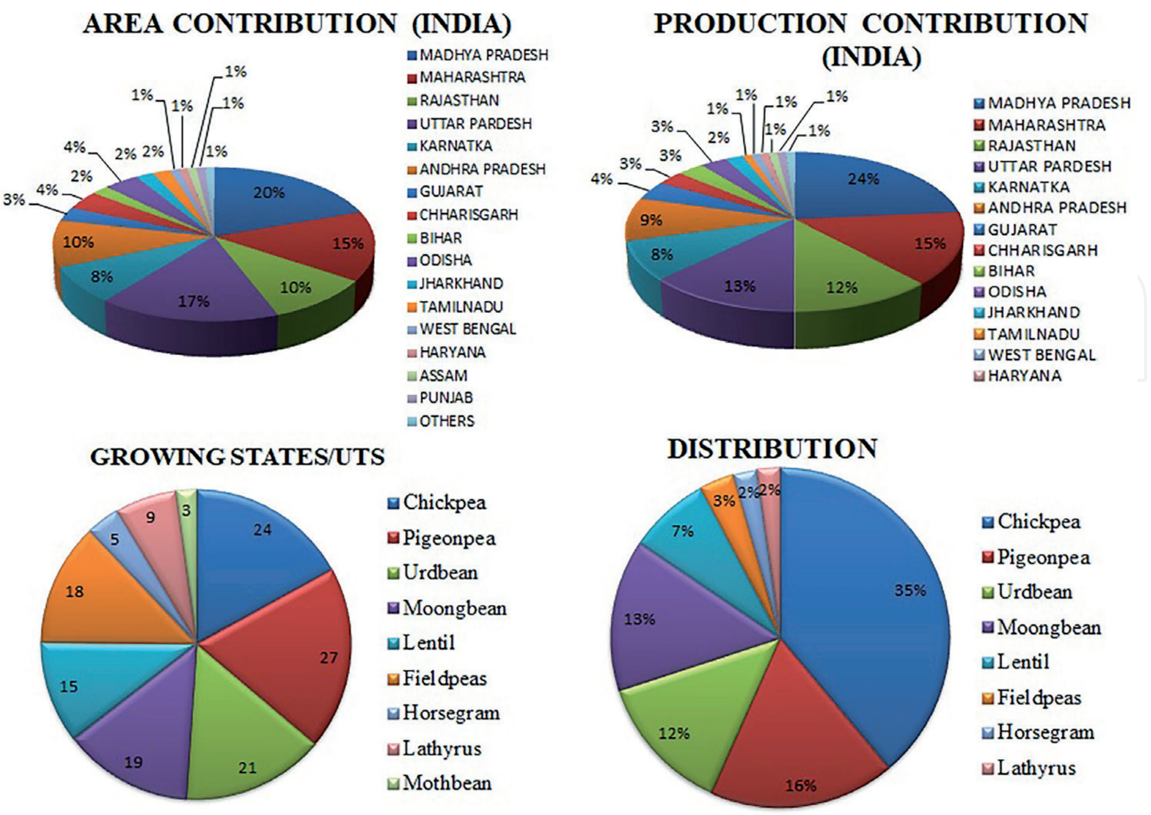


Figure 1.
Domestic production of domestic pulses in different states of India with percent distribution of each legume. Source [11].

Some of the earliest domesticated legumes include: lentil ~9000 years [6], beans and soybean (~3000 year) [7, 8]. Legumes include ~750 genera and ~18,000 species [9, 10]. Legumes form an important part of human daily diet especially in several developing and some developed countries and therefore sometimes legumes are considered as poor man's meat. Pulses contain various amino acids and also have medicinal properties and hence, are consumed as Dal, the easily available source of protein. In addition to the nutrient rich seed/grain, plant parts like leaves, pod coats etc. are used as animal fodder e.g., moong bean, lobia, urad bean and gram. These plants are also used as green organic manure to maintain soil health and fertility.

Legumes are under explored crops in comparison to staple cereal crops like wheat, rice and maize and hence are prioritized over pulses in most of the crop improvement programs. In addition to that pulses being sensitive to biotic and abiotic stresses, farmers have reduced their cultivating due to low yield potentials. Hence, keeping these facts in view, it is required to pay more attention for sustainable production of pulses in arid and semi-arid regions.

India will face intense pressure on its land and water resources in agriculture because of diversion of resources to domestic, industrial and other sectors of economy and the likely degradation of these resources, having to feed 1.6 billion people by 2050. Ever increasing demand for good quality land and water resources in the domestic and industrial sectors has already generated enhanced interest in the utilization of salt affected soils. While salt affected soils currently constitute 6.74 M ha in different agro-ecological regions, the area is likely to increase to 16.2 M ha by 2050. Thus, salt affected soils represent an opportunity that can be exploited to increase agricultural production and productivity to ensure national food and nutritional security. The distribution of salt affected soils occurs mostly in arid and semi-arid regions although such soils may exist in every climatic region including a good area of irrigated lands. In addition, the coastal salinity is another big challenge. Hence, the diversity of soil properties in different agro-climatic conditions requires different approaches to reclaim and maintain the soil properties.

The dynamics in the global pulses sector are ever changing and keeping pace with them is much like running on a treadmill. For the past few decades, India has been trying its best to make pulses more and more accessible to its citizens given the rapid drop over the previous few decades. On the other side, there is increased interest in vegetarianism, healthier diets, apart from falling real incomes following slowing economies and the relative lower cost of protein through pulses, all of which increase demand in countries like US and China. There is an increased "return to traditional foods" in African countries like Egypt and Morocco that are adding to the demand mainly import demand. From 2005 when Spain was the second largest importer, followed by Italy and Mexico, in 2012, the profile of importing countries had moved to China, Pakistan, Bangladesh, Egypt and then Spain. The cheaper access to proteins that pulses provide is clearly important in this age of tough economies.

Pulses import basket now has mainly dry peas resembling palm oil in edible oils. Yet the record domestic chana production and 40% correction in chana price have not been able to compete with peas. Similar is with Pigeon Peas. India traditionally imported dry peas mainly from Canada, but now cheaper imports from Russia, Ukraine and France are also keeping the prices under pressure making it difficult to keep Chana and Pigeon peas competitive. None of the steps taken in the recent years seem to have paid off in terms of better farmer remuneration, or better availability and better prices for consumers. The only real solution to this problem is increasing domestic production to the extent that over 90–95% of the demand is met internally and the imports are supplemental to ensure prices are not volatile. It requires policies that encourage better technologies, better quality, better post-harvest management and better distribution of the pulses.

In the current season chana, moong, tur and urad have all seen production increase with increases in acreages and excellent weather. This may be a good opportunity to also open exports and see if farmer incomes and long term acreages increase with these measures as against the known vicious cycle of acreages decreasing after a season of good production following the crash in prices led precisely by the high production. It may take a few years for the prices to settle and farmers to become globally integrated, but the time has indeed come to take this leap of faith [12].

2. Mode of formation of saline soils

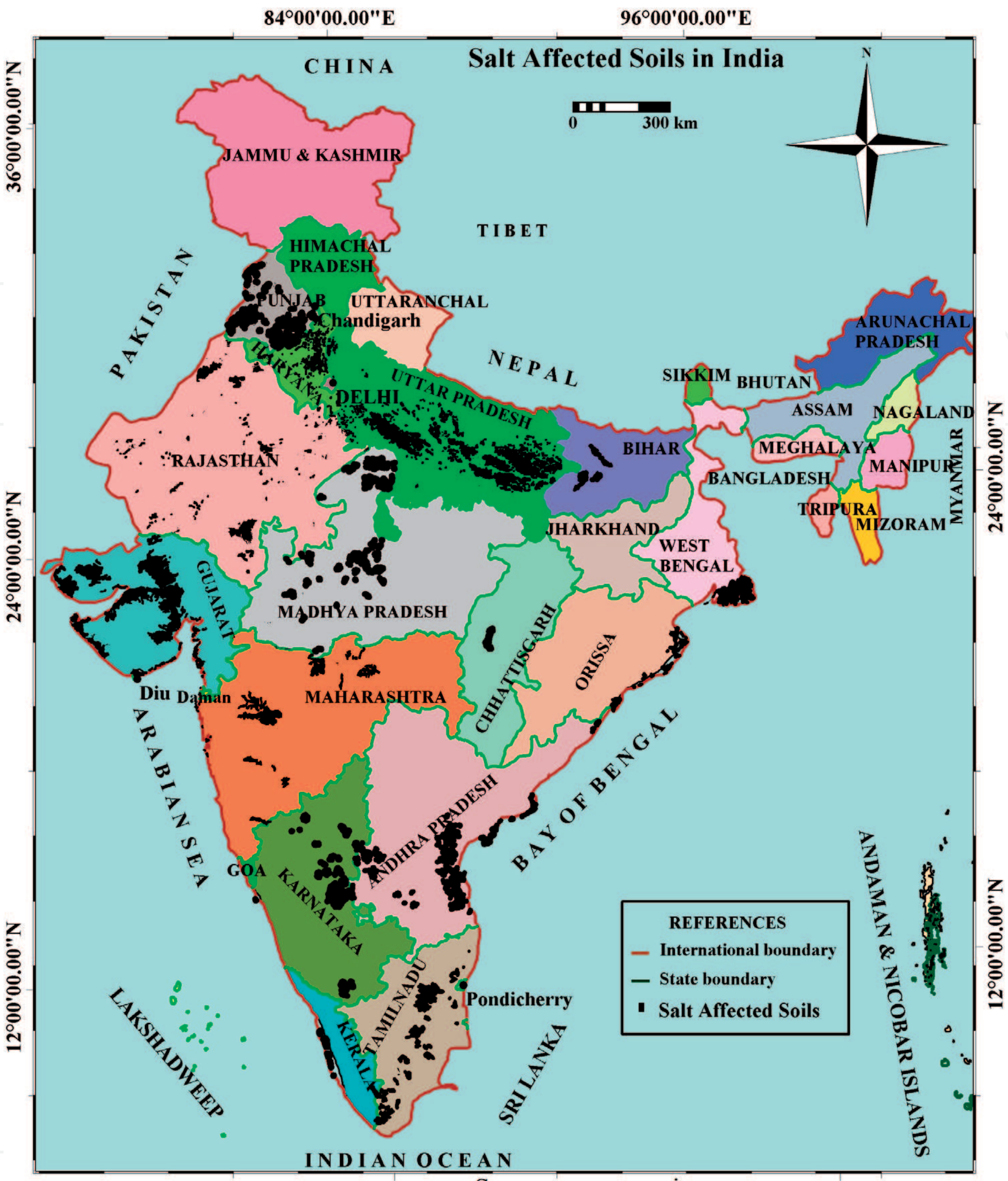
A big monetary loss created due to soil salinity in India. About 175 M ha (53%) land is degraded by various means from a total of 329 M ha of land in the country. Ministry of Agriculture, GOI stated that 7.61 M ha of land is salt affected in India which ranges from 8.56 M ha to 10.9 M ha. Majorily saline—alkali and waterlogging problems occur in Gujarat, Andhra Pradesh, parts of Punjab, Haryana, Rajasthan, Maharashtra, Karnataka, Uttar Pradesh, Madhya Pradesh, and Tamil Nadu (**Table 1**). Total salt affected soils in India are 1,710,673 ha with maximum in Gujarat followed by Rajasthan (**Figure 2**) while Coastal saline soils are 1,246,136 ha with maximum in Gujarat followed by West Bengal and Orissa.

Thus briefly following reasons can be assigned for salinization of the soils:

- Non-systematic irrigation with more than required irrigation cycles
- Evapotranspiration in arid conditions leads to accumulation of salts in the top layer

Sr. no.	State	Saline soil (ha)	Alkali soil (ha)	Coastal saline soil (ha)	Total (ha)
1	Andhra Pradesh	0	196,609	77,598	274,207
2	A & N islands	0	0	77,000	77,000
3	Bihar	47,301	105,852	0	153,153
4	Gujarat	1,218,255	541,430	462,315	2,222,000
5	Haryana	49,157	183,399	0	232,556
6	J & K	0	17,500	0	17,500
7	Karnataka	1307	148,136	586	150,029
8	Kerala	0	0	20,000	20,000
9	Maharashtra	177,093	422,670	6996	606,759
10	Madhya Pradesh	0	139,720	0	139,720
11	Orissa	0	0	147,138	147,138
12	Punjab	0	151,717	0	151,717
13	Rajasthan	19,557	179,371	0	374,942
14	Tamil Nadu	0	354,784	13,231	368,015
15	Uttar Pradesh	21,989	1,346,971	0	1,368,960
16	West Bengal	0	0	441,272	441,227
	Total	1,710,673	3,788,159	1,246,136	6,744,968

Table 1.
Extent and distribution of salt affected soils in India.



Source: www.cssri.org

Figure 2.
Distribution of salt affected soils in India.

- Seepage in perennial river basins/irrigation sources causes water logging conditions
- Heavy use of chemical fertilizers containing chlorides, sulfates etc.
- Poor drainage conditions.

  i. Use of saline groundwater: the areas where no other source of water is available, irrigation with highly saline groundwater leads to accumulation of salts in plant root surrounding environment. This problem is more prone in soils with poor drainage.

  ii. Saline seeps is a major problem in areas with change in land use pattern, when natural forests are being used for cropping system or following a fallow season in green lands or some change in farming system. This problem mainly found in Australia, North America and some other countries. The impermeable horizontal layers intercept the percolating water passing through saline sediments and then transport laterally to landscape depressions which brings about soil salinization [13].

iii. Other important sources for creating salinity are sea tidal waves, transport of salt sprays through wind or underground aquifers. Another procedure of salinization includes exchange of soluble salts between sea and land through marine sediments uplifting on earth's surface. In arid or semi-arid regions, the lowest level of rainfall equal to evapotranspiration also brings salinization by accumulation of salts in the root zone of plants.

iv. Generally soluble salts move from higher levels to lower levels and this localized movement of salts also builds a significant level of salinity. Salts from moist to dry and watered fields to adjacent dry fields create salinity. The industrial/commercial developmental activities like laying of roads or rail tracks also create salinization specifically in areas where natural drainage is restricted due to these activities.

In rainfed areas, management of unirrigated lands is a major problem specifically when cropping is done in such fields. Dryland salinity is a worldwide threat to available cultivable land and water resources in countries including. Great Plains region of North America, Iran, Afghanistan, India, western Australia, Thailand and Canada and South Africa and probably some other countries. Such dryland saline spots are most commonly known as saline seeps, occurring frequently from marginal saline to extreme saline lands without any cultivation.

3. Management of saline soils

There are two major approaches to improving and sustaining productivity in a saline environment-either modifying the environment to suit the plant or modifying the plant to suit the environment [14]. The farmers very well know the adverse effects of soil salinity in terms of reduced plant growth and yields. Since the saline area is increasing day by day, the farmers are shifting to various other alternates like change of cropping pattern, green manuring, dairying etc. along with use of open drainages and mulching. Although it is difficult to manage saline soils through any chemical amendment, the only precautionary method is to use good quality water and grow salt tolerant varieties of crops.

The consideration of various studies on soil salinity have led to only a single observation for timely implementation of corrective measures to stop further salinization and conversion of fertile soils to waste lands. This approach cannot be achieved by a single adaptation, it needs to be a cumulative effort to spread the awareness about soil sustainability and enhanced crop production. In the coming time the concept of soil management and sustainability should be the one of the important issue to be taken care of or we have to bear the low crop productivity (www.nabard.org).

4. Crops and saline soils

Most crops do not grow well on soils that contain salts. Homeostasis of ions is disturbed in the cell due to high salt concentration in the rhizosphere, thereby, creating water deficit under salt stress conditions. This leads to abbreviations in structure and function of various proteins. Under such circumstances, a signaling pathway is activated in the cell to synthesize the metabolites, proteins or enzymes involved directly in scavenging free radicals and maintaining the ionic flux through osmoregulation. Detoxification of free radicals is an important defense mechanism under salt stress. Pulses in general are the most salt sensitive crops. One reason is that salt causes a reduction in the rate and amount of water that the plant roots can take up from the soil. In legumes, salt stress imposes a significant limitation of productivity related to the adverse effects on the growth of the host plant, the root-nodule bacteria, symbiotic development and finally the nitrogen fixation capacity. Also, some salts are toxic to plants when present in high concentration. Some legumes plants are more tolerant to a high salt concentration than others e.g., lentils are more tolerant than soybean and chickpea. Recently, few salt tolerant chickpea lines have been identified for survival at early seedling stage in saline soils with EC of irrigation water from 3 to 12 dS/m [15]. Earlier, pea genotypes have been categorized as sensitive, moderately tolerant or tolerant to salinity based on physiological and biochemical expressions of salt tolerance [16].

5. Pulses and sustainability

The most potential technologies in pulse production include improved crop establishment and management practices, integrated soil fertility and pest management practices, etc., which enhance not only the productivity and profitability but also warrant environmental and social sustainability besides nutritional security [17]. Role of pulses in maintaining sustainability is very wide since pulses are an important component of crop rotations, requiring very less fertilizers than other crops. Legumes are beneficial part of the rotational crops to maintain soil fertility.

Good soil management practices for crop rotation also includes pulses with different crops like wheat, barley, oats, oilseeds such as canola, flax, sunflowers, etc. The nitrogen fixing ability of pulses enriches the soil quality and fertility and hence leading to enhanced productivity in subsequent crop rotations. Soil health in also improved through pulses as they feed soil microbes. Even the crop residue of pulses contains different amino acids and bio-chemicals than non-legumes. This diversity in soil composition provides better protection against disease-causing microbes and thus helps crops to thrive under adverse conditions. The number and diversity of soil microbes is markedly increased with intercropping of pulses [17, 18]. An environment of 'live' soil with diversity of soil micro-organisms is considered best for crops because these micro-organisms enhance the nutrient uptake rate and efficiency in different soils. Additionally, the abundance of diverse soil micro-organisms 'crowd out' the disease-causing bacteria and fungi, and thus protects the plants.

Pulses are considered as low carbon footprint crops since they use half energy inputs than other crops. Soil bacteria are utilized for nitrogen fixation from air which replaces additional requirement of nitrogen fertilizers in pulse crops. Nitrogen enriches the soil in different forms like fertilizer, manure or crop residue, then most part of it is converted into a powerful greenhouse gas, nitrous oxide. Globally, nitrous oxide represents around 46% of the greenhouse gas emissions from agriculture and is almost 300 times more potent than carbon dioxide (CO_2) [19]. As nitrogen fertilizers are related directly with greenhouse gas emissions therefore, pulses have lower carbon footprint than other crops due to their nitrogen-fixing ability. Nitrogen is manufactured from natural gas and is the most needed fertilizer in crop production. The unique feature of pulses is that they take nitrogen from the air directly and fix at their own, hence, application of nitrogen as fertilizer in pulses is minimal in comparison to other crops.

The nitrogen fixation property of pulses reduces the footprint of other crops in the soil adding to the food production cycle. In a study on durum wheat, it was found that carbon footprint was reduced by 17% in durum wheat when preceded by chickpeas or lentils, nitrogen-fixing crops, than preceded by a cereal crops. The impact of pulse-pulse intercropping with wheat system was much stronger than traditional cereal-cereal-durum rotation by reducing the carbon footprint of durum wheat up to 34%.

The water requirement of pulses is also very less i.e., 1/2 to 1/10 of water in comparison to other protein rich crops [20]. Few pulses are well adapted to dry climates and hence can be produced better under dry/drought conditions, e.g., peas and lentils roots absorb less water from a lower depth. The water available in deep soil is, in this way, used by next crop, thereby increasing the water use efficiency of the entire cropping system.

6. Role of legumes in improving soil quality

Legumes have long been recognized and valued as “soil building” crops. Growing legumes improves soil quality through their beneficial effects on soil biological, chemical and physical conditions. When properly managed, legumes will:

- Enrich the soil N power with increased reserved organic matter
- Enhance soil biological activity with improved soil structure
- Increase soil aeration with reduced soil erosion
- Improve water-holding capacity of soil

These improvement factors depend on legume type, remaining plant residue left over in soil along with environmental conditions.

The legumes crops that are capable of fixing large amounts of nitrogen under good moisture conditions, can significantly improve the nitrogen supply for succeeding crops when grown annually. Annual grain legumes are normally grown for grain production along with green manure crops. The selection of legume type and variety mainly depends on minimum support price of the crop, including the climatic adaptability to that particular area (e.g., few varieties of chickpea and lentil are more drought-tolerant than faba bean and pea), adaphic factors, disease tolerance, etc. The effect of perennial forage legumes on soil quality is generally to greater extent and for longer duration than of annual pulse crops. The root structure and growth habit generally determines the amounts of nitrogen fixed by grain legumes and the shallow roots of pulses with short growth cycle become a limitation for their influence on soil physical conditions. However, during the growth of grain legumes, considerable amounts of nitrogen are leaked from roots into the soil. Also, the residues from these crops have a higher nitrogen content than cereal straw and they break down more readily, releasing nitrogen into the soil. Thus, cereal crops that follow grain legumes require less N fertilizer.

Biennial forage legumes e.g., sweet clover, yellow-flowered type is preferred by farmers. It is more drought-tolerant, shorter, and finer stemmed and leaved. These characteristics make it a more palatable livestock feed and easier to incorporate as green manure. Sweet clover is one of the most suitable crops for use as a green manure. This helps in recovery of soil moisture reserves and residue decomposition during the partial fallow period. Sweet clover is very well suitable on moderately saline soils or soils that have poor structure due to very low levels of organic matter. An experiment on wheat with sweet clover green manure in rotation for 3 years at Indian thin black soils yielded significantly more than with crop rotations with fertilized crops or fellow lands [21, 22]. Although unfertilized green manure-wheat-wheat rotation also yielded highest during the initial years of this study.

Perennial forage legumes also add humus and soil nutrients in addition to fixing nitrogen. Again, the selection of perennial legume depends mostly on the usefulness of crop and soil type.

Alfalfa is a well-known legume tolerant to drought, moderate salinity, winter hardy along with high yields which is widely grown over diverse range of adaphic conditions. Neutral to slightly alkaline soils favor the production and persistence of alfalfa but acidic soils (pH less than 6.0) limit the production severely. The drought tolerance of alfalfa is due to deep root system and hence it grows best on well-drained soils. It cannot grow well on soils with poor drainage and hence is flooding intolerant.

Red clover, a perennial legume, has growth cycle shorter than alfalfa and therefore included in short duration intercropping system. Since, it is well adapted to diverse soil types, it is grown mostly for seed and feed in the moist areas. Red clover is sensitive towards salinity or drought but tolerance level to acidic soils is more than alfalfa.

Forage legumes have deep root system and longer growth period thus have greater capacity for nitrogen fixation and hence improve soil quality more effectively. Biennial and perennial forage legumes add more nitrogen and organic matter in second year after under seeding in cereals in wet areas. Regular green manuring with forage legumes on degraded soils with typically low organic matter contents, adds more nitrogen and organic matter to the soil. It was found that yield of 12 successive wheat crops increased significantly than a non-legume system on a Gray soil in Northern Alberta. The reason may be addition of nutrients and nitrogen to soil from the deep-rooted legume improved soil quality. The benefit of using forage legumes as green manure enriched soil organic matter with nitrogen and readily decomposable plant residue. This also enhances the production of soil microbes and thus, fastens the nutrients availability. It was found [23] that deep-rooted perennial legumes take up phosphorus from the subsoil although available phosphorus is mostly found in the 0–6 inch depth and not below than 2-foot depth. Thus, green manuring with these legumes increases availability of soil nutrients.

In an experiment at Saskatchewan, it was observed that tillage was easier with lower power requirements on soils following a perennial legume crop than after cereal grains. The reason may be improved soil structure with more porosity due to readily decomposable soil organic matter leftover by legumes. As a result, the water holding capacity of soil is increased and it becomes more friable and less erosive and easier to till.

Forage legumes also have the tendency to reduce salinity problems. Alfalfa uses excessive water through its deep roots and thus deep penetration of roots improves the internal soil drainage. A study at Outlook with irrigated alfalfa plowed-down in late fall or early spring indicated that the following cereal crop required little nitrogen fertilizer, while the second cereal required two-thirds of its usual amount (Henry, University of Saskatchewan, Saskatoon).

In view of above facts, key insights and findings from the literature and case studies across the three pillars of sustainability, environmental, social and economic impacts of pulses are summarized below.

7. Environmental impacts

Nitrogen fixation: the unique role of pulses in the global nitrogen cycle is due to their property of fixing atmospheric nitrogen in soils. The intercropping of pulses with traditional crops reduces fertilizer requirements of soil in subsequent crop cycles by actively fixing nitrogen in the soil. The leftover nitrogen in the soil also increases the productivity in subsequent crops. Hence, the benefit of pulses observed in different cropping systems to enhance the soil properties and crop productivity is a matter of an ever-evolving science.

The changing patterns in traditional planting methods of maize and bean affect the nitrogen balance in cropping systems in Sub-Saharan Africa. It was found that, intercropping of cowpea with maize and groundnut enhanced the nitrogen benefits. Also, modified strip-cropping of cowpea and sorghum altered to traditional farming practices prevented the nutrient losses in the dry savannahs of Nigeria and Niger. The environmental benefits of pulses are prominent in terms of their nitrogen fixation abilities, reduction in fertilizer nitrogen requirements and nutritional enrichment (protein content) of succeeding cereal crop strong. Related benefits of the reduced synthetic nitrogen fertilizers requirements in cropping systems, when pulses are added in rotations, include the reduced emissions and energy use associated with the production, use and disposal of fertilizers.

In the twentieth century, the negative effects of human impacts on the global nitrogen cycle are mainly due to increased and imbalanced fertilizer use and fossil fuel combustion causing severe water pollution and high emissions of N_2O. It has been observed that nitrogen fertilizer use has increased by roughly 800% from 1960 to 2000, which is almost half of that being used for wheat, rice, and maize production [24]. Synthetic fertilizers provided close to half of all the nutrients received by crops globally during the mid-1990s, demonstrating both a large dependency on synthetic fertilizers, but also inefficient management of nitrogen in global agriculture [25]. Cereal crops such as wheat, rice and maize typically only utilize 40% of fertilizer applied, leading to significant waste and environmental impacts such as eutrophication of coastal waters and creation of hypoxic zones [24].

It was observed that field pea, lupin or faba bean fulfilled about 70% of nitrogen requirements from atmospheric nitrogen with an average of 19 kg of nitrogen fixed per ton of pulse shoot dry matter during 2001–2013. The study was conducted across the geographic range of southern and central New South Wales, Mallee and Wimmera in Victoria, and the high rainfall zone of south-eastern South Australia [26]. The two most important interventions to decrease nitrogen requirement are systematic crop rotation including pulses/legumes into maize-based systems and optimizing the timing of application with balanced amounts of fertilizer [24]. Biological nitrogen fixation is a crucial alternative source of nitrogen, and can be enhanced along with other integrated nutrient management strategies such as animal manure and other biosolids, and recycling the nutrients contained in crop residues [27].

Conservation tillage: changes in tillage practices have had a significant effect on shifting conventional cereal-based cropping systems to more diversified crop rotations that utilize pulses or oilseeds and that result in less soil disturbance. Long-standing patterns of monoculture cereal cropping resulted in pest and disease outbreaks and erosion, and fallowing led to increased soil salinity and loss of soil nitrogen and water. The nitrogen fixation capability of pulses is the greatest environmental benefit into cereal-fallow rotations thereby reducing fertilizer nitrogen requirements in the current and succeeding crop along with improved soil capacity to supply nitrogen. Farmers in Saskatchewan changed the tillage requirements by managing herbicide practices leading to reduced rates of applications.

Changes in tillage practices have been an important part of shifts from conventional cropping systems, based on grain production, to more diversified crop rotations utilizing pulses or oilseeds. Importantly, implementing conservation tillage practices has often involved introduction of pulses and oilseeds into grain-based crop rotations. Many studies have demonstrated the nitrogen fixation benefits of conservation- or no-tillage, with pulse and oilseed bean nodulation improving after multiple years of no-till and nitrogen fixation rates increasing (moderated by changes in rainfall patterns) [28].

Productivity vs. area expansions: Addition of pulses into different crop rotations increases the efficiency of any production system and hence increases the overall crop yields by reducing the need of expanded production area.

In Sub-Saharan Africa to improve the production rate for accomplishment of the food and feed demands is very crucial as maximum pulse production, although relatively low, occurs in rainfed areas with minimal inputs. It is estimated that the requirement of pulses (mainly cowpeas and beans) is expected to increase up to 155% till 2050. However, there are some examples which indicate enhanced production rates i.e., the yield of cowpea is increased at a greater proportion than the hectares planted in Ghana. This reflects the efficiency of production system due to supply of better quality seeds and improved varieties, cost-effectiveness for farmers, increased demands for better markets.

Climate change mitigation and adaptation: In crop rotation system, due to lower fertilizer requirement, pulses can aid in lowering GHG emissions. In Western Canadian cropping systems, about 70% of non-renewable energy used is due to nitrogen fertilizers specifically. SK, research at Swift Current, evaluated net GHG emission in four cropping systems (fallow-wheat-wheat, fallow-flax-wheat, lentil-wheat and continuous wheat). They observed the lentil-wheat system as the most efficient in GHG emissions due to the lower requirement of nitrogen fertilizer by wheat. In addition, increased nitrogen availability results into enhanced biomass production.

8. Social impacts

Nutrition and disease: the food consumption per capita may decline in developed countries by 2024, but in developing countries the demand will increase primarily based on increase in protein consumption. Globally, the contents of human diet shifted to more energy-dense foods containing highly saturated fats which are very risky for developing obesity, diet-related diseases like diabetes, coronary heart disease and cancer, etc. Along with the fruits and vegetables, pulses and legumes are important diet rich in micronutrients for healthy choices. Pulses help to control cardiovascular disease, increasing gut health and healthy nutrition. The global consumption level of pulses is declining, specifically in developing countries e.g., in 1963 pulse consumption in China was 30 g per capita per day which declined significantly to only 3 g per capita by 2003 [29].

The total caloric consumption is expected to increase at global level. The rate of food consumption in developed countries is in stagnant growth whereas it is significantly increasing in developing countries, as indicted by OECD/FAO Agricultural Outlook to 2024, reflecting increase in protein consumption. The rate of consumption of cereals is expected to increase about 390 Mt by 2024, which suggest that cereals will remain most consumed agricultural product [30]. India provides a counterpoint to China, as pulses there provide an increasing source of protein, now accounting for almost 13% of overall protein intake [31]. India is the largest pulse producer and consumer, and the country grows the largest varieties of pulses in the world, accounting for about 32% of the area and 26% of world production. The increased pulse crop yield from 0.63 t/ha in 2007–2008 to 0.79 t/ha in 2012–2013 is a measure of efficient production system. Along-with this, the annual yield growth is likely to overtake in production area. However, the production of pulses in India is still below the global average as the Indian needs for the pulses are increasing, causing more import, which is expected to grow about 5.1 Mt by 2023 [31].

Nutrition and food security: food security may be best defined as: “a situation comprising of all people always having access to safe, sufficient and nutritious food fulfilling their all food preferences and dietary needs to run a normal, active and healthy life in all good physical, social and economic environment [32]. Pulses add minerals, vitamin B, proteins as well as essential amino acid like lysine to cereals making it protein-rich. A number of new methods, in manufacturing food products, are being used now days to increase production and use of pulse protein fractions.

Gender: gender aspect of pulse production relates primarily to women’s involvement in pulse production commercially, to feed families, and to benefit from income derived from pulse sales.

9. Economic impacts

Reduced reliance on fossil fuels and lower fuel costs: Pulses and oilseeds are commonly used in crop rotations where conservation of tillage practices has been adopted. By adopting no-till practices, the farmers are expected to see the long-standing economic benefits in terms of lesser degradation of soil, air and water with reduced consumption of fossil fuels.

10. Economic challenges for pulses in India

India is the largest consumer of pulses, but government subsidies and price controls in the agricultural sector created distortions that affected domestic production. In 1990s, government removed the import restrictions and lowered the tariffs on agricultural products which resulted into reversal of protectionist policies of 1970s and 1980s. The external trade in all major crops was regulated except basmati rice and durum wheat, and government agencies were authorized for all the imports. However, the import tariffs on pulses were considered differently which were gradually reduced and ultimately eliminated by 1996. The hope of augmented imports due to liberalization of domestic pulse market also could not be materialized rather; total pulse imports share in merchandise trade fell down after liberalization [33]. Minimum support prices are an important part of the policy decision to stabilize commodity prices, improve the economic viability of farming in India, this also enhance food security by diversification into oilseeds, pulses, livestock and fish. However, the MSP for pulses did not give the same trend as that of rice. During 2008–2009, prices for pulses were increased at a rate higher than for food grains, but the area covered under pulses not increased proportionally and this resulted into pulse cultivation risks. If we compare this case with paddy crop cultivation such risks are not associated, and the farmers are also assured for procurement by government agencies [31].

11. Pulses and livestock feed diversification

Pulses not only increase nitrogen supply [34] but also increase the meat production if used in livestock production systems. By 2050, demand for meat may increase to 200 MT per annum, with corresponding demand for livestock feed [35]. Field pea is being promoted as enriched source of protein and energy in cattle feed in the northern Great Plains of the US and Canada since it is easily digestible by cattle, but the starch fermentation and ruminal protein degradation rates are slower than for other common feeds. Dry matter intake by cows is also increased using field pea in livestock feed ration acting as a binding agent for pelleting formula feeds [36].

Significant economic benefits have been recorded in investment policies in pulse crop research. Across four CGIAR centers, the CGIAR Research Program on Grain Legumes, a global alliance coordinating efforts estimated that the net present value of gross benefits of its legume research and extension was US$ 4.5 billion in 2012, nearly to US$ 535 million per year. During 2014–2020, proposed activities by CGIAR program included legume research to address food security through increased availability of food (over 8 MT), nutrition security from more availability of protein, and environmental benefits through biological nitrogen fixation (a fertilizer cost saving of US$ 418 million). In South and South-East Asia and Sub-Saharan Africa, where most of the world's poorest communities are located, the CGIAR estimated more than 50% of the projected economic benefits through legume research and extension [37, 38].

12. Suitability of some pulses for marginal areas

Drought prone areas having lowest rainfall 300–450 mm/year are best suited for cultivation of drought-tolerant pulses including lentils, Bambara beans and pigeon peas. Normal crops cannot survive and produce under such adverse conditions. The benefit of these drought-tolerant legumes is their adaptability towards such harsh environments by deep-root systems surviving in water scare regions and thus improves the crop productivity in marginal environments. Using locally adapted pulses, farmers in dry environments, can intensify their production systems in a sustainable manner where food security represents a huge challenge. Additionally appropriate policies and programs, marketing trade systems to support the marginal farmers need to be encouraged for pulses to increase the availability and consumption of drought-resistant pulses.

Malnutrition is a major issue in many countries and pulses can be grown in these regions to overcome the hunger threat. The food and nutritional security can be achieved to some extent with the production of pulses in these regions [39].

Farmers are forced to use saline water for crop irrigation in arid and semi-arid regions due to water shortage or by poor quality water. Every crop has a threshold level of salinity tolerance above which yields decrease with increasing salinity. Soluble salts accumulate in saline soils affecting plant growth at various stages and creating yield differences of crops at maturity. This requires immediate controlling measures for soil salinization and preponderance of saline water sources along with cultivation of salt resistant crops.

In India, nearly 6.73 M ha area is affected with salinity and sodicity stresses covering various states of the country. Nearly 20% of the irrigated agricultural land is transforming into saline area with 1–3% per year either due to natural salinity or due to human interference. Global effects of increased salinity at agronomically important land will be visible by the middle of the twenty-first century [40–42]. Further, the arid and semiarid areas in different states are associated with saline underground water, which have to be used for irrigation purpose. The development and use of plant species that can tolerate high salt level is important for sustainable crop production on such soils and water conditions and is cost effective. This may be achieved by making use of variations in tolerance both, between and within cultivars. Low yield potential coupled with biotic and abiotic stresses has further reduced cultivation of grain legumes (chickpea and mung bean) by the farmers. Recently, realizing the significance of grain legumes in improving nutrition and the livelihood of poor farmers, more research is now being carried out for their genetic amelioration by various institutes. Though CSSRI have released a salinity tolerant desi chickpea variety (CSG 8962) in 1997, yet further improvements are required to recombine salt tolerance and high yield, which is the need of hour.

Omic approaches for crop improvement: the networks of genetic and environmental factors controlling various abiotic stresses are complex and hamper breeding strategies. There is a limit for traditional approaches for crop improvement; novel approaches in agriculture need to be adopted to meet the demands of an ever-growing world population. Various technological advances have led to the emergence of high throughput tools to explore and exploit plant genomes for crop improvement to counteract the aforementioned agricultural challenges. These approaches aim to explore the entire genomics to gain insights into plant molecular responses ultimately to provide specific strategies for crop improvement. Functional genomics techniques have long been adopted to unravel gene functions and the interactions between genes in regulatory networks, which can be exploited to generate improved varieties.

In these contexts, exploring management strategies to use low inorganic N with suitable grain legumes would help to sustain crop productivity.

Future strategies for increasing pulses productivity and production: to increase area and production of pulse crops we need crop specific and region specific approaches, which should be adopted in the overall framework of systems approach. The major thrust areas to be addressed are as follows.

- Input responsive and non-lodging varieties
- Biotic and abiotic stress tolerance
- Super-early varieties for green grains
- Machine harvestable and herbicide tolerant varieties
- Nutritionally enhanced varieties
- Integrated pest and disease management
- Public-private partnership for sustaining chain and to minimizing post-harvest losses
- Linking MSP to market prices can bridge the gap between demand and supply
- Climate smart varieties

13. Next steps in the pulse contribution

While the global pulse industry, and the pulse industry in India, successfully celebrated International Year of Pulses in 2016, let us also think about what will be done to ensure that pulses lead by example to help end hunger. The Zero Hunger Challenge and 2016 International Year of Pulses are opportunities to make a significant difference in the global fight against hunger, and to demonstrate to the world how pulses support healthy people and a healthy planet [38]. The aim of National Food Security Mission of India is to improve production of pulses and for this approximately Rs 1100 crore were distributed for during 2016–2017. The positivity of this program was executed by organizing quality seed production-cum-awareness field days highlighting the importance of quality seeds through allocation of Rs. 20.39 crore to ICAR/Agriculture Universities for increasing the availability of new pulse-variety breeder seeds. Inter cropping of pulses with other crops is being encouraged. A number of schemes have been launched for the development of agriculture and farmers' welfare. In view of good monsoon in India, in spite of two consecutive drought years, pulse production reached 25.23 MT (2017–2018) which is still lower than the domestic demand (27.91 MT) (Source: Directorate of Economics and Statistics, Department of Agriculture & Cooperation and Department of Commerce, Govt of India). Therefore, the BRICS nations have been approached and it was commented that India would like to seek cooperation from member countries (BRICS) in helping to meet our production shortfall in crops like pulses and oilseeds.

Let us show the same creativity and leadership that has built a strong global community within the pulse industry and also become the leaders of a basic human right—the Right to Adequate Food. It is time to get to work. It is time for the global pulse industry to step up to the challenge!

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