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Pulses: Nourishing Communities and Ensuring Food Security in Rainfed Areas

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Pulses are a group of leguminous crops that include beans, lentils, chickpeas, and peas. They are a vital source of plant-based protein and essential nutrients, serving as a key component in diets worldwide. In rainfed areas, where agriculture is heavily reliant on rainfall rather than irrigation, pulses play a crucial role in sustaining food production. Due to their ability to fix nitrogen in the soil, pulses improve soil fertility, making them suitable for rainfed agricultural systems. The cultivation of pulses in rainfed areas helps enhance the nutritional status of soils and promotes sustainable agriculture practices. Pulses not only contribute to food security but also have several socio-economic benefits. They provide opportunities for income generation and employment, empowering local communities and reducing rural poverty. Furthermore, pulses have significant environmental benefits, such as reducing greenhouse gas emissions and enhancing biodiversity through crop rotation and intercropping. However, despite their nutritional and environmental advantages, the

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production and consumption of pulses face various challenges. These challenges include limited access to quality seeds, inadequate post-harvest management practices, and low awareness of pulse-based nutrition. Addressing these challenges requires interventions at multiple levels, including research and development, policy support, and promotion of pulse-based nutritious diets. In conclusion, pulses are a crucial component in ensuring food security and promoting sustainable agriculture practices in rainfed areas. Their cultivation and consumption contribute to improved nutrition, income generation, and environmental sustainability. To fully harness the potential of pulses, it is essential to address the challenges and create an enabling environment that encourages their production, consumption, and value addition throughout the food system.

Keywords: Agriculture; Diversification; Food Security; Nutrition; Pulse; Rainfed; Sustainability.

1. INTRODUCTION

Pulses are grown worldwide, with nearly half of the production concentrated in Asia, notably India. While global cultivation is extensive" [1]. "Canada stands out as a major producer and exporter of pulses" [2]. "Recent data reveals that the annual average pulse production globally amounts to 730 million tons, with productivity rate of 904 kg/ha from 807 million ha. In India, the pulse production rate witnessed a 68% increase from 2013–2014, reaching 764 kg/ha compared to 441 kg/ha in 1950–1951. However, India's pulse production rate remains lower than that of cereals, comprising only 10% of wheat production. A 2011 global survey on per capita pulse consumption reported figures ranging from 2.7–10.8 kg/year, highlighting lower consumption in Europe and higher rates in Africa" [3]. "Pulses play a significant role in the diets of various countries. Notably, India leads in pulse consumption, with 15.4 kg/year per capita, followed by Kenya at 17.0 kg/year per capita, and Turkey at 13.6 g/year per capita" [4]. "The United Nations and FAO jointly designated 2016 as the 'International Year of Pulses (IYP),' emphasizing pulse seeds as 'nutritious seeds for a sustainable future.' Rich in protein, dietary fiber, and various micronutrients, pulses are recognized by the Indian Pulse and Grain Association as a crucial future source for nutritional and health benefits. Pulses play a significant role in enhancing food and nutritional security while also rejuvenating soil nutrients, thereby holding immense potential in addressing the global demands for future food security, nutrition, and environmental sustainability. Both small and large-scale farmers can leverage pulses to create valuable economic opportunities, boosting their income and reducing risk by diversifying their crop and revenue sources" [5]. In addition to the environmental advantages of incorporating pulses into crop rotations, there are also notable social and economic benefits associated with pulse cultivation. These benefits include meeting protein requirements, mitigating soil degradation, and promoting diversification in both food production and consumption. It is crucial for pulse producers and all stakeholders to comprehend the livelihood and developmental advantages that come with increased pulse production and consumption.

2. MAJOR PULSE GROWING AREAS IN INDIA

Madhya Pradesh, Maharashtra, Uttar Pradesh, Rajasthan, and Andhra Pradesh emerged as the primary contributors to pulse production. Throughout this timeframe, pulse productivity averaged 661 kg/ha. The most substantial yields were observed in Punjab (905 kg/ha), Haryana (891), Bihar (839), Uttar Pradesh (823), and West Bengal (811) [6].

3. MAJOR PULSES GROWN IN RAINFED AREA

Pulses such as soybean, cowpea, mungbean, black gram, chickpea, lentil, khesari, horse gram, fababean, and pea etc can be grown in these regions [8]. Enhancing the productivity and production of pulses in India.. Moreover, pulses have wide adaptive mechanisms such as very deep rooting system in pigeonpea and chickpea, high degree of dehydration tolerance, phenotypic plasticity, wide ranging sensitivity towards photothermoperiods and higher moisture retention capacity. The water requirement of pulses such as chickpea is about 1/5th of the requirement of cereals, though response of different pulses varies towards diverse climatic conditions as per their genetic make-up. There is a scope for expansion of small-seeded varieties of pulses such as lentil, lathyrus, and chickpea in the states of Uttar Pradesh, Madhya Pradesh, Jharkhand, Bihar, West Bengal and Assam.

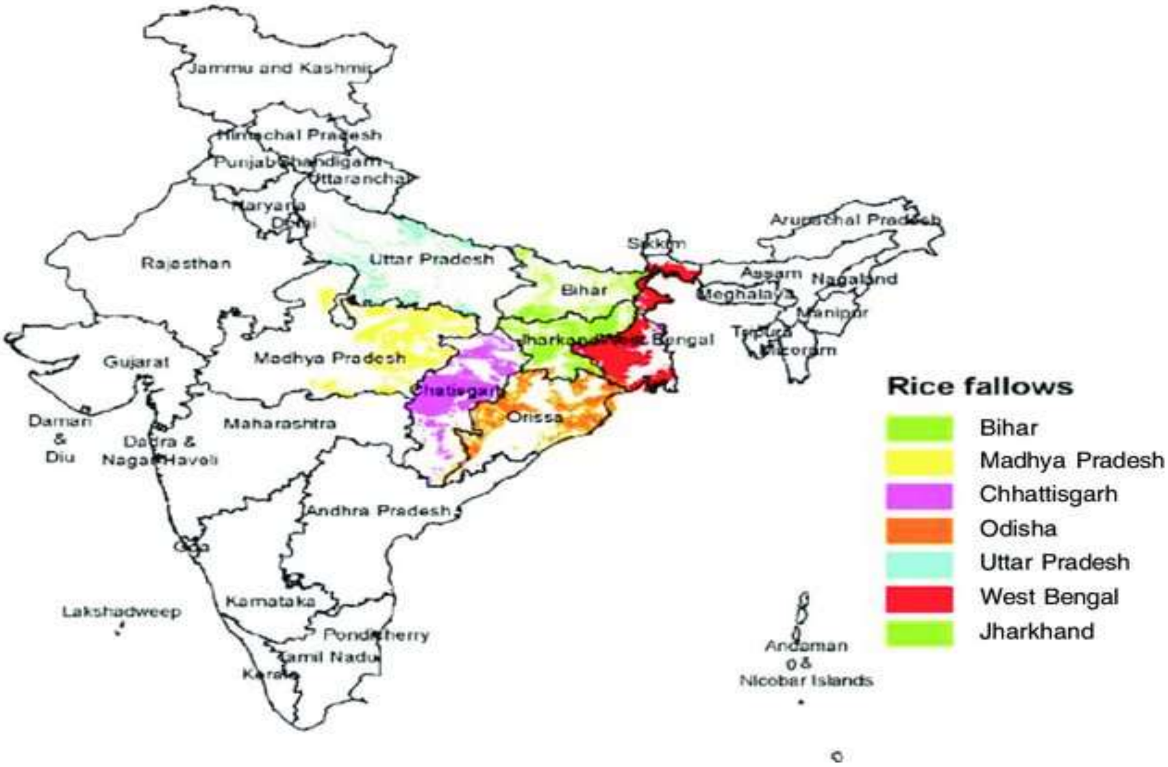

Fig. 1. Potential rainfed areas for pulse cultivation in central and eastern
India Source: Pande et al. (2012) [7]

4. IMPORTANCE OF PULSE IN CROPPING SYSTEM

Pulses are a vital component of agricultural biological diversity, essential for addressing climate change and serving as an energy source for vegetarians. They play a crucial role in mitigating climate change by reducing dependence on synthetic fertilizers, which artificially introduce nitrogen (N) into the soil. The high demand for and manufacture of chemical fertilizers contribute to the emission of greenhouse gases (GHGs), and their overuse can harm the environment. Additionally, meeting the increasing demand for vegetal protein within most global agroecosystems is challenging, particularly under stressed rainfed conditions.

5. ECOSYSTEMS SERVICES UNDER PULSES BASED CROPPING SYSTEM

5.1 Nitrogen Fixation

Synthetic nitrogen fertilizer is the most widely used and, paradoxically, the most deficient plant nutrient in soils worldwide. Pulses, however, play a distinctive role in the global nitrogen cycle. Through a symbiotic partnership with rhizobia, soil bacteria, pulses can fix atmospheric nitrogen in the soil, rendering them self-reliant in nitrogen and adaptable to a wide range of soil types without the need for external fertilizer inputs. The period from 1960 to 2000 witnessed an astonishing 800% increase in nitrogen fertilizer usage, with approximately half of it allocated to the cultivation of wheat, rice, and maize [10]**.** Notably, cereal crops like wheat, rice, and maize only utilize 40% of the applied fertilizer, resulting in substantial waste and environmental consequences, including coastal water eutrophication and the formation of hypoxic zones. The incorporation of pulses into crop rotations is a practical approach to curbing the demand for synthetic fertilizers, particularly in cereal-based systems. Implementing systematic crop rotations that include pulses reduces the necessity for synthetic fertilizers and fine-tuning the timing and quantities of fertilizer applications to crops represents two pivotal measures to reduce nitrogen usage [11]. Furthermore, biological nitrogen fixation emerges as a vital alternative nitrogen source, which can be enhanced alongside integrated nutrient management strategies, including the utilization of animal manure and recycling nutrients contained in crop residues. The increased availability of nitrogen to subsequent cereal crops also translates into enhanced yields. Studies conducted in southeastern Australia demonstrated that including pulses in crop sequences results in greater soil nitrogen availability for subsequent crops, with an additional 40 to 90 kg N/ha in the first year and 20 to 35 kg N/ha in the second year compared to cereal-cereal sequences [12]**.** Beyond improved yield, other advantages include breaking the cycle of disease and pest buildup that arises from continuous monoculture cropping.

Fig. 2. Chickpea and Clusterbean grown under rainfed areas during rabi and summer season at ICAR-IARI

5.2 Conservation Tillage

Traditional plow-based farming practices leave the soil exposed to the risks of water and wind erosion, contribute to agricultural runoff, degrade soil quality, and result in the release of greenhouse gas emissions. These emissions stem from both soil disruption and the use of fossil fuels for machinery. In contrast, no-till or direct seeding, combined with a mulch layer from the previous crop, serves as a restorative approach. It involves a set of practices that minimize mechanical soil disturbance, maintain permanent organic soil cover, and encourage the diversification of crop species within sequences and/or associations [14]. The integration of conservation tillage practices into crop rotations, particularly the inclusion of pulses and oilseeds alongside cereals, has been shown to enhance nitrogen fixation. Over time, the nitrogen fixation benefits of conservation- or no-tillage practices, coupled with pulse and oilseed nodulation, tend to improve, leading to increased nitrogen fixation rates [15].

5.3 Reduced Greenhouse Gas Emissions

Pulse crops play a pivotal role in mitigating greenhouse gas emissions within agricultural production. They achieve this by reducing greenhouse gas emissions through decreased fertilizer requirements, as pulses have the capacity to supply their own nitrogen and contribute nitrogen to subsequent crops[16]. This not only supports sustainable agriculture but also contributes to environmental conservation by diminishing the environmental footprint associated with traditional farming practices. [17] reported that conservation agriculture reduced greenhouse gases emission compared to conventional tillage.

5.4 Social Benefits

5.4.1 Nutrition

It is a well-established fact that the human body requires a daily intake of approximately 50 grams of protein for maintaining good health and optimal work performance. However, in India, the per capita daily intake of protein is only around 10 grams, significantly lower than the recommended amount. The human body relies on 22 amino acids for various physiological functions, and while it can synthesize 14 of them, the remaining eight must be sourced from food. When a single food item contains all eight essential amino acids, it is termed a complete protein. For vegetarians, leguminous plants, including pulses, serve as a primary source of protein. Notably, a considerable percentage of protein in common beans, such as cowpea, is easily absorbed after consumption—84% in the case of common beans and 94% in cowpea. Nevertheless, pulses, in general, contain lower protein concentrations compared to animal sources, and with the exception of soybeans, they are not considered complete proteins. Hence, a vegetarian diet often necessitates the combination of two or more pulse varieties. Given the vital role that pulses play in human nutrition, it is imperative to enhance their domestic production to meet the growing demand. Interestingly, the global consumption of pulses has dwindled, particularly in developing countries like China, where daily per capita intake plummeted from 30 grams in 1963 to a mere 3 grams by 2003 [18]. In India, pulses contribute to almost 13% of the total protein intake, highlighting their significance. Pulses are unparalleled in their efficiency as natural protein producers, harnessing essential elements like sunlight, soil nutrients, and water. However, the domestic supply of pulses falls short of the increasing demand from consumers. Addressing this imbalance is of paramount importance.

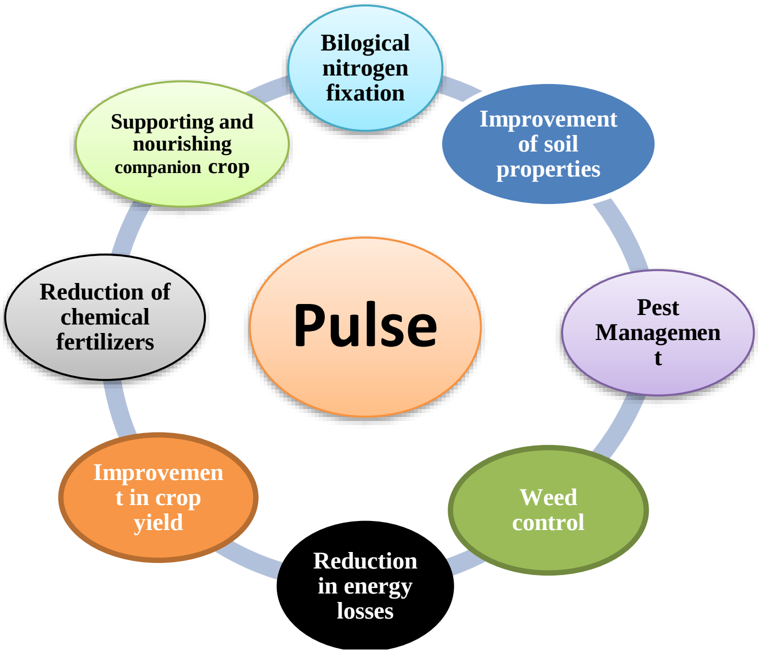

Fig. 3. Significance of pulses [9]

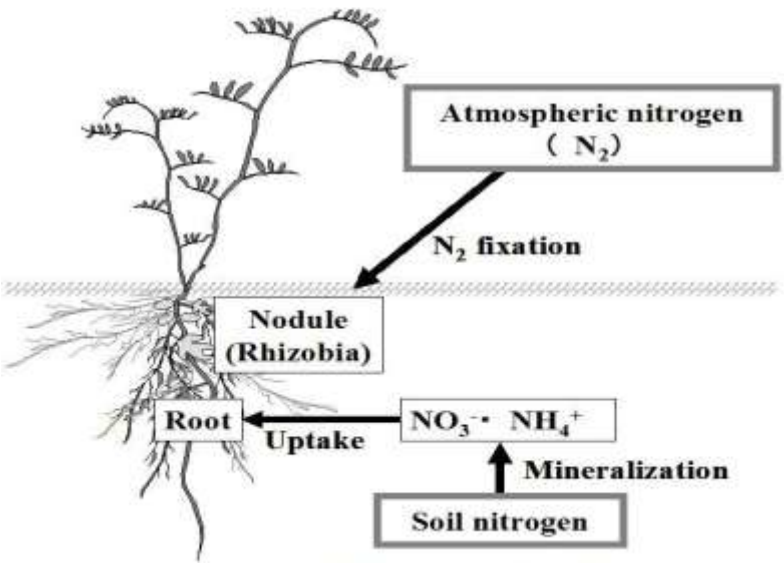

Fig. 4. Nitrogen flow and utilization of a pulse plants (Takashi Sato) [13]

India dedicates roughly 26 million hectares of land to pulse cultivation, yielding approximately 17 million tons of pulses annually. As the largest producer and consumer of pulses globally, India boasts an impressive array of pulse varieties, covering approximately 32% of the total cultivated area and contributing to 26% of global pulse production. Chickpeas, pigeonpeas, urd beans, mung beans, lentils, and field peas are some of the notable pulse crops grown in India. Notably, pulse production soared to a record high of 18.4 million tons in 2012-13, a substantial increase from the 15 million tons recorded in 2007-08. Pulse crop yields also witnessed an upswing, climbing from 0.63 tons per hectare in 2007-08 to 0.79 tons per hectare in 2012-13. This signifies improved production efficiency, with annual yield growth projected to outpace expansion in the production area. Nevertheless, India's average pulse productivity remains below the global average. Projections indicate that production may struggle to keep up with demand, potentially leading to a surge in imports to 5.1 million tons by 2023 [19]. Consequently, per capita pulse availability in India is anticipated to decline progressively, dropping from 69 grams in 1961 to 32 grams in 2005 [20]. Factors such as climate change, resource depletion, and demographic shifts exert a substantial influence on the availability and pricing of agricultural commodities [21]. Pulses play a crucial role in providing essential micronutrients in diets, alongside fruits and vegetables [18]**.**

Incorporating pulse crops into grain and oilseed production systems has proven to be economically advantageous for farmers. These benefits arise from lower input costs and increased profits attributed to the improved efficiency of nitrogen fertilizer usage, reduced tillage, and, in some cases, decreased pesticide applications. Adopting reduced and altered tillage practices not only lowers reliance on fossil fuels but also results in reduced overall fuel expenses. No-till systems integrated with pulse crops provide a foundation for sustainable agricultural intensification, embracing holistic crop management approaches. By transitioning to no-till systems, farmers can save approximately 30-40% of their time, labor, and fossil fuel consumption compared to conventional tillage methods [22]. Incorporating pulses into crop rotations in economically disadvantaged regions, such as Bihar, can offer substantial benefits by providing much-needed nourishment and income to small-scale farmers who rely solely on agriculture for their livelihoods. Roughly 12 million hectares that are used for rice cultivation during the rainy season in India remain fallow in the subsequent post-rainy (rabi) season. Efforts to introduce pulses in these rabi conditions could have a profound economic and poverty alleviation impact [23].

The soaring prices of pulses since 2008 can be attributed to the nearly stagnant production levels, resulting in a decline in per capita pulse availability. Pulses are generally cultivated in the post-monsoon period and are susceptible to drought-induced losses in the absence of sufficient rainfall. Presently, approximately 25 to 26 million hectares of land are devoted to pulse cultivation in India, yielding around 17 million tons of pulses annually. To meet the demand, India needs to import about 2-3 million tons of pulses each year. The yield, averaging around 700 kilograms per hectare, falls below the global average, and per capita availability is about one-fifth less than what nutritionists recommend. The demand for pulses in India is expected to grow further with a rising population and sustained economic growth.

The sustainability of the Indian agricultural system in the long run has raised major concerns due to consistent declines in soil fertility and the loss of essential soil nutrients, mainly as a result of exhaustive cropping systems implemented after the Green Revolution. While the Green Revolution achieved self-sufficiency in cereal production, it pushed pulses into rainfed environments, resulting in poor productivity and an imbalance in soil micronutrients. A balanced approach is essential, involving the judicious use of natural resources, soil microflora preservation, and reduced application of chemical pesticides and fertilizers to sustain the ecosystem. Pulse crops contribute to soil health by enhancing nitrogen content, long-term fertility, and overall sustainability of the cropping system. Their inclusion in cereal-based cropping systems enriches organic nitrogen, reduces the demand for chemical fertilizers, enhances soil microflora, and addresses protein malnutrition among a significant portion of the population experiencing "hidden hunger." Despite notable progress in developing techniques for achieving high pulse yields, their production has stagnated over several decades, primarily due to various biotic and abiotic constraints in rainfed environments [24].

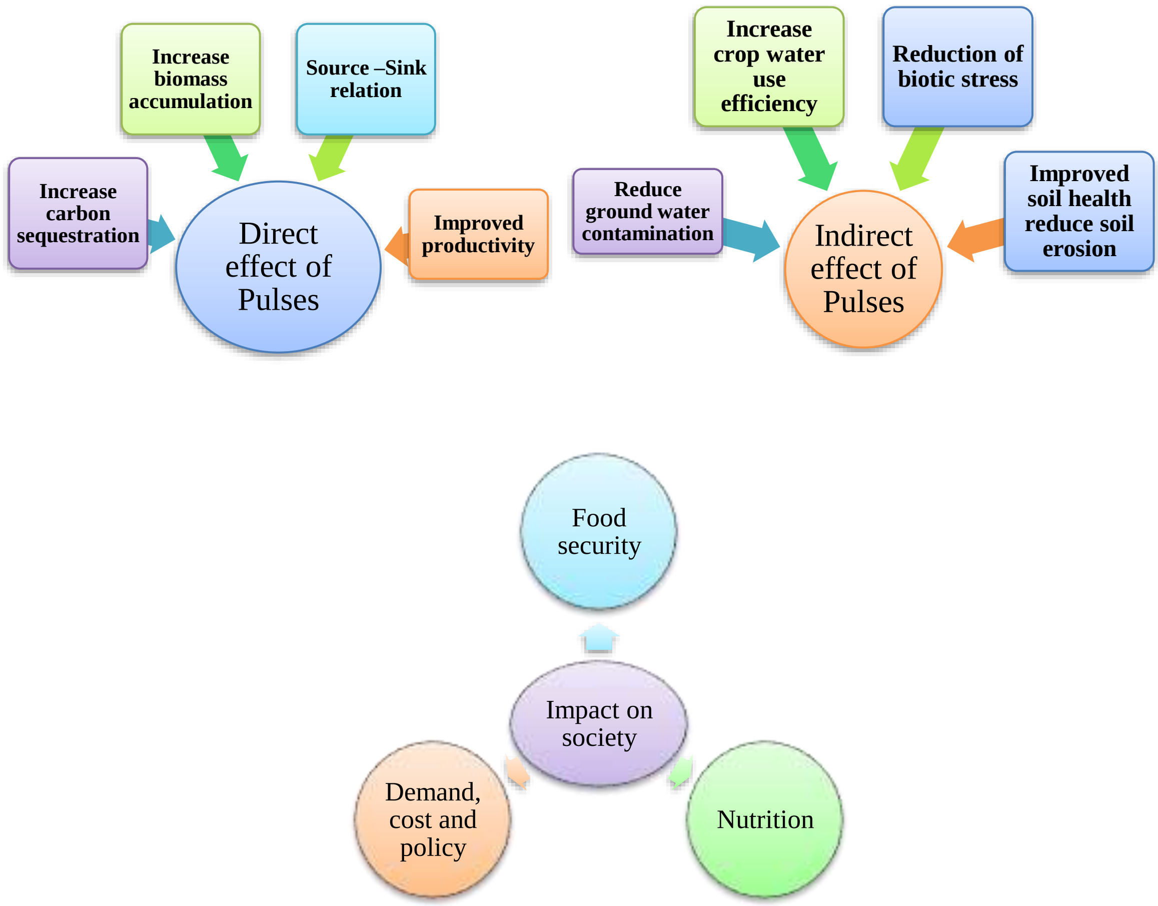

Fig. 5. Direct and indirect impact of pulses (Dutta et al., 2022)[25]

5.4.2 Challenges

Rainfed agriculture plays a significant role in our economy, covering approximately 60% of the cultivated land and contributing to 45% of the total agricultural output, with over 80% of the pulses and oilseeds production, as well as a substantial portion of horticulture and animal husbandry products [26]. A top priority is to address the management of water resources, as water is expected to become increasingly scarce in the twenty-first century. Currently, our irrigation efficiency stands at an estimated 30%, and there is a pressing need to raise it to at least 50% to significantly boost agricultural production. Given the challenges posed by climate change, farmers are facing issues related to intra-seasonal variability in rainfall, extreme weather events, and unseasonal rains, leading to significant crop losses annually. Therefore, it is imperative to expedite efforts to develop climate-resilient crop varieties, crop rotation patterns, and agricultural management practices. This includes the creation of effective in situ soil moisture conservation and water management strategies, the promotion of micro-irrigation techniques, such as drip and sprinkler irrigation, to enhance pulse productivity, the utilization of resource-conservation approaches, and the introduction of climate-resilient varieties of pulse crops. Additionally, eco-friendly biopesticides and fungicides must be developed to control emerging pests and diseases. Technology demonstrations in farmers' fields should be conducted on a larger scale, and efforts should be made to connect farmers with profitable markets. Furthermore, the promotion of pulse exports, including products like lentils and kabuli chickpeas, is essential. The development of value-added pulse products and the creation of short-duration climate-resilient cultivars suitable for new niches are also critical tasks that need to be undertaken.

There are the some major constraints cultivation of pulse under rainfed

5.5 Decline in Pulse Cultivation Area

The plains, Tal, and Diara regions of Bihar, once major pulse producers, have witnessed a reduction in pulse cultivation. This decline is attributed to factors such as extensive irrigation networks encouraging cereal and cash crop cultivation, Ascochyta blight epidemics, Helicoverpa armigera infestations in pulses, incentives for rice-wheat production, and the comparatively lower economic viability of pulses.

5.6 Yield Gap

Pulses face challenges due to a narrow genetic base and inefficient plant types, leading to low harvest index. These crops are often grown in resource-limited, harsh environments with poor management, as they offer lower returns compared to crops like paddy, wheat, and maize.

5.7 Production Instability

Pulse production and productivity exhibit significant instability, with vulnerability to environmental fluctuations. Factors contributing to this instability include susceptibility to drought during critical growth stages (mostly grown in rainfed conditions), sensitivity to abiotic stressors like temperature extremes, excessive moisture, and salinity, as well as biotic stresses from insect pests and diseases.

5.8 Climate Change Impact

Climate change poses a risk to pulse crops. Asymmetric temperature changes, with more rapid nighttime warming than daytime warming, affect photoperiodic responses, flowering, and source-sink relationships. Extreme weather events, such as sudden temperature shifts beyond tolerance levels, lead to flower drop, shorter reproductive periods, and reduced grain yields. These effects are more pronounced in plains where high nighttime temperatures negatively impact winter pulses and temperature extremes affect reproductive physiology and grain filling in various pulse varieties, increasing the risk of disease and pest outbreaks.

5.9 Seed Replacement Rate

The seed replacement rate in pulses is notably low, contributing to reduced yields. Central and state seed corporations, as well as private seed companies, show less interest in pulse seed production.

5.10 Post-Harvest Losses

Inefficient harvesting and threshing equipment, high infestations of stored grain pests (bruchids), and traditional dal mills with low dal recovery result in substantial post-harvest losses, which could be mitigated through improved post-harvest machinery.

5.11 Price Fluctuations

The unorganized pulse market and lack of assured procurement have led to wide price fluctuations. Addressing these issues is crucial, especially considering that critical inputs are often scarce for pulse growers, primarily marginal and small farmers.

5.12 Technology Transfer

Small and marginal pulse growers, often from impoverished farming communities, lack access to agricultural technologies developed by institutes and universities. Insufficient awareness of the latest pulse production technologies is a significant gap that hinders pulse productivity. Limited exposure to improved technologies is due to the scarcity of trained extension personnel and inadequate communication between state agriculture departments, research institutions, and private agencies.

5.13 Expanding Pulse Cultivation

To expand pulse cultivation, short-duration varieties of pigeonpea, kabuli chickpea, field pea, and summer mungbean can be popularized in rice-wheat cropping systems. Moreover, large areas of agricultural land remain fallow, and bringing these additional areas under pulses like lentil can enhance prospects. Promoting pulses in intercropping with short-duration, thermo-insensitive varieties of mungbean/urdbean alongside crops like spring sugarcane, pre-rabi chickpea with mustard/linseed, and pigeonpea with groundnut/soybean/millets can further boost pulse production.

6. CONCLUSION

Pulses play a vital role in addressing global challenges of food security, nutrition, and environmental sustainability. While India excels as a major pulse producer and consumer, it faces hurdles such as diminishing cultivation areas and susceptibility to climate change. Incorporating pulses into crop rotations not only yields environmental benefits like nitrogen fixation but also fosters social and economic advantages for farmers. Addressing production constraints, managing water resources, and advancing technological transfer are pivotal for unlocking pulses' full potential. To overcome challenges, comprehensive strategies involving increased investments, diverse cropping systems, climate-resilient varieties, and empowerment of small farmers are essential. As India strides towards agricultural intensification, pulses stand as a linchpin for a resilient and nourished future

7. FUTURE PROSPECTS

7.1 Provision for life-saving irrigation in pulse under rainfed areas

There has been a high degree of risk in pulse production, with over 87% of the pulse-growing areas currently relying on rainfed agriculture [27]. The mean rainfall in major pulse-growing states such as Madhya Pradesh, Uttar Pradesh, Gujarat, and Maharashtra is around 1000 mm, with a rainfall coefficient of variation ranging between 20% and 25%. Crop failure, often attributed to moisture stress, is a prevalent issue, leading to low yields [28]. A significant improvement in productivity could be achieved by implementing life-saving irrigation, particularly for rabi pulses cultivated on residual moisture. To ensure yield stability and increased productivity, it is imperative to adopt rainwater harvesting for life-saving irrigation. The creation of farm ponds and community reservoirs in every village in pulse-growing districts nationwide is essential. Additionally, the provision of micro-irrigation through sprinklers or drip systems at the Panchayat level should be considered.

7.2 Accent on Diversification of Agriculture and Value Addition

In order to address the ever-increasing demand for food and agricultural production while coping with diminishing natural resources, the future of agriculture in the region lies in agricultural intensification. Significant emphasis needs to be placed on post-harvest handling, agro-processing, and value addition technologies. These efforts should aim not only to reduce substantial post-harvest losses but also to enhance product quality through proper storage, packaging, handling, and transportation. Furthermore, the role of biotechnology in post-harvest management and value addition should be further developed and leveraged. It is advisable to establish agro-processing facilities in close proximity to production areas, especially in rural regions, as this can foster off-farm employment opportunities. Agricultural cooperatives and Gram Panchayats should play a leading role in driving these initiatives, all while taking into account the specific needs of small farmers.

7.3 Increased Investment in Agriculture and Infrastructure

The majority of India’s poor (some 770 million people or about 70 percent) are found in rural areas. India’s food security depends on producing cereal crops, as well as increasing its production of fruits, vegetables and milk to meet the demands of a growing population with rising incomes [29]. To do so, a productive, competitive, diversified and sustainable agricultural sector will need to emerge at an accelerated pace. It is imperative to increase investments to facilitate agricultural and rural development in the region. Despite the importance of pulses, their productivity has only increased by 45 percent between 1951 and 2008, while the cultivated area for pulse production has grown by a mere 25 percent, which is lower compared to other food grains. Per capita availability of pulses has declined from 60g/day in 1970-71 to 36g/day in 2007-08 [30]. Additionally, approximately 30 percent of agricultural produce goes to waste each year due to insufficient storage, transportation, cold chain, and other infrastructure facilities. There exists significant potential for pulse production in rainfed areas through the implementation of resource conservation and water harvesting techniques. Incentives for pulse cultivation, including nitrogen credits for farmers and collaboration with research institutes to access better technologies, will promote pulse cultivation. The introduction of improved pulse varieties can enhance productivity, ensuring greater availability of pulses to a larger population at affordable prices.

7.4 Fighting Poverty and Hunger

Rainfed areas have a higher concentration of impoverished and undernourished individuals compared to irrigated regions. A significant improvement in the intensity of irrigation, even by just 20 percent, leads to a substantial reduction in the levels of poverty and hunger [31]. This effect remains consistent regardless of further increases in irrigation intensity. Therefore, increasing irrigation not only reduces poverty and hunger but also promotes equity, environmental protection, and the conservation of natural resources. To achieve this, an effective water policy and institutional support are crucial for ensuring fair and efficient allocation, distribution, and utilization of water and water resources.

7.5 Accent on Empowering the Small Farmers

Small and marginal farmers play a significant role in providing food for the growing population, despite their vulnerability. Creating off-farm and non-farm job opportunities for them is crucial. Developing skills and knowledge in agriculture and other sectors is necessary for their economic and social progress. Balancing agricultural and non-agricultural employment is essential, as is investing in human resource development, research, extension services, and infrastructure. These efforts enhance agricultural productivity and flexibility in responding to market dynamics. Improved agricultural technology, irrigation, literacy, and watershed development are key to ensuring food security. Localized programs should be implemented to address specific needs and improve nutritional security. Investments in post-harvest handling, cooperatives, education, and research, as well as creating a favorable policy environment for smallholders, are important. Mechanized tools that reduce labor-intensive work are needed to boost productivity. Safety nets must be designed for the benefit of these farmers. Disseminating post-harvest technologies is essential to reduce losses and enhance product quality through proper storage and transportation.

7.6 Assured procurement can boost pulses production

Assured procurement through Minimum Support Prices (MSP) signals the government's commitment to increasing pulse crop productivity by incentivizing more farmers to engage in pulse cultivation. With improved yields, the development of stress-resistant pulse varieties, increased MSP support, and knowledge exchange, farmers will be encouraged to cultivate pulses on a larger scale, alleviating supply-side limitations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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