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Rice Fallow Pulses for Agricultural Potential for South Asian Region

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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

Rice fallows refer to lowland areas where rice is cultivated during the monsoon *(kharif* season) is left unplanted during the winter season (*rabi*) due to various factors. These include the early cessation of monsoon rains which resulted in soil moisture stress during winter season; waterlogging and excessive moisture in November/December, led to unsuitable for winter crops; the absence of suitable varieties for late planting at winter season and socio-economic issues such as damage by stray cattle or blue bulls. India accounts for a significant majority of about 79% of South Asia's total rice fallows which amount to 11.65 million hectares out of the region's total of 15.0 million hectares. The review assess the scenario of rice fallow pulses, production technologies and its constraints in the present trend.

Keywords: Rice fallow; monsoon; pulses; technologies.

1. INTRODUCTION

Rice fallow pulses is a rainfed lowland agro-ecology which is presently seeking attention for a sustainable cropping system in the Southern parts of Asia where rice is grown as a major staple crop. Rice fallows refer to the lowland regions used for rainfed rice cultivation is left unused or uncropped after the rice harvest [1]. There is great potential to increase the cultivation of pulses in rice-fallow conditions, which could enhance food and nutritional security. To achieve this, it is crucial to conserve the remaining soil moisture in these fallow lands. This conservation will allow for the successful introduction of pulses into rice-fallows, leading to increased productivity and profitability. Data estimated that around 11.70 million hectares of land in India remain fallow after the rice harvest. Around 82% of this fallow land is located in Eastern India, with the remaining area distributed among three southern states: Tamil Nadu, Karnataka and Andhra Pradesh [2].

Pulses play an important role in the human diet as they are more rich in protein sources than any other cereals and millets. Thereby, pulses is known as poor man’s meat. Pulses are used in day-to-day food in the Asian diet. It has gained an irreplaceable locus in Indian cuisine. The mineral content consists of calcium (286 mg), iron (15.67 mg), magnesium (553 mg), phosphorus (785 mg), potassium (2035 mg), sodium (79 mg), zinc (6.93 mg), copper (2.03 mg), manganese (3.16 mg) and protein (52.18 g). Additionally, it contains various vitamins such as vitamin A (2.14 mg), C (2.62 mg), B1 (0.27 mg), B2 (0.25 mg), B3 (1.45 mg), B6 (0.91 mg), B9 (0.28 mg), B12 (216 mg) and vitamin B15 (0.91 mg) [3]. Pulses, which are part of the Leguminosae family are widely distributed throughout the Indian subcontinent and are commonly referred to as "dal." If pulses are grown as rice fallow crops it supplements soil by implanting nitrogen on the soil and utilizes the unused fertilizer left in the soil at the time of crop cultivation. Pulses enhance the physical, chemical and biological characteristics of the soil, which leads to a decrease in the fertilizer needs of subsequent crops [4]. Recognizing the significance of pulses in human nutrition, the year 2016 was designated as the International Year of Pulses.

With all such significance, the production of pulses is now attaining a stage of decline due to various constraints faced in the present scenario. Due to ever increase in population, rise in income of people and pulses being the major source of dietary protein in India, the demand for pulses continues to grow obviously [5]. About 20% of the total pulse demands are met by imports only. The recommendation for pulses (43 g/day) by the Indian Council of Medical Research but as per the Directorate of Pulses Development in 2016, the recommended daily intake for adult males is 60 g/day and for adult females is 55 g/day. However, the per capita availability in India is only 42 g/day. Kadakia and Jacob, (2009) estimated that to overcome protein deficiency, pulses alone in India will require 38 million in 2017-18 and to produce this quantity domestically it would be essential to either double its area at current yield levels or double the productivity keeping the acreage constant.

2. SCOPE OF RICE FALLOW PULSES

“There is a significant opportunity to expand total cropland by strategically utilizing rice fallows for cultivation” [6,7]. “Pulses stand out due to their high protein content (20 to 25%), capacity to fix atmospheric nitrogen (around 30-150 kg/ha) and their role as a reliable source of income and employment for small-scale and marginal farmers. This places them in a prominent position within global agriculture" [8]. Iriti and Varoni [9] "stated that throughout human history, pulses have been the cornerstone of staple food preparation, serving as the most vital food grain. They have been extensively relied upon to fulfil basic protein and energy requirements, making them indispensable in sustaining populations across time". "The accelerated maturation of crops in Direct Seeded Rice presents a chance for the enhancement and broadening of rice fallow lands" [10]. "Poor farmers often rely on incorporating perennial grasses or legumes with varying growth durations into crop rotations as a primary method to enhance soil fertility and increase the availability of food and fodder. This approach is crucial for sustaining agricultural productivity while ensuring sufficient nutrition for both humans and livestock" [11].

3. RICE FALLOW PULSES FOR VARIOUS REGIONS

"Pulses are well-suited for the rice-fallow conditions as it demand less water for cultivation and possess deep-rooted systems capable of accessing soil moisture up to 0.4 meters deep. This makes them an excellent choice for maximizing land productivity under rice fallow situations" [12]. "Pulse crops characterized by fast growth, early maturation and the ability to establish extensive ground cover with deep roots are highly sought after rice harvested fields, where soil moisture is typically scarce after harvest of rice" [13]. "Rice fallows in areas of Andhra Pradesh, Tamil Nadu and Karnataka are covered under coastal peninsular zone. The conventional rice–pulse relay systems (lentil, lathyrus, mung bean and urd bean) are being practiced in Odisha, West Bengal, Chattishgarh, Jharkhand, Andhra Pradesh and Tamil Nadu" [1]. "The rice fallows of central region covers Chhattisgarh, Madhya Pradesh and Maharashtra. Soils are generally clay in nature (Vertisols), become hard and develop deep cracks on drying and poor in soil nutrients" [14]. "Fallow Pulses meets up to 80% of its nitrogen fixation from air and leaves behind substantial amount of residual nitrogen and organic matter for subsequent crops. This makes them valuable not only for their own cultivation but also for enhancing soil fertility and productivity over the long term" [15]. The Utera cultivation of pulses can be made more efficient by using short duration and high yielding varieties of rice, as rice will be harvested from the field during September-October [16]. Maji et al., [17] suggested Cool-season food legumes such as lentils, chickpeas, field peas and grass peas show great promise in improving productivity and sustainability within the rice-fallow systems of eastern India and the central plateau region.

4. SUITABLE PULSE CROP FOR RICE FALLOW

"Pulses like lentil and chickpea are the most candidate crops for Temperate regions" [18]. "In locations where competitive crops such as linseed and sesame are cultivated in rice fallows, the practice of intercropping these crops with pulses, facilitated by appropriate agricultural machineries, provides an additional avenue to increase crop yield per unit area" [19]. "Pulse crops that show rapid growth, early maturity and form rapid ground cover with deep root systems are much desired for rice fallows as the soil water content is limited after the rice harvest" [13]. "The desirable traits of pulses, including their deep root system, capacity to access moisture from deeper soil layers, minimal water requirements and ability to establish crops through surface seeding, make them well-suited for cultivation in moisture-limited conditions typically found in rice fallows. Similarly, oilseed crops such as linseed and mustard can also be incorporated into rice-fallow ecosystems to enhance system intensification" [20,21].

Table 1. Pulse Varieties suitable for rice fallows in southern India

S.no.	State	Crop	Rice-fallow crops(varieties)	Reference
1	Tamil Nadu	Black gram	ADT 3, ADT 6	Ramesh and Rathika [22]
		Green gram	ADT 3	Umamageswari et al., [23]
		Horse gram	CRIDA 18R	Vijayakumar and Jalaluddin [24], Hanif et al., [25]
2	Karnataka	Black gram	TAU 1	Shashikumar et al., (2013)
3	Andhra Pradesh	Green gram	LGG 460', 'TM 96-2', 'LGG 410', 'LGG 407	Rao et al., [26]

S.no.	State	Crop	Rice-fallow crops(varieties)	Reference
4	Telangana	Black gram	LBG 17', 'LBG 602', 'LBG 623','LBG 402'LBG 611','LBG 22', 'LBG 648','LBG 685','LBG 645',(2017)'LBG 709' and 'LBG 752	Reddy and Reddy, (2017)
		Green gram	Pusa 9072', 'NARM 1','NARM 2','NARM -18', 'LGG460','LGG 410','LGG-450','LGG-407' and 'IM 96-3'	
		Groundnut	Kadiri 4', 'Kadiri 6','TAG 24', 'Greshma', 'Rohini', 'Tripura 4' and' Narayani'	
5	Kerala	Cowpea Black Gram Red Gram	PGCP 6 Syama, Sumanjana, Sa 1	Adarsh and Jacob, [27] https://pop.kau.in/pulses.htm [28]

5. PLANT POPULATION AND ESTABLISHMENT

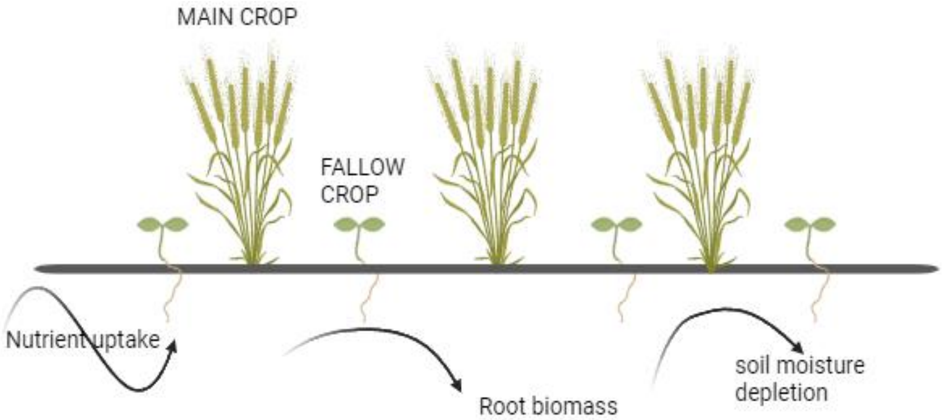

Fig. 1. Illustration of rice fallow crop rotation

Amuthaselvi et al., [29] observed that "in rice fallow black gram cultivation, broadcasting method resulted in a higher plant population per unit area compared to sowing with seed drill. Ensuring an adequate plant population is essential for maximizing returns from rice fallow pulse cultivation" [30]. "Practicing diversification such as combining rice with pulses in farming systems, enables farmers to mitigate risks and attain a steadier more varied income. This approach enhances their resilience and ability to adapt over time. In the utera production system, the primary difficulty lies in sustaining the ideal plant density" [1]. The effect of organic amendments on yield tends to be either positive or neutral, primarily due to their role in improving soil fertility and nutrient cycling, which are crucial factors for crop productivity [31]. Iqbal, [32] observed that 5 per cent solution of moringa leaf extract promoted both the rate and overall percentage of germination in pulse seeds.

6. NUTRIENT APPLICATION IN RICE FALLOW PULSES

"Foliar nutrients are known to influence a wide array of physiological parameters like alteration of plant archetype, assimilate partitioning, promotion of photosynthesis, uptake of mineral ions, enhancing nitrogen metabolism, promotion of flowering, uniform pod formation, increased mobilization of assimilates to defined sinks, improved seed quality, induction of synchrony in flowering and delayed senescence of leaves" [33]. In addition to other management practices such as irrigation and plant protection, blackgram responds markedly to précised application of plant nutrients in combination with foliar nutrition especially when applied in a balanced amounts and at the appropriate time [34]. Gupta et al., [35] found that 20 kg N ha^{-1} + rhizobium + PSB + PGPR + 2% urea spray at flowering and 10 days produced a maximum number of nodules and nodule dry weight in chickpeas. Devaraju and Senthivel, [36] revealed that "application of pulse wonder at 5 kg ha^{-1} through foliar spray led to increased plant height, increased accumulation of dry matter and enhanced yield characteristics and resulted in a higher yield of 870 kg ha^{-1} and maximum net returns of Rs. 22149 ha^{-1}, with a benefit-cost ratio of 2.19 in blackgram cultivation". Vinoth, [37] concluded that "soil application of recommended NPKS and $ZnSO_4$ at basal and foliar spray of 1% TNAU pulse wonder at flowering and 15 days later is the profitable nutrient management package to black gram for getting higher income in terms of higher yield and benefit cost ratio". Sakthivel et al., [38] "reported *Pongamia pinnata* as green leaf manure and foliar sprays of *Moringa oleifera* 5% increased number of pods, number of seeds per pod and yield in blackgram".

7. MICROBIAL STATUS IN RICE FALLOW PULSES

Organic matter content of the soil can increase the presence of microbial population in the soil. Residue incorporation results more microbial activity than residue removal or burning [39]. Growing of legume crops under rice fallow conditions increase the nitrogen content of soil due to their root nodulations. Maintenance of microbial diversity of soil is necessary for soil health and interactions of rhizosphere with higher plants [40]. After harvesting of pulses the beneficial microbial load in the soil may help to maintain better growth of succeeding crop. Pulses grown in dry/post-rainy season after rice harvest may increase the activity of soil enzymes around 10–25% [41]. Intensification of rice fallows with the incorporation of legumes in dry season can be helpful in improving soil health via nitrogen fixation [42]. Increase in essential soil nutrients indicated that the combination of rock phosphate and microbial inocula significantly increased the soil fertility among all treatments [43,44]. Venkatesh et al., [45] reported that 10−15% increase in soil microbial content and 10–11% increase in total organic carbon with the inclusion of legumes in rice-based cropping systems.

8. CHALLENGES FOR LOW PRODUCTIVITY OF RICE FALLOW PULSES

Mostly rice fallow pulses are grown under rainfed, low fertile, problematic soils and unpredictable environmental conditions in India with a high degree of risk and often face many constraints. Despite immense scope, the extensive use of rice fallows for pulse cultivation is mostly restricted because of several biotic, abiotic and socio-economic constraints [46].

8.1 Abiotic Stress

Insufficient moisture levels during the flowering and harvest stages of winter crops can be detrimental to their growth and yield are common abiotic factors that often results in drought conditions [16]. Due to the absence of tillage operation weeds pose a significant challenge in relay cropping systems [14]. Previous season rice crop itself may act as weed and is neglectable. Severe deficiencies in zinc, iron, boron and molybdenum as well as secondary nutrients like sulphur are particularly notable in traditional pulse cultivation [47]. More than 90% of farmers suffer lack of suitable rice fallow variety which act as the prime reason for a large area that remains fallow in rabi season [1]. "If ploughing is done after the harvest of rice to remove stubbles, the sowing of rabi pulses are delayed and germination will also be affected due to the formation of large size clods" [14]. "Rice harvesting through combine harvester in relay cropping resulted in seedling mortality of about 10-15 per cent. Pulses sown after rice under zero tillage conditions is affected due to improper seed dropping in the presence of stubbles and fast drying of surface soil. Regrowing of rice stubbles after harvest is another major problem in the rice fallow relay cropping system in many parts of the country. After harvest of rice soil moisture content gradually declines causing mid and terminal drought at flowering and pod-filling stages which adversely affects the productivity of pulses in rice fallows and sometimes causes 50% reduction in seed yield" [48]. "In rice fallows, application of manure or fertilizer is denied due to no-tillage under relay planting and consequently, crops face nutrient stress" [49]. "Unlike manual harvest, machine harvesting of paddy damages the establishing pulse plants due to the trampling effect of wheels on the field traverse. With the wider adoption of mechanised harvesting, it has emerged as a major abiotic stress in rice fallow cultivation" [30].

8.2 Biotic Stress

Powdery mildew and yellow mosaic virus are serious diseases of rabi-planted urd bean and mung bean. Legumes are vulnerable to attack by Blue Bulls in the Indo-Gangetic Plains [50].

Table 2. Constraints and technologies to Boost Rice Fallow pulses productivity

S.no	Properties	Constraints	Technologies to overcome constraints
1.	**Population management**	Poor crop stand and establishment	Tillage machines, sowing methods, seed priming, higher seed rate, timely planting, seed treatment with fungicides
2.	**Nutrient management**	Poor crop growth	Foliar spray of urea/DAP to supplement N and P
3.	**Dry spell**	Terminal drought during critical stages of crop growth results in reduction in crop growth and yield	Residue mulching and spraying of TNAU crop boosters may help to mitigate stress conditions
4.	**Weed menace**	Early season rice crop and other weed flora interventions	Post-emergence herbicides like Quizalofop ethyl and Imazethapyr
5.	**Pest and disease management**	Pest and disease incidence	Development of IPM modules
6.	**Lack of mechanization**	Lack of labours and mechanization in rice fallows	Tillage machines, zero-till planter and harvester

Among the biotic constraints, several fungal and viral diseases, insect pests and nematodes constraint both cool season and warm season pulse production in Rainfed rice fallow lands [16].

9. ADVANTAGES OF RICE FALLOWS

Under organic farming practices, the soil organic carbon content significantly increases from 0.54% to 1.17% due to the cultivation of a legume crop [51]. "Legumes provide nitrogen (N) to agroecosystem through their exclusive capability to fix atmospheric N in symbiotic relationship with soil rhizobia" [52]. Due to its ability to establish with surface seeding, appropriateness for relay/para cropping and resilience against soil moisture and temperature stress, pulses are the best crops to plant in the spaces left empty after rice [48].

10. SWOT ANALYSIS

10.1 Strengths

The major strength of the rice fallow pulse crops is the existence of large rabi fallow lands that virtually have zero cost. Besides, pulses have better adaptability to marginal lands. Yields of pulses(chickpea) in Chattisgarh and Madhya Pradesh are also higher than the national average. The pulse cultivation on the residual moisture after kharif rice helps in better moisture conservation.

Unavailability of quality seed, poor accessibility to markets, practice of cultivation of long duration rice varieties, lack of short-duration chickpea varieties, weak extension system, drought-like situations at the time of crop maturity and uncertain rainfall are some of the obstacles to production in Rainfed rice fallow lands. Besides water-saving/harvesting technologies and improved tools and implements required for crop establishment.

10.2 Opportunities

The Government of India is committed to introduce the 'Food Security Act (FSA)' in the near future and the success of FSA will depend on augmentation of agricultural production by raising agricultural productivity or cropping intensities of mono-cropped, rainfed and marginal lands apart from other measures. Pulses complement cereals in both production and consumption. These improve soil fertility, requires less water in comparison to cereals and control diseases and pests in rotation with cereals. This indicates scope for legume production in which chickpea plays a significant role.

10.3 Threats

Imbedded production and price risk is the most serious threat to chickpea production. Year to year variation in pulse production is a regular feature. Prices also show erratic behaviour. When farmer cultivates rice fallow pulses in isolated areas, menace of stray animals such as neelgai (blue bull) and monkeys are acute but substantial. Problems of *Helicoverpa* and wilt are the other persistent threats that need immediate attention.

11. CONCLUSION

From this review, it can be concluded that cultivation of rice fallow pulses offer a significant advantage for farmers in terms of incorporating pulses into rice fallows is a sustainable and profitable practice. It also enhances the agricultural productivity, soil health and per capita availability of pulses. Policy and technology driven approach is essential to promote rice fallow pulses area and productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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