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Pulses in Rice Fallow: A Way towards Achieving Nutritional Security: A Review

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ABSTRACT

Rice is the most important staple food crop of our country. Due to climatic condition and geographical situation our country is the most important rice growing country of the whole world. It is mostly grown during *kharif* season, but interestingly around 11.7 M ha of land remains fallow after *kharif* rice were harvested due to several limitations. Efficient utilization of these fallow land may increase the productivity and make the whole system sustainable. Soil condition and climatic situation clearly suggest that short duration crop can easily be fit in that situation. Pulse takes an important position in human's daily life. It not only providing high quality protein but also benefit the cropping system in several ways. The resources present in the rice fallows clearly giving an opportunity to introduce different pulse crop there. It will surely be an excellent inclusion. If the location specific constraints are been managed efficiently then those unutilized lands can be efficiently converted into productive one. It will not only increase the production of the system but also strengthen the economic condition of the farmers, improve the soil condition and more over it will ensure nutritional security of the people of our country.

Key words: Nutritional security, Pulse, Rice fallow.

The major backbone of India is agriculture and it inherited a stagnant in agriculture from the time of its independence. So, the first task of its Indian Government in the post-independence session was, thus, to pledge the growth and development in the agricultural sector. Whenever we are reviewing about these growth processes of our agriculture during the last seven decades post-independence, we find numerous success stories which have transformed our motherland from "begging bowl" situation to not only self-sufficiency in food grains but also in a condition to become a leading exporter of some agricultural products in the worldwide. In this arduous journey, our country has got supremacy in her credit by imposing revolutions.

In the agricultural sector-like *Green, White, Yellow and Blue,* of which the "*Green Revolution*" is considered as the most astonishing occasion at the worldwide surpassing the population growth rate. The green revolution during mid-sixties, directed by research oriented new technological expansion linking new materials, methods and ways of organizing farm inputs like seeds, water, fertilizer, chemical etc. and the government policy transformed the agriculture dramatically. As a result, the output exhibited manifold increase in production and productivity. Regardless of this glorious development during the last few decades we cannot overlook the unattractive side of the story as well. Presently, around 26.1 per cent of our population live below the poverty line and however we have significant food replacement, still a vast section of our society goes hungry to the bed every day (Chowdhury, 2015).

India is now self-sufficient in cereal food production and with the improvement of agricultural technologies we are able to feed the ever-mounting population. Now, if we are to achieve nutritional security, we must have to go for crop diversification in cropping pattern introducing crops like pulses and vegetables. On the other hand, to encourage the Protein Energy Malnourished people and to maintain soil health appropriately pulse/s must be included in the cropping system. So, in a country like India where population is a big challenge for agriculturist and hence urgent need to increase the food production and crop diversification is the potential way to increase over existing land management and cropping system through horizontal and vertical utilization of resources.

Pulses are rich sources of protein and strength, but in India, these are largely cultivated beneath power starved conditions, wholly on marginal and sub-marginal land. More than three-fourth of the area below pulses remains to be rainfed resulting in low crop productivity (Choudhary 2013). Pulses are basic part of many diets across the country and are considered to have great potential for human health. Legumes play an important role in soil conservation, environment safety and also contribute to food security (Singh *et al*. 2009). India is the largest producer of pulse,

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but inauspiciously it has emerged as the largest importer of pulses in the world too. The per capita production and convenience of pulses in the country have experimented a sharp decline which is further intensified by farmers increasing preference for cultivation of cereal and cash crops. Due to letdown in dipping the gap between demand and supply of the pulse in India, the nutritional security, especially of the poor are awfully conceded.

Besides, our nation occupies miserably a low place in respect of yield levels in comparison to many other countries. It is also a fact that in a country like India supplementing crop production by increasing the area under cultivation is almost next to impossible. The miserable situation regarding the low position in respect of yield levels is accredited to input use efficiency, degradation of resources like soil and water and slowing of total system productivity. Thus, in brief, we must have to acknowledge that at the new millennium, the evidence is overwhelming that an agricultural transformation is urgently needed to meet the global challenges of feeding the massive human population of our motherland.

Pulses in cropping system

The inclusion of pulses in a cropping system not only enhances the production under a limited area but also helps to achieve a nutritional security. Besides this they improve the soil properties, reduce the intensity of insect and diseases infestation. On the other hand, in respect to fight with changing climatic situation and decrease in the productivity of the system, inclusion of pulse in the cropping system is an important issue. Its specific role in the cropping system consists of high carbon sequestration capacity, low carbon footprint, fixing atmospheric nitrogen in soils, low water footprint, hydrogen fertilization of soils and improving soil biodiversity. Pulses provide an economic stability to farmer (Adarsh *et al*. 2019). Biological nitrogen fixation is another unique feature of pulse crop. It provides a chance to addition of considerable amount of organic matter through root biomass and leaf fall. The deep root systems of pulses help in mobilization of nutrients, provide protection of soil against erosion and improving microbial biomass, they keep soil productive and alive by bringing qualitative changes in physical, chemical and biological properties. This results into an increment in productivity of cereals following a preceding grain legume to 40-60 kg N equivalent (Table 1) (Kumar *et al*., 2018a).

Nutritional aspect of pulse

Pulse consumption has an important role in the individual's nutritional status (Padmaja *et al*., 2016). Pulses are good source of vitamins, high iron content is makes them potent food for preventing iron deficiency, aneamia in woman and children. These contain high dietary fibre which is known to reduce LDL cholesterol, thus reducing the risk of coronary heart diseases. Pulses are gluten free, contain high quality protein responsible for growth and development. Pulses promote bone health and are rich in bioactive compounds such as phytochemicals and antioxidants, these contains anti-cancer properties. With high fibre content, low fat and low glycemic index pulses are suitable for diabetic patient (FAO 2016). Pulses also contain pantothenic acid, folic acid, biotin, nicotinic-acid etc. which plays a major role in human dietary (Table 2). The country's existing per capita availability of pulses is 52.9 gm per day against the Recommended Dietary Allowances (RDA) of 60 gm and 55 gm per day for adult male and female (Tewari and Shivhare, 2017). So, there is no doubt that pulses play an important role in achieving nutritional security of our country.

Rice fallow pulses

Pulses are mostly cultivated under irrigated as well as rainfed conditions either as sole or intercrop. Rice fallow pulses is another unique ecosystem. Rice is grown during kharif season (June-October/November) which is normally followed by a fallow during the *rabi* season (November-February). In Southern India the situation slightly changes, where the foremost rainfall occurs during *rabi* season as the rainfall pattern follows mostly a bimodal type. The major constraint for majority of these rice fallow is the incongruity of growing rice again during *rabi* due to its high-water requirements. Rice fallow pulse is mostly restricted in eastern India (around 80%) covering the states of Assam, West Bengal, Bihar, Jharkhand, Chhattisgarh, Odisha, few areas in Madhya Pradesh and North Eastern Hill states (Table 3) (Singh *et al.,* 2016). The remaining 20% area is been occupied by southern states of Andhra Pradesh Tamil Nadu and Karnataka (Subbarao *et al*., 2001). Traditionally, grasspea and lentil are sown after rice as a relay crop in low land rice fields of West Bengal, Bihar, Jharkhand, eastern parts of Uttar Pradesh and Chhattisgarh. However, blackgram or greengram in coastal peninsular area comprising Odisha, Andhra Pradesh, Tamil Nadu and Karnataka (Table 4). In present days with developed crop management could permit profitable raising of a pulse as a rotational crop after rice (Praharaj *et al*., 2017).

Based on agro-climatic situation and soil type rice fallow

Table 1: Nitrogen economy due to inclusion of pulses in sequential cropping.

Preceding legume	Following cereal	Fertilizer N-equivalent (kg N/ha)
Chickpea	Maize	60.0
	Rice	40.0
Cowpea	Rice	40.0
	Wheat	43.0
Greengram	Rice	40.0
Pigeonpea	Wheat	40.0
Greengram/Blackgram	Wheat	30.0
Lentil	Maize	30.0
Field pea	Maize	25.0
Rajmah	Rice	10.0

Source: Ali and Venkatesh (2009).

Table 2: Nutritional levels of various pulses grown in India.

Name of food stuff	Gram	Blackgram	Lentil	Tur	Mung	Cowpea	Pea	Kulthi	Khesari
Protein	20.0	24.0	25.0	22.0	25.0	23.0	22.0	22.0	31.0
Vit. A (I.U.)	316.0	64.0	450	220	83	60	31	119	200
Vitamin C	3.0	-	-	-	-	-	-	1	-
Vitamin K	0.29	0.19	0.25	-	-	-	-	0.42	-
Thiamine	0.30	0.41	0.45	0.45	0.72	0.5	0.47	0.2	0.39
Ribo-fla-vin	0.51	0.37	0.49	0.5	0.15	0.48	0.21	1.5	0.41
Nicotinic-acid	2.10	2.0	1.5	2.6	2.4	1.3	3.5	-	2.2
Biotin (g/100 g)	10.0	7.5	13.2	7.6	-	202.0	-	-	7.5
Folic acid (g/100 g)	125	144	107	83	-	-	-	-	100
Cholin	194.0	206	299	183	-	-	-	-	-
Inositol	204.0	90	130	100	-	-	-	-	140
Pantothenic acid	1.3	3.5	1.6	1.5	-	-	-	-	2.6
Total no. of Vitamins/Minerals present	12	11	11	10	5	6	5	6	9

Source: Pulses Revolution from Food to Nutritional Security, 2018, Govt. of India.

may be classified into three sub-groups *i.e*., Eastern and Northeast region, Central India and Coastal Peninisula region. Pulses like lentil, lathyrus, greengram and blackgram are grown in these rice fallows after the harvesting of kharif rice mostly as paira crop (Table 5).

The soil and climatic condition of these regions under rice fallow pulse are diverse and unique. Depending upon the location or that specific agro-climatic situation diversity is seen (Table 6). The crop establishment and productivity largely depend on soil, climate and time of sowing.

Table 3: Area of pulses under rice fallow of India.

States	Area (M ha)
Odisha	2.961
Chhattisgarh	2.856
West Bengal	1.159
Jharkhand	0.475
Bihar	0.049
Jharkhand	0.475
Other States	4.50
Total	**12.0**

Source: Modified from Annual Report 2016-17, DPD, Page 46.

In Eastern and Northeast region, the soil moisture content remains high in the medium to low lands of eastern UP, Bihar, West Bengal and Odisha, where the soil is mostly alluvial and calcareous with low soil organic carbon and phosphorus. Large areas in this tract receive high rainfall during the monsoon season resulting in leaching of cations from the upper layer causing soil acidity. This requires a schedule reclamation on sustainable basis. In the alluvial tracts of eastern UP, Bihar and Jharkhand short duration crop like lathyrus and lentil are mostly grown after harvesting of *kharif* rice. With a better management practices and with a better residual soil water conservation method and restricting grazing, long duration pulses like pea and chickpea were introduced here. In the north eastern hilly areas two different situations are noticed. In the low laying areas, there is presence of excessive soil moisture which even creates a problem in harvesting in rice during October-November. On the other hand, in the hill terrace due to seepage from the high hills the land remains too wet,

Table 4: Distribution of Rice fallow pulses.

States	Major Districts
Andhra Pradesh	Krishna, Guntur, East Godavari, West Godavari, Srikakulum, Nellore and Prakasam
Bihar	Kisanganj, Sahibganj, Gaya, Aurangabad, Katihar and Bhagalpur
Chhattisgarh	Surguja, Jashpur, Raigarh, Durg, Bilaspur and Bastar
Jharkhand	Ranchi, Purbi Singhbhum, Paschim Singbhum, Hazaribagh, Gumala Sahibganj, Deogarh, Palamau, Dumka and Dhanbad
Maharashtra	Dhule, Amravati, Nagpur, Wardah, Bhandara, Chandrapur and Nanded
Madhya Pradesh	Shahdol, Seoni, Balaghat, Damoh, Mandla, Rewa, Betul and Sidhi
Odisha	Koraput, Kalahandi, Sambalpur, Sundergarh, Bhadrak, Cuttack, Puri, Dhenkanal and Mayurbhanj.
West Bengal	Purulia, Bankura, Birbhum, Bardhaman, Medinapur, Murshidabad, South 24-Parganas, Maldah, West Dinajpur, Jalpaiguri and Coochbihar
Uttar Pradesh	Gonda, Siddarthnagar, Lakhimpur, Kheri, Pilibhit, Etawah, Mirzapur and Sonbhadra
Karnataka	Shimoga and Belgaum
Tamil Nadu	Salem, Namakkal, Tiruchirappalli, Cuddalore, Ramnathpuram, Madurai and Villupuram

Source: Annual Report 2016-17, DPD, Page 46.

Table 5: Regions, States and major pulses grown under rice fallow pulse system.

Regions	States	Pulse crop taken after rice
Eastern and Northeast region	Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal	Lathyrus
	and north-eastern states	Lentil
	Odisha	Greengram and blackgram
Central India	Chhattisgarh, Madhya Pradesh	Lathyrus
	and Maharashtra	Lentil
Coastal Peninisula region	Coastal areas of Andhra Pradesh, Tamil Nadu and Karnataka	Greengram and blackgram

Source: (Singh *et al.,* 2016).

Table 6: Location specific soil and climatic condition of different rice fallow pulse growing areas.

Parameters	Kanpur (UP)	Kalyani (WB)	Umiam (Meghalaya) Upland	Raipur (Chattisgarh)	Aduthurai (Tamil Nadu)
	Eastern and Northeast region			Central India	Coastal Peninsular region
Soil texture	Sandy loam	Clay loam	Sandy clay loam	Clay loam	Alluvial Clay
Annual rainfall (mm)	722	1470	2617.1	1582	1139
Mean annual Max. and Min. Temp. (°C)	33.0 and 20.0	35.0 and 18	24.2 and 10.2	42.3 and 11.6	30.0 and 23.0
pH	8.22	7.1	5.12	7.7	7.8
Bulk density (g/cc)	1.39	1.35	1.21	1.35	1.20
Soil organic carbon(% of dry soil)	0.25	0.52	1.43	0.60	0.69
Available N (kg/ha)	243	261	252	207	245
Available P (kg/ha)	17.5	58.6	15.4	9.8	81.0
Available K (kg/ha)	199.1	248	202.4	197.3	264

Source: Modified from Singh *et al.,* 2016.

resulting in delayed rice harvest. However, with appropriate land preparation and with a proper management practices cultivation of lathyrus and lentil become successful in the rice fallows there. In the typical rice growing tract of West Bengal, lathyrus is mostly used in some pockets as paira crop after Aman rice. In Odisha after harvesting of rice blackgram or greengram are mostly grown as a major legume in rice fallow pulse system, which is been practiced in around 15 districts covering 12.2 lakh ha of land here (Singh *et al*., 2017).

In the Central India Region, covering Chattisgarh, Madhya Pradesh and parts of Maharastra the soil type plays an important role. The area is mostly predominated by clay. Different soil type such as alluvial, laterite, loamy, red loamy, medium black, deep black, sandy red and black, red sandy, mixed red and black with acidic and salinity with pH of 5.0 to 8.0 are also found in some pockets (Singh *et al*., 2017). The nutrient status of these soils varies a lot. During the later stage of the crop period the soil become too heavy and solid due to unique characteristics of swelling and shrinking. Early withdrawal of monsoon and terminal drought in the later part with heat stress disturbs the cropping system plot. Lathyrus and lentil are mostly used as a relay crop in this system.

Coastal peninsular region is one of the major rice growing zones of our country. The zone is having a typical characteristic of receiving bimodal rainfall. This create a major problem in sowing of pulse crop here. The soil of this region is deltaic alluvium, coastal alluvium and lateritic with a vast soil reaction ranging from 5.0 to 8.0. The winter span is very short here. So due to the presence of high soil moisture content if the sowing gets delayed beyond January the production of pulses hampered heavily due to primarily poor plant stand and moisture stress in later period. Blackgram and greengram are mostly taken in this tract. Besides, blackgram and green gram, soyabean was introduced in rice fallow. The crop is a highly sensitive to high temperature (≥34°C) particularly at reproductive stage. If it is exposed to such condition it develops pods without seeds due to high temperature during reproductive stage. It caused heavy loss to the farmers, which inhibited further promotion of soyabean area and cultivation in Ccauvery delta zone of Tamil Nadu (Singh *et al*., 2017).

Constraints of rice fallow pulses

The rice fallow pulse system has an immense potential not only towards increasing the total pulse production of the country but also toward achieving nutritional security and improving the soil quality. But likewise, the sole pulse cropping it also suffers with several factors. These factors may be categorized under common *i.e.* biotic, abiotic or socio-economic and production constraints.

Incidence of insects and diseases prevails even though the crops are sown in proper time and under proper condition. The major pest of pulse is the pod borer whereas the pulse crop is mostly infested by yellow vain mosaic virus (YVMV). Terminal drought, low temperature and temperature stress also hamper the growth and development at different

Table 7: Major biotic and abiotic stress identified for Rice fallow pulse of India.

Crop	Stress	
	Biotic	Abiotic
Moong/Greengram	MYMV, Powdery Pre-harvest sprouting, mildew, Rust, Sucking, Sucking insect pest	Terminal drought, low and high temperature
Urd/Blackgram	MYMV, Ascochyta blight, Anthracnose, Sucking insect pest	Pre-harvest sprouting, temperature stress, terminal drought
Lentil	Fusarium wilt, Root rot, Rust	Mid and terminal drought, temperaturestress
Chickpea	Fusarium wilt, Root rot, chickpea stunt, Botrytis GrayMould and Pod-borer	Low and high temperature and terminal drought

Source: Modified from Kumar *et al.* 2018a. Page 110 and Pulses Revolution from Food to Nutritional Security, 2018, Govt. of India page 9.

pulses. The biotic and abiotic stresses of different pulse crop have been depicted in Table 7.

Lack of scientific knowledge, non-availability of improved cultivar and poor technical knowledge, absence of seed storage and life-saving irrigation along with poor marketing support are the socio-economic constraints in pulses production of our country (Praharaj *et al*., 2016 and 2017). Besides this poor financial condition of the small and marginal farmer bared them to go for cultivating pulses after rice rather keep the land fallow. Fragmented land holdings, low purchasing capability, lack of input availability, limited access to institutional credit, lack of extension services directly or indirectly discourages the farmers to take another crop after kharif rice (Joshi *et al*., 2002). Likewise, lack of labour availability and grazing problems also discourage the farmers.

Proper management practices are important factor towards achieving a better yield. The sowing of pulse in rice fallow depends upon the duration of rice variety. Withdrawal of monsoon and late rainfall eventually affect the dynamics of the rice fallow pulse system. So late sowing and lack of proper cultivar for rice fallow system further limit its adaptation. Soil moisture condition during sowing time of pulses plays an important role, on the other hand anaerobic condition in rice limits the nutrient availability to pulse. The crop often suffers with nutrient stress either due to its less or no application of nutrients or its non-availability due to poor soil aeration. All these leads to a poor plant growth resulting in less productivity. Farmers even do not give proper attention towards giving proper seed rate, seed inoculation and other important management practices such as foliar nutrient application. Even the crop establishes well under residual moisture content but due to lack of winter rain or unavailability of irrigation water during flowering and pod formation, it may lead to complete crop failure (Kumar *et al*. 2019).

Weed is another limiting factor. It poses sever difficulties to *paira crop* as it is grown under uncultivated situation (Ali *et al.,* 2014). Quick moisture loss from the soil surface does not allow any scope to go for manual weeding (Kumar *et al*. 2018a). Lack of proper selective post emergence herbicide further increases the difficulties. Soil pH also affects the system a lot. Majority of the pulses under this system are grown in acidic condition. Pulse crops are sensitive to acidity and have direct influence to biological nitrogen fixation. Strongly acidic soil has been noticed in rice-fallows of Chhattisgarh and Assam (Kumar *et al.* 2016).

Scopes of pulse cultivation in rice fallows

Around 11.7 M ha area remains fallow after rice harvest and majority (> 75%) of it lies in the states like Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, West Bengal and North Eastern states and Andhra Pradesh, Tamil Nadu and Kernataka (Kumar *et al*., 2018a). Research finding reveals that these unutilized areas can be converted into second cropping by utilizing the residual soil moistures during *rabi* (Das *et al.,* 2014). Rice fallow is a suitable condition for introduction of pulse as they require short-season of 3-4 months, with low water-requirement as they can thrive best on residual moisture with adequate conservation measures. So, grain legumes such as chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris*), urdbean (*Vigna mungo* L.), mung (*Vigna radiata* L.) can easily be introduced. Pulses are well recognized for their role in upgrading of soil health, system productivity and sustainability. They are also performing well under conservation tillage in rainfed agro-ecosystem of rice-fallows. Therefore, overall productivity and sustainability of the system will improve with inclusion of pulses in rice-fallows (Kumar *et al*., 2018a).

Strategies for increasing pulse production in rice fallows

I. Implementation of resource conservation technologies

Generally, pulse seeds are broadcasted on standing crop under *paira/utera* cropping. During harvesting of rice after 10-15 days of sowing either manually or by machine, it destroys a considerable n of pulse seedlings or even create some unfavorable condition for the seeds to germinate. This eventually reduces the plant population. Resource Conservation Technologies such as zero tillage (ZT) along with residue incorporation also implement the same principle of soil moisture conservation. On the contrary it will not destroy the seedlings and it will also provide a condition to apply herbicide to restrict the weed growth. Sowing via ZT will also ensure to use mulching using the rice crop residue. Results clearly indicating that retention of rice crop residue/

mulching at 5 t/ha or 30–40 cm stubble have been found effective in the soil moisture conservation and increasing the crop yields and monitory returns in rice-fallows. Reduced tillage has increased the yield of pulses (lathyrus, greengram, blackgram, field pea) by 33-44% over conventional tillage (Kar and Kumar, 2009). ZT after rice harvest also facilities timely sowing of winter pulses and helps to escape negative effects of terminal drought and rising temperature in spring-summer in rice-fallows (Kumar *et al*. 2019). Experimental findings from several locations in IGPs showed that ZT farmers saves on preparatory operation by Rs 2500/ha and reduced diesel of 50–60 l/ha (Sharma *et al.* 2005).

II. Mode of crop production

To utilize the maximum soil moisture content and maximize the system productivity a proper rice cultivar has to be selected. For that the long duration rice varieties to be replaced by medium to short duration cultivars. It may provide a perfect time for sowing of the succeeding pulse crop without any delay both under *paira* or ZT condition, this will provide a better condition to utilize the residual soil moisture resulting in uniform germination. Mechanical transplanting or line transplanting of rice gives higher yield of fallow *paira* crops (Mishra and Kumar 2018).

III. Use of optimum seed rate

Towards obtaining a proper crop stand and better yield optimum seed rate in an important factor in rice fallows. Less plant population is always an issue in rice fallows. It is recommended to increase seed rate by 20–25% to have a desired plant population in rice–fallows (Bhowmick *et al.* 2005).

IV. Suitable crops and varieties

Availability of superior quality seeds is an important limitation. Depending upon the climatic condition and availability of residual soil moisture with availability of other resources a proper crop and a suitable variety should be selected. Even though selection of a early to medium duration rice cultivar like Prabhat, Naveen, Shreya will provide a handsome time period to advance sowing of succeeding pulse crops for efficient utilization of stored soil moistures and other resources. Widespread trapping of the rice–fallows needs short-duration and hardy pulses varieties that can efficiently avoid terminal drought and fought against other limitations efficiently (Table 8). Pulses genotype with fast growing nature with wide canopy cover could minimize the evaporation losses from soil surface (Kumar *et al.,* 2019).

V. Seed inoculation and seed priming

Poor nodulation and biological nitrogen fixation were always an issue in the rice fallows. This is due to poor aeration and soil structure. It is always a beneficial fact for pulse seed to get inoculated with a specific *Rhizobium* culture. Prior to that the seeds should be treated with fungicide. Pulse seeds are also inoculated using phosphate solubilizing bacteria (PSB) and vesicular-arbuscular mycorrhizae (VAM) and *Trichoderma* before sowing to obtain a disease-free plant stand and better nodulation. Seed priming is another important phenomenon to obtain a good germination. Seeds are soaked in water or nutrient overnight before sowing. Experimental findings reveal that of primed seed either sprouted or 2% KH_2PO_4 soaked followed by twice foliar application of 2% urea/DAP at pre-flowering stage and 10 days thereafter would be a potential cost-effective technique for augmenting the production of lathyrus under utera cropping in the rice-fallows (Bhowmick *et al.* 2014). Seed priming along with *Rhizobium* inoculation in blackgram effectively increases nodulation, nodule dry weight, yield attributes such as 36.4 and 8% higher in pods/plant and 100-seed weight, respectively and 25% more seed yield than control. Seed priming alone reportedly increases seed yield up to 10.5% (Singh *et al* 2017).

VI. Foliar nutrient application

Foliar nutrient feeding to the pulse was always been a special character. Pulses often suffer from micronutrient deficiency. It can easily be rectified by application of micronutrients as foliar. Research findings clearly showing that application of 2% urea at pre-flowering stages had the maximum seed yield of 1040 kg/ha and 2% DAP spray yielded 983 kg/ha (Bhowmick *et al.* 2014).

VII. Soil moisture conservation and life-saving irrigation

The problem of moisture stress and terminal drought in rice fallows can be mitigated by effective moisture conservation practices. Initially, the pulse crop should be sown immediately after harvesting of the rice crop. Sowing with zero till seed drill followed by mulching with paddy straw eventually conserves soil moisture. ZT prevents soil moisture loss and advances planting by seven days (Mishra *et al.*

Table 8: Potential pulse varieties for rice fallow.

Crop	State	Variety
Chickpea	Uttar Pradesh, Bihar, West Bengal	GCP 105, Pusa 372, JG 14, Rajas, Pant G 186, Pusa 547
	Chhattisgarh and Madhya Pradesh	Rajas, JG 14, JG 130
Urdbean	Odisha	LBG 752, Pant U 31, LBG 402, LBG 709
	Tamil Nadu andhra Pradesh, Karnataka	
Lentil	West Bengal, Assam, Bihar, Uttar Pradesh, Jharkhand	HUL 57, KLS 218, Narandra Masoor 1, WBL 58
	Chhattisgarh, Madhya Pradesh	JL 3, IPL 81
Lathyrus	Chhattisgarh, Madhya Pradesh, Bihar	Ratan, Prateek, Mahateora

Source: Modified from Singh *et al.* 2017.

2016). Kar and Kumar (2009) described RT increase pulses yield like lathyrus/lentil/chickpea by 33-44% over CT in rice-fallow. They also confirmed that moisture-conservation potential of RT is better than NT/relay cropping. Similarly, higher yield of pulses with RT was reported by Ghosh *et al.* (2010). So, it is quite clear that water stress drastically affects pulse crop's growth and development. It has been observed that sometimes severe soil moisture stress leads to crop failure of pulse under rainfed rice fallows. Under this circumstance one life saving irrigation can change the whole scenario. It has been proved that with single application of life saving irrigation applied at flowering or pod development stage under in rice + pulse relay cropping as well as rice-pulse sequential cropping under rice fallow pulses, recorded an enhancement in plant growth parameters and yield of pulse crops upto 20-35% (Singh *et al*. 2017).

VIII. Weed management

Rice-fallows pulses are heavily infested with varied types of weeds. To obtain maximum yield benefits, the crops must be kept free from weeds. Weed management is a difficult task in this system as the soil surface loose moisture and it will become an un-favorable for manual weeding. Pre-emergence herbicides are not effective here as the seeds are sown in standing crop mostly. Controlling the rice ratoons is another important issue here as they compete for inputs resulting in low pulse production. Studies reveal that application of quizalofop-ethyl 100 g/ha at 15-20 days after sowing of pulses is beneficial (Kumar *et al*. 2019). Glyphosate and paraquat are also used to check the growth of rice stubbles that causes significant moisture losses in rice–fallows. Herbicides should be applied before sowing of winter crops (Kumar *et al.* 2018b). In ZT- sowing post emergence herbicides effectively control weeds in pulse field. Application of quizalofop @ 50 g/ha at 15-20 days after sowing has been found effective in checking the regrowth of rice as also the grassy weeds (Kumar *et al.* 2016).

IX. Pest management

Pulse crops are severely infested by yellow mosaic virus, root rot and powdery mildew. Among insect's pulse pod borer is the most dangerous. All of these pests cause major problems in pulse grown in rice fallows. For controlling these diseases and insects an integrated management process will be a better choice. Seed treatment with fungicide, using *Trichoderma* as seed treating materials or soil drenching would be better. Spraying should be done on need basis. Choosing a resistant crop variety and use of bio-control agents would be preferable. Seed treatment with *Trichoderma* + carboxin/alternately carbendazim + thiram for root rot, collar rots/wilt in chickpea, lentil, greengram/ blackgram is useful for pulse production (Kumar *et al*. 2019).

X. Improvement of rural credit system and marketing

Weak purchasing power of farmer and deprived socio-economic condition force them to skip the 2nd crop after paddy. To deal with this condition, subsidy in farm inputs with credit and crop insurance scheme to be implemented. Marketing facilities need to be reinforced because these are directly connected with farmer's condition. A free-flowing marketing facility would encourage the farmers towards adopting multiple crops.

CONCLUSION

Keeping all these discussions in mind it can be concluded that rice fallow has a tremendous opportunity to introduce pulse in it. With the adaptation of improved technology, soil moisture conservation process, selecting best rice varieties along with a best suited pulse crop, along with a proper strategy to deal with the biotic stress, the rice fallow pulse would defiantly be a new way out for the farmers. Problems of rice fallow areas are location specific, so if this problem can be managed efficiently, then theses unutilized lands can be utilized toward growing suitable pulses. This would benefit the system productivity, improve the soil health, strengthen the financial condition of the farmers and also provide a new way to fulfill the nutritional security.

REFERENCES

Adarsh, S., Jacob, J. and Giffy, T. (2019). Role of pulses in cropping system: A review. Agricultural Review. 40(3): 185-191.

Ali, M. and Venkatesh, M.S. (2009). Pulses in improving soil health. Indian Farming. 58(11): 18-22.

Ali, M., Ghosh, P.K., Hazra, K.K. (2014). Resource conservation technologies in rice fallow. In: *Resource Conservation Technology in Pulses*, [Ghosh P K, Kumar N, Venkatesh M S, Hazra K K, Nadarajan N. (Eds)]. Scientific Publishers, Jodhpur, Rajasthan, India. pp. 83-88.

Annual Report DAP (2016-17). Directorate of Pulse Development. Ministry of Agriculture and Farmers Welfare. Govt of India. pp-46.

Anonymous (2018). Pulses Revolution from Food to Nutritional Security. (2018). Govt. of India.

Bhowmick, M.K., Aich, A., Aich, S.S., Shrivastava, M.P., Gupta, S., Man, G.C. (2005). Crop diversification through paira (utera) cropping with rabi pulses. SATSA Mukhapatra-Annal Technology. 9: 43-60

Bhowmick, M.K., Dhara, M.C., Duary, B., Biswas, P.K., Bhattacharyya, P. (2014). Improvement of lathyrus productivity through seed priming and foliar nutrition under rice-utera system. Journal of Crop and Weed. 10: 277-80.

Choudhary, A.K., Raje, R.S., Datta, S., Sultana. R., Ontagodi. T. (2013). Conventional and molecular approaches towards genetic improvement in pigeon pea for insects resistance. American Journal of Plant Sciences. 4: 372-385.

Chowdhury, Md. R. (2015). Nutrient management through combined use of organic, inorganic and biological sources under rice-onion-greengram crop sequence. Ph.D. Thesis, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal.

Das, A., Lal, R., Patel, D.P., Ramkrushna, G.I., Layek, J., Ngachan, S.V., Ghosh, P.K., Bordoloi, J., Kumar, M. (2014). Effects of tillage and biomass on soil quality and productivity of

lowland rice cultivation by small scale farmers in North Eastern India. Soil and Tillage Research. 143: 50-58.

FAO News (2016). Nutritional Benefits of Pulses. www.fao.org/2/pulses2016e

Ghosh, P.K., Das, A., Saha, R., Enboklang, K., Tripathi, A.K., Munda, G.C., Ngachan, S.V. (2010). Conservation agriculture towards achieving food security in North East India. Current Science. 99: 915-921.

Joshi, P.K., Birthal. P.S., Bourai, V.A. (2002). Socio-economic constraints and opportunities in rainfed *rabi* cropping in rice fallow areas of India. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, pp 58.

Kar, G. and Kumar, A. (2009). Evaluation of post-rainy season crops with residual soil moisture and different tillage methods in rice-fallow of eastern India. Agricultural Water Manage--ment. 96: 931-938

Kumar, N., Hazra, K.K., Singh, S., Nadrajan. N. (2016). Constrains and prospects of growing pulses in rice fallows of India. Indian Farming. 66(6): 13-16.

Kumar, N., Yadav, A., Singh, S., Yadav, S.L. (2018a). Growing pulses in rice fallow: Ensuring nutritional security in India. In: Conservation Agriculture for Advancing Food Security in Changing Climate. 1: 107-122

Kumar, R., Mishra, J.S., Rao, K.K., Kumar, R., Singh, S.K., Bhatt, B.P. (2018b). Evaluation of crop establishment techniques in rice fallows of Eastern Indo–Gangetic Plains. Paper presented in the National Conference on "Organic Waste Management for Food and Environmental Security" during 8-10th February 2018; Jointly Organized by ICAR–Indian Institute of Soil Science and Bhopal Chapter of Indian Society of Soil Science, Bhopal at Nabibagh, Berasia Road, Bhopal, (M.P.), pp 26.

Kumar, R., Mishra, J.S., Upadhaya, P.K. and Hans. H. (2019). Rrice fallow in eastern India: Problems and prospects. Indian Journal of Agricultural Sciences. 89(4): 567-77.

Mishra, J.S. and Kumar, R. (2018). Zero tillage options of pulses in rice-based cropping system. *Farm Mechanization for Production*. [Khare D, Nahatkar S B, Shrivastava, A K. Jha (Eds)]. A K. Scientific Publishers, India, New Delhi. Pp: 122-136.

Mishra, J.S., Kumar, R., Kumar, R., Rao, K.K., Singh, S.K., Idris, M., Jha, B.K., Naik, S.K., Mali, S.S., Bhatt, B.P. (2016). Evaluation of pulses and oilseed under different crop establishment methods in rice-fallows of Eastern India. Extended Summaries Vol. 2. 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India, pp 1272-1274.

Padmaja, R., Soumitra, P., Bantilan, M.C.S. (2016). Role of pulses in enhancing nutritional status of rural poor: micro-level evidence from semi-arid tropics of India. Agricultural Economics Research Review. (29): 65-74.

Praharaj, C.S., Ummed Singh, U., S.S. Singh, S.S. and N. Kumar, N. (2017). Micro-irrigation in rainfed pigeonpea-Upscaling productivity under Eastern Gangetic Plains with suitable land configuration, population management and supple--mentary fertigation at critical stages. Current Science. 112(1): 95-107.

Praharaj, C.S., Singh, U., Singh, S.S., Shivay, S.Y. (2016). Supple--mentary and life-saving irrigation for enhancing pulses production, productivity and water use efficiency in India. Indian Journal of Agronomy. 61 (4th IAC Special issue): S249-S261.

Sharma, A.R., Singh, R., Dhyani, S.K. (2005). Conservation tillage and mulching for optimizing productivity in maize-wheat cropping system in outer western Himalaya region- a review. Indian Journal of Soil Conservation. 33: 35-41.

Singh, K.K., Ali, M., Venkatesh, M.S. (2009). Pulses in Cropping Systems. Technical Bulletin, IIPR, Kanpur.

Singh, N.P., Praharaj, C.S., Sandhu, J.S. (2016). Utilizing untapped potential of rice fallow of East and North-east India through pulse production. Indian Journal of Genetics and Plant Breeding. 76(4): 388-398.

Singh, S.S., Kumar Narendra, Praharaj, C.S., Singh, N.P. (2017). Agro-technologies for enhancing pulses production in rice fallows. ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India. pp 36.

Subbarao, G.V., Kumar Rao, J.V.D.K., Kumar, J., Johansen, C., Deb, U.K., Ahmed, I., Krishna, M.N., Venkataratnam, L., Hebbar, K.R., Sesha Sai, M.V.R., Harris, D. (2001). Spatial distribution and quantification of rice-fallows in South Asia-potential for legumes. Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. Pp 316.

Tewari, A.K. and Shivhare, A.K. (2017). Pulses in India: Retrospect and prospects. Govt of India, Ministry of Agriculture and Farmers Welfare.