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Issues and strategies for promotion of pulses in untapped rice-fallow in India: A review

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ABSTRACT

Out of 43.95 m ha under rice in India, about 11.7 m ha area remains fallow after the rice harvest. A number of abiotic, biotic and socio-economic factors limit cultivation of crops after rice in these areas. Factors like low soil moisture content after rice harvest followed by fast decline in water table with advancement of crop season and mid-and terminal-drought at flowering and pod filling stages are the major bottlenecks for growing of crops in rice fallow. Pulses like lentil, chickpea, urdbean, mungbean and lathyrus are the candidate crops for rice fallow due to their better survival under surface seeding and rainfed situation. The inherited soil physical and biological constraints of rice fallow affect pulses seed germination, seedling emergence and crop establishment due to disruption of soil structure, poor aeration and mechanical impedance in the seed zone. To exploit these areas under rice fallow with pulses, location specific resource conservation practices may be fallowed. The present paper deals with the constraints and strategies related to rice fallow-pulse system in different agro ecological regions of the country.

Key words: Abiotic stress, Biotic stress, Constraints, Cropping system, Resource conservation, Rice fallow.

1. INTRODUCTION

In India, rice is cultivated across the length and width of the country occupying 43.95 million hectares (DAC, 2015). It is grown both under irrigated and rainfed conditions under various cropping systems. In irrigated areas, rice-wheat, rice-rice, rice-sugarcane, rice-groundnut, rice-vegetables and rice-mustard are important crop rotations whereas in rainfed areas, rice-pulses, rice-sunflower, rice-sesame and rice-fallow are prevalent (Frolking *et al.* 2006; Yadav and Subba Rao 2001). More than 11 million hectares of land in India is left fallow after rice harvest due to number of biotic, abiotic and socio-economic constraints (Subbarao *et al.* 2001). Out of them, 82% areas of rice-fallow lies in the states of Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Chhattisgarh, Odisha, West Bengal and North Eastern states. The remaining 18% area in states likes Tamil Nadu, Karnataka and Andhra Pradesh (Das *et al.* 2013; Joshi *et al.* 2002; Pande *et al.* 2010) which gives a large scope for expansion of area under pulse crops (Subbarao *et al.* 2001). The details of rice fallow areas are given in Table 1. Despite of ample opportunities, rice-fallow systems did not get enough attention in the past.

Pulses with properties like low input requirements, short duration, ability to establish with surface broadcast in standing rice fields and soil fertility restoration are ideal for rice fallow (Ali *et al.* 2014). They are rich source of protein and have ability to fix atmospheric nitrogen and thus improve soil fertility (Joshi 1998). Pulses are an effective source of reversing the process of soil deterioration and can contribute significantly to achieving the twin objectives of increasing productivity and improving the sustainability of the cereal based cropping system (Ahlawat *et al.* 1998; Ahmed *et al.* 2001; Ali *et al.* 2012a; Lauren *et al.* 1998; Sharma and Sharma 2006; Yadav *et al.* 1998). The existing rice fallow area (11.7 mha) is almost equivalent to the net sown area of Punjab, Haryana and western Uttar Pradesh –the sheet of green revolution in India (DAC 2015; Joshi *et al.* 2002). If this area is brought under cultivation it may benefit millions of poor and small farmers solely dependent on agriculture for their livelihood. The nation would also save foreign exchange incurred in importing pulses and ensuring nutritional security of poor section of the society. Better utilization of rice fallows by cultivating pulses should improve soil organic matter and fertility status, thereby contributing to the long-term sustainability of rice based cropping (Kumar Rao *et al.* 1998; Sharma *et al.* 1995). Traditionally, lathyrus and lentil are sown after rice under relay cropping in low land rice fields of Bihar, eastern Uttar Pradesh and Chhattisgarh, and urdbean/mungbean in coastal peninsula (Ali *et al.* 2014; Das 2000; Gupta and Bhowmick 2005; Sharma and Pandey 2001). Non-availability of quality seeds of pulses suitable for rice fallow in desired quantity (NAAS 2013) at appropriate time and reasonable cost is also a big hurdle.

Table 1. State-wise estimates of rice fallow area during *rabi* (2007-08).

State	Kharif-Rice Area ('000 ha)	Rabi-Fallow ('000ha)*	Rice fallow area as % of total kharif rice area
Madhya Pradesh and Chhattisgarh	5311.3	4,382	82.5
Bihar	3462.2	2,196	63.43
West Bengal	4208.1	1,719	40.85
Assam	2001.0	539	26.94
Uttar Pradesh	5690.0	353	6.2
Others	18781.8	2,463	13.11
Total	39454.4	11,652	29.53

*Source: ICRISAT (2009)

In early 1960's rice fallow states were the major contributors i.e., 2/3 of area and 1/2 of pulse production in India. But in early 2000s, the area and production share declined drastically, although at the national level these witnessed a positive trend, the increased yield have compensated the steeper fall in production of pulses in rice fallow. Amongst the *rabi* pulses, the area under chickpea declined in Madhya Pradesh, lentil in West Bengal and lathyrus in all the rice fallow states. About 0.5 million ha area of rice fallows are already under pulses. An additional 2.0 to 3.0 million ha rice fallow area can be brought under pulses cultivation by introducing disease resistant and short duration new varieties along with improved production technologies, especially for in-situ conservation of residual soil moisture in different states as shown in Table 2.

Bringing fallow land under pulse cultivation would help in overcoming many of the social and economic problems of these regions (Joshi *et al.* 2002). A detailed SWOT analysis of rice fallow regions was made to explore the possibility of promoting pulses and bringing additional area under pulses (Table 3).

Table 2. Potential areas in rice fallows for pulses production.

Crop	States	Approx. additional area (Lakhs ha)
Chickpea	Eastern Uttar Pradesh, Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh	47.00
Urdbean/mungbean	Chhattisgarh, Andhra Pradesh, Tamil Nadu, Orissa	23.30
Lathyrus	West Bengal, Jharkhand, Orissa, Chhattisgarh, Bihar	3.16
Lentil	Eastern Uttar Pradesh, Bihar, Karnataka, Assam, Meghalaya, NE States	25.03

Source: IIPR (2013)

2. Issues in rice fallow

Pulses productivity in rice fallow is generally low due to various abiotic stress (drought, high temperature, etc,), biotic stress (pests and diseases), poor crop management and socio-economic reasons. However, in general the major constraints in rice fallow areas can be grouped into three main categories viz., abiotic, biotic and socio-economic.

2.1 General constraints:

2.1.1 Abiotic constraints

Low fertility, problematic soils and unpredictable environmental conditions are major abiotic constraints which lead to low pulse production in rice fallow during past several years. Soil moisture and high temperature are the major constraints in rice fallow. Drought and High temperature (>35^{o}C) stress at flowering and pod filling stages adversely affect the productivity of pulses in rice fallow and reduces seed yields up to 50% (Toker and Cagirgan 1998). Another major problem is soil salinity and alkalinity which restrict the root and shoot growth of pulses. Soil acidity is the major problems in eastern India, on the other hand salinity and alkalinity in rice fallow areas of lower and middle Gangetic plains and in central India (De Datta 1981). The unfavorable soil physico-chemical conditions restrict the growth of the pulse crops due to less availability of nutrients, less microbial (*rhizobium*) activity and poor root growth (Adisarwanto *et al.* 1989; Awadhwal *et al.* 1989; Kirchhof *et al.* 2000; Pasaribu and McIntosh 1985; Oussible *et al.* 1992; Sharma *et al.* 2003; Sharma and De Datta 1985). Besides the inherent constraints, rice fallow also affect seed germination, seedling emergence and crop establishment due to disruption of soil structure, soil water deficit, poor aeration and mechanical impedance of the seed zone (Adisrwanto *et al.* 1989;

Table 3. SWOT analysis of rice fallow areas.

Description	Characteristics
Strength	• Availability of large area (11.7 m ha) under rice fallow in diverse agro-ecological regions • Availability of early maturing varieties of rice and pulses suitable for rice fallow situation (System approach) • On an average, monsoon rainfall is good and available soil moisture is sufficient for seed germination followed by 1 or 2 winter rainfall • Technical and economic feasibility of pulses cultivation
Weaknesses	• Very low extent of cultivation • Delayed sowing of rice and lack of initiative to introduce early maturing rice variety • Uncertain winter rainfall • Lack of appropriate varieties of pulse crops suitable for diverse agro ecological regions of rice fallow • Use of poor quality seed with low germination (local seed) • Higher incidence of insect-pests and diseases in pulses • Lack of irrigation facilities • Non practice of foliar application of 2% urea/DAP • Terminal drought and heat stress during the reproductive and grain filling stage • Lack of efficient machines for tillage, sowing and weeding for pulses • Weak extension system for effective transfer of improved technologies • Poor understanding the ecology of rice fallow
Opportunities	• Availability of pulses for cultivation on residual soil moisture • Pulses are low input requiring crops • Resource conservation technology is available for both the crops • Pulses can intercrop with competitive crops like oilseeds, sorghum and maize • Income augmentation • Employment generation
Threats	• Low and instable yield • Production risks due to uncertain rainfall and high incidence of insect-pests and diseases • Timely non-availability of key inputs (Fertilizer, seeds, pesticides etc.) • Low or no input application

Source: Joshi *et al.* (2002) and author's inputs based on field experience.

IRRI 1984; Mahata *et al.* 1990; So and Woodhead 1987; Varade 1990; Woodhead 1990). Amongst these, soil hardiness is the most limiting factor followed by low organic matter content in the soil. Soil hardiness in the puddled rice fields deteriorates the hydraulic properties of the soil, which adversely affects the soil moisture distribution and root growth of deep rooted pulses (Adisarwanto *et al.* 1989). This hostile environment creates potential threat to microbial activity, nutrient availability, root growth (root is mostly confined in top soil layer) and water and nutrients uptake, thus sub-soil resources in rice fallow remain unutilized. Under relay (*paira*) cropping, plant population is often low because of low seed germination due to poor contact of seed with soil, seed rotting as well as dryness of soil in patches. If ploughing is done after harvest of rice to remove stubbles, sowing of *rabi* pulses are delayed and germination will also be affected due to formation of large size clods.

2.1.2 Biotic constraints

Due to anaerobic conditions in rice cultivation, many of the organisms including rhizobia would not be able to survive (Adisarwanto *et al.* 1989). Even if the crop is sown timely and established well, pulses experience high incidence of insect pests and diseases. In fact, detailed studies on disease pest dynamics of pulses in rice fallow are not done. Evidence indicates that pulses are the most susceptible to damage by insects (Deshpande and Singh 2001). In chickpea, insect pests (particularly *Helicoverpa*) are reported to be a potentially threat in Chhattisgarh, Jharkhand and Madhya Pradesh (Table 4). Diseases are also viewed

Table 4. Constraints in relay cropping and in rice fallows.

Crop	Stress	
	Biotic	Abiotic
Chickpea	FW, root rot, chickpea stunt, BGM, pod-borer	Low and high temperature, Terminal drought
Mungbean	MYMV, root and stem rot, stem agromyza, sucking insect pests stress, Pre-harvest sprouting,	high temperature, terminal drought, excessive soil moisture at sowing
Urdbean	MYMV, root and stem rot, stem agromyza Pre-harvest sprouting,	temperature stress, terminal drought, excessive soil at sowing
Lentil	FW, root rot, rust	Soil moisture, high temperature (under late sown)

BGM= Botrytis Gray Mould, FW= Fusarium Wilt, MYMV= Mungbean Yellow Mosaic Virus.

as a severe problem. In Odisha and West Bengal, area under chickpea is small and farmers perhaps are not much aware of the pest problem. Non- availability of pesticides in adequate quantity and at right time is also an important hindrance in cultivation. Another important pest affecting pulses are nematodes, among which root-knot nematodes are important in terms of spread and damage to crop yield in rice fallow areas (Ali 2009). Powdery mildew is a serious disease of *rabi* planted urdbean and mungbean (Ali *et al*. 2012; Thakur and Agrawal 1995). Similarly, rust and *Fusarium* wilt are common in lentil (Choudhary et al. 2013; NAAS 2013; Sen Gupta 1974).

2.1.3 Socio-economic constraints

Lack of knowledge, non availability of improved seed and poor technical guidance are few socio-economic institutional constraints (Joshi *et al.* 2002; Pande *et al.* 2003; Subbarao *et al.* 2001) while seed storage, poor irrigation and poor marketing were socio-economic infrastructural constraints (Ali and Gupta 2012; Amarender Reddy 2004) in pulses production in rice fallows. Public extension system is weak to effectively deliver the technology, inputs and information to the farmers (Balaji *et al.* 2007; Singh *et al.* 2012). In most part of the country improving farmer's access to information related to crops and their cultivation practices is important in the process of utilization of fallow areas. As per farmer's perspective, states with rice fallow are inhabited by poor people (Joshi *et al.* 2002), scarcity of labor is the biggest bottleneck during the sowing and intercultural operations. This is because of higher demand for labour for rice harvesting and threshing, while at the same time farmers have to quickly sow the next crop so as to utilize the available soil moisture. Some farmers do not possess draft power and thus they also need credit support to acquire bullocks or tractor to ensure timeliness in sowing. The net result of non-utilization of this vital resource is agricultural backwardness, low levels of income or rural population, abject poverty and unemployment (Joshi *et al.* 2002). In addition, cattle grazing and stray cattle are another big issue in many parts of the rice fallow areas after harvest of rice crop.

Sometimes, farmers lack information on different soil conservation technologies and sowing technologies that help to germinate the seed in low moisture regime. Poor farmers lack sufficient capital to purchase critical inputs such as seed, fertilizer and pesticides. Non-availability of these inputs particularly quality seeds are constrains of growing rabi crops in rice fallows. Low volume of produce and lack of proper markets may deprive the small and marginal producer to get the market price. Non-availability of high yielding, early maturing and disease resistant varieties at village level and improved post-harvest technologies to reduce post harvest losses also hinder cultivation of pulse crops in rice fallow areas.

2.2 Zone-wise specific constraints

On the basis of soil and agro-climatic conditions, rice fallow may be classified into three sub groups i.e., *Eastern and North-East region* (Eastern Uttar Pradesh, Bihar, Odisha, West Bengal and Assam) where lentil and lathyrus are grown after rice under relay cropping (*paira*) except in Odisha where mungbean performs well. The second is *Central region* (Chhattisgarh, Madhya Pradesh and Maharashtra) where lathyrus and lentil are traditionally broadcast as *paira* crop. The last is *Coastal areas* (coastal areas of AP, Tamil Nadu and Karnataka): excessive soil moisture and mild winter are main characteristics of the region which favoring urdbean and mungbean cultivation after rice harvest (Ghosh *et al.* 2012).

2.2.1 Eastern and north-east region

In Eastern and north-eastern region of India, a large part of the area remains fallow after the *kharif* season rice (Das *et al.* 2012). The soils of this region are deep alluvial and calcareous in nature except in upper Assam where acid soils are prevalent. Soils are generally deficient in OC, P and Zn. Excessive moisture or water logging is common in low lands during October/November (at harvest of rice). During *rabi* season, due to excess moisture owing to seepage from surrounding hillocks in rice fallow, land preparation is very difficult. Winter is severe and stray cattle after harvest of rice are serious threat to next crop. Under this region lentil has a very good potential for increasing farm income as well as cropping intensity (Das *et al.* 2013). The eastern part of India is West Bengal bordering with Bangladesh, is a unique example where rice is cultivated in all the three seasons viz., summer, autumn and winter. The State has to feed almost 70 million people with the support of only 5.8 million hectares of cultivable land. Due to high ODAP content in local land races of lathyrus (Mehra *et al.* 1996; Srivastava and Khokhar 1996) and also with the advent of irrigation facilities, the farmers tended to shift from relay cropping of lathyrus to more remunerative crops like rapeseed, mustard, potato, other vegetables and winter rice which require more water. Thus the area under lathyrus, in particular, diminished drastically in these regions. Huke (1982) reported that in high altitudes of north eastern India low temperature is a constraint where a high night temperature in lower altitudes limits pulses growth and yield, thus temperature becomes one of the important production constraints.

2.2.2 *Central India*

The region covers Chhattisgarh, Madhya Pradesh and Maharashtra. The mean rainfall of these states is about 1,000 mm and the coefficient of variation of the rainfall is 20-25%. Moisture stress is the oft-cited reason for crop failures in this region. Terminal drought and high temperature stress results in forced maturity with low yields (Basu *et al.* 2009; Erskine *et al.* 1993; Summerfield *et al.* 1984). Drought stress alone may reduce seed yields up to 50 per cent (Conci and Toker 2009). Thus, a quantum jump in productivity can be achieved by applying life saving irrigation especially in *rabi* pulses grown on residual moisture (Reddy 2009). Soils in these regions are generally deltaic alluvial, coastal alluvial, laterite, red loamy, medium black, red sandy, deep black, sandy red and black, mixed red and black with pockets of acidic and saline soils with pH 5.0 to 8.0. These soils are generally deficient in nitrogen, organic matter and calcium. Laterite soils are usually low in nutrient status, organic matter with poor water holding capacity and strongly acidic. Early withdrawal of rains leads to soil moisture stress at planting of winter crops is major concern. Relay (*paira*) cropping of lentil/lathyrus is more common in this region. Seeds of lathyus/lentil are broadcasted in standing rice field at 7-15 days before harvesting of rice. This region offers great scope for promoting chickpea in rice fallow. However, susceptibility of chickpea to root rot and wilt as well as to the pod borer *Helicoverpa armigera* are the major concern in this region.

2.2.3 *Coastal peninsula*

Coastal areas of Andhra Pradesh, Tamil Nadu and Karnataka are covered under this region. Excessive soil moisture during early crop growth stage, severe soil moisture stress during reproductive phase and mild winter are main characteristics of the region. Short growing period and mild winter favouring urdbean and mungbean cultivation in this region after rice under relay cropping. The region receives bi-modal rains. Sowing of urdbean and mungbean under rice fallow conditions if delayed beyond 31st January, there is drastic reduction in the productivity of these crops. Poor plant stand and terminal moisture stress are the two major constraints for rice fallow pulses in this region. Urdbean and mungbean are susceptible to Mungbean Yellow Mosaic Virus (MYMV), besides they are susceptible to powdery mildew, cercospora leaf spot and leaf curl virus. Similarly, with the traditional practices of rice-pulse relay cropping prevalent in the state of West Bengal, Odisha, Chhattisgarh, Jharkhand and Tamil Nadu, the productivity of pulses (lentil, lathyrus, mungbean, blackgram) is very low because of insufficient plant population possibly due to poor seed-soil contact, low soil moisture, severe weed infestation and low microbial population.

3. Strategy for improving pulses productivity in rice fallow

Productivity and profitability from second crop in rice fallow can be improved with suitable crop management technique even by utilizing residual soil moisture (Kar *et al.* 2004; Pratibha *et al.* 1996). By adopting improved technologies like resource conservation, improved variety, optimum time of sowing, plant population, suitable biofertilizers inoculation, fertilizer application methods, timely weed management practices, need based plant protection measures coupled with proper irrigation schedule (life saving irrigation at critical crop growth stages) would definitely increased the yield of pulses in rice fallow agro-ecological regions. The major rice based cropping systems are also identified (Table 5)

Table 5. Rice based major cropping systems in rice fallow states.

State	Rice based cropping system
Andhra Pradesh	Rice-rice, rice-groundnut, rice-pulse, rice-fallow, fallow-rice
Bihar	Rice-rice, rice-chickpea, rice-oilseed, rice-potato, rice-pulse, rice-fallow
Karnataka	Rice-rice, rice-groundnut, rice-pulse, rice-fallow
Madhya Pradesh/Chhattisgarh	Rice-millet, rice-oilseed, rice-pulse, rice-wheat, rice-fallow
Odisha	Rice-rice, rice-groundnut, rice-pulse, rice-vegetable, rice-fallow,
Tamil Nadu	Rice-rice, rice-rice-groundnut, rice-pulse, rice-sorghum, rice-vegetable, rice-fibre crop, rice-groundnut, rice-sugarcane, rice-fallow, rice-rice-fallow
Uttar Pradesh	Rice-oilseed, rice-potato, Rice-potato-mungbean, rice-lentil/chickpea, rice-vegetable, rice-wheat, Maize/bajra-chickpea, pigeonpea-wheat, fallow-chickpea, rice-fallow
West Bengal	Rice-rice, rice-oilseed-rice, rice-pulse rice-potato, rice-lentil/chickpea, rice-vegetable, rice-wheat, rice-sunhemp, rice-vegetable-sunhemp, rice-potato, rice-fallow
Eastern states	Rice-groundnut, rice-millet, rice-pulse, rice-sorghum, rice-oilseeds, rice-fallow

in rice fallow regions that can be considered before finalization of strategies for promotion of pulses in these regions. In this paper following five approaches are highlighted to increase productivity of pulses in rice fallow-

3.1 Resource conservation technology (RCT)

Abiotic stress is the prime factor hindering pulses production in rice fallows in which more than 50% of problems are due to degraded puddle rice soil, soil compaction and soil hardiness. RCT which deals with soil moisture conservation, organic matter build-up, improvement in soil structure and microbial population could be an appropriate approach to address these problems in rice fallow. Therefore, if crop residues are retained on the soil surface in combination with suitable planting techniques (zero-till planting or paira cropping), it may alleviate terminal drought condition in pulses by conserving soil moisture and bring overall improvement in resource management (Kumar *et al.* 2013). Minimum soil traffic by adoption of suitable technology involving no-tillage and minimum soil disturbance and management of crop residues (conservation tillage) could lead to favourable effect on soil properties that further enhance the overall resource use and production capacity of pulses in rice fallow (Kumar *et al.* 2015).

Conservation tillage with proper crop residue management is found to reduce soil water evaporation, soil sealing and crusting (Gangwar *et al.* 2006; Kumar *et al.* 2013; Meelu *et al.* 1994; Verma and Bhagat 1992). It is also evident that hydraulic conductivity under straw-retained under zero-till drill is up to 4 times greater than that of straw-burnt conventional tillage (Chan and Heenan 1993). In fact higher yield of pulse after wet season (rainy season) rice with reduced tillage was also reported by Pratibha *et al.* (1996) and Mahata *et al.* (1992) from the rainfed areas of eastern India. This will also reduce cost of cultivation through savings in labour, time and farm power, and improve input-use efficiency. In north-eastern hill (NEH) region of the country, during *rabi* season due to excess moisture owing to seepage from surrounding hillocks in rice fallow, the productivity of pulses remain very low. Simply field drainage in such situation may improve pulses productivity and consequently bring substantial area under pulse production. Two basic principles of RCTs viz., no-tillage and retention of crop residue on soil surface are already followed under relay (*paira*) system of production. Under this system seeds of pulses (lentil, lathyrus and urdbean) are broadcasted in standing rice field without any tillage (Figure 1). Further, 20-30% rice residue as stubbles are

Fig 1. Pulse seed broadcasting in rice before harvest

Fig 2. Urdbean crop in stubbles

retained in the field (Figure 2). Under other system where pulses are sown after harvest of rice with land preparation, zero-till seeding may be advocated as it facilitates advance planting by 7 to 10 days and saves energy and labour.

3.2 Varietal approach

- Early to medium duration varieties of rice needs to be introduced to enable farmers to grow pulses on residual soil moisture in time.
- Depending upon winter temperature, soil texture and soil moisture, selection of pulse crop should be made. In rice fallows, small seeded varieties perform better than large seeded due to better contact with soil, less rotting and thus better plant stand. In central region, small seeded chickpea may be introduced although lentil has an edge over chickpea. Lathyrus is most versatile and

hardy crop being ideal both for north-east and central zone but due to its ODAP content and consequent ban on its trade; it is being replaced by lentil. However, the newly developed lathyrus varieties 'Ratan', 'Parteek' and 'Mahateora' have low ODAP content and suitable for rice fallows. In coastal region, powdery mildew is a fatal disease in urdbean and mungbean which was restricted by developing resistant varieties like 'LBG 17', 'LBG 602', 'LBG 623' of urdbean and 'Pusa 9072', 'NARM -1', 'NARM-18'. 'LBG 17' was the first powdery mildew resistant urdbean variety with yield potential of 1.5 t/ha revolutionized *rabi* urdbean cultivation in rice fallow of coastal peninsula (Satyanarayana et al. 1997). Small seeded lentil varieties 'WBL 77', 'KLS 218', 'NM 1', and 'DPL 15' having resistance to rust are performing well in NEH.

- Introduction of fast growing, early high biomass accumulation and early maturing type pulse genotypes for proper utilization of residual soil moisture and escaping of terminal drought. Apart from these, availability of quality seeds is to be ensured on time.

3.3 *Production technology*

- Timely sowing of short duration rice followed by short duration pulses in rice-fallow need to be ensured for successful crop of pulses. Intercropping of pulses with competitive crops like oilseeds or sorghum can also be followed for risk minimization and income augmentation (Sarkar and Chakraborty 2000; Sarkar and Sanyal 2000).
- In rice fallow, generally no manure/fertilizer is applied due to no-tillage under relay planting and consequently pulse crop face nutrient stress. The physical condition of soil and rhizobial population is poor due to anaerobic condition under transplanted rice and consequently nutrient mobilization is also reduced. Site-specific application of required amount of organic matter to rice in any form (FYM/green manure/crop residue incorporation/Azolla) is must to improve the deteriorated soil structure in puddled rice soil (Kumar *et al.* 2014). Once the soil structure is improved, it will take care of water holding capacity, availability of nutrient and carry over soil moisture to enhance the activity of native rhizobium and productivity of pulse crops. In fact, fertilizer scheduling in rice will be on IPNS mode to benefit succeeding pulses. Pulses grown in rice fallow may or may not respond to direct application of rhizobium/PSB, however, the residual effect of organic matter may influence the activity of these organisms.
- Apart from addition of organic manures rice cultivation methods like direct seeding and unpuddle transplanting can be practice to avoid ill effects of puddling to next crop.
- Over-night soaking of seeds referred as seed priming hastens seed germination and establishment under relay cropping. Since all broadcasted seeds do not establish good contact with soil, the seed germination is low and therefore 20-25 per cent higher seed rate is recommended to ensure desired plant population to achieve higher yield. Site-specific technologies that help in seed germination in the low soil moisture regime should be promoted. For example, in acid soil, application of lime and seed priming with Mo will be effective while in calcareous soil, application of pyrite and seed priming with water/ KNO_3 will be effective.
- To utilize residual soil moisture in rice fallow, pulses need to be sown immediately after harvest with zero-till drill. Thus, there is a need of specific farm implements for zero till drill in different growing situations of rice fallow. In rice fallow (optimal or sub-optimal soil moisture at rice harvest), exiting farm machinery like roto-till drill/ strip-till drill with some modification like attachment of straw cutting and chopping will be effective. In relay cropping (optimal or sub-optimal soil moisture at rice harvest), the existing practice of broadcasting of seeds before rice harvest causes low plant establishment. Some improvement like harvesting of rice and sowing of pulse crop simultaneously (seed metering and dropping at proper depth) in the existing paddy harvester will ensure line sowing, proper seed-soil contact and desired plant population of pulse crop.
- In lowland rice with excess soil moisture at rice harvest, the sub-surface (deep) channel or mole drainage system at definite interval (3-4 m) will be useful depending upon soil type and field slope to drain excess soil moisture for timely sowing.
- At least 30% rice residue should be retained on soil surface in rice fallow to maintain soil-plant water balance during terminal soil moisture stress.

- Since application of fertilizers under relay cropping is not feasible, seed pelleting and foliar application of nutrients should be practiced. A large numbers of front line demonstrations under All India Coordinated Research Project (AICRP) showed that foliar application of 2 per cent urea/ DAP at flowering and pod formation significantly improved yields of mungbean, urdbean and lentil under rainfed conditions by increasing leaf N content making them photosynthetically more active (Ali and Kumar 2009). Seed pelleting with micronutrients like Zn and Mo is also recommended.
- Most of the rice fallow soils examined were low in N, P, B, Mo and Zn and native rhizobia. As pulses are very much responsive to micronutrient application specially Zn, Fe, B and Mo, supplementary application of micronutrient is necessary in rice fallow for optimizing the pulse production.
- Due to anaerobic condition in puddle transplanted rice, population of aerobic microorganism like rhizobium reduced drastically. Thus, for enhancing nodulation in pulses seed should be treated with appropriate rhizobium.
- Pelleting of seeds with super phosphate, rhizobum culture and plant protection chemicals has been reported to improve establishment, nodulation and grain yield in multi-location trials conducted under the AICRP in different parts the country. Molybdenum application through seed priming (0.5-4.0 g sodium molybdate kg seed^{-1} or litre water^{-1}) increases nodulation up to 90 per cent and grain yield up to 30 per cent and is as good as soil application in increasing yield (Das *et al.* 2012a; Farooq *et al.* 2012; Johansen *et al.* 2007; Khanal *et al.* 2005; Kumar Rao *et al.* 2004). The main advantages of Mo application through seed priming are ease of application, uniform application and cost saving.
- Introducing sprinkler irrigation system on subsidy basis to provide life saving irrigation from stored water in farm ponds can be promoted to minimize losses against terminal moisture stress.
- Farm implements for weeding at suitable inter-row distance are needed. Alternatively, pendimethalin 1.25 kg ha^{-1} as preemergence will be used along with cultural or postemergence herbicides (imazethapyr or quizalofop-ethyl) as weed management strategy (Kumar and Hazra 2012). Ratooning in rice is another big threat which also competes with pulses for residual soil moisture. Thus, postemergence herbicides like quizalofop-ethyl 0.1 kg ha^{-1} can be used to contain the re-growth of rice stubbles (Figure 3) in relay or zero-till drill pulse crops after rice harvest (Kumar *et al.* 2013a).

Fig 3. Rotooning in rice

- Wherever other competitive crops like linseed, sorghum and maize are in place in rice fallow, intercropping of these crops with pulses can be open up an another opportunity to harvest more crop per unit area and time.

3.4 *Plant protection technology*

- The major diseases prevalent in chickpea are wilt, root rot and color rot; lentil- stem phytophthora blight, rust, wilt and mungbean and urdbean are MYMV and powdery mildew, whereas major insects are *Helicoverpa* and cut worm in chickpea, aphids in lentil, sucking pest in mungbean. Thus, need based location specific management (based on available resources) of these pests may be adopted.
- To prevent the spread of soil and seed borne diseases, seed treatment with fungicide / biocontrol agent is to be promoted (Bavistin 2 g kg^{-1} of seed or *Trichoderma viride* 4 g kg^{-1} of seed).
- IPM modules which include bird perches, spray of NPV, chemical and botanical pesticides at ETL can be effective for *Helicoverpa* management.
- Wilt resistant genotypes in chickpea and rust resistant in lentil should be promoted in eastern (Uttar Pradesh, Bihar, Jharkhand, Assam and

West Bengal) and central (Madhya Pradesh and Chhattisgarh) India.

- Resistant varieties of MYMV and powdery mildew in mungbean and urdbean should be promoted in the southern part of country (Andhra Pradesh, Tamil Nadu, Karnataka and Odisha).
- Low cost botanical formulations to control diseases and insect pest will be promoted.

3.5 Knowledge dissemination

- Farmers would require considerable amount of information particularly in the initial stages of introduction of *rabi* crops in the rice fallow. This can be achieved either by strengthening the existing technology transfer system or evolving innovative mechanism for effective transfer of technology and information.
- There is need of strong interface between researchers, extension system and farmers for participatory research in diverse agro-ecological regions of rice fallow.
- Training, field days etc. can be conducted for fast dissemination of knowledge.
- Mass and print media may be used under awareness programme.

4. CONCLUSION

The projected pulse requirement for the year 2030 is 32.0 million tonnes with an anticipated growth rate of 4.2%. India has to produce not only enough pulses but also remain competitive to protect the indigenous pulse production. In view of this, there is need to develop and adapt progressively more productive and efficient technology along with favorable development policies to encourage farmers to bring more area under pulses. The knowledge and research gaps need to be identified for pulses production in rice fallow. Research should focus on evolving short duration drought escaping varieties of pulses ad promoting short duration varieties of rice to facilitate early sowing of pulses in rice fallow for maximizing the use of residual soil moisture, technologies that help seed germination in low soil moisture regime under surface or zero-till drill seeding and soil moisture conservation technologies. Development and promotion of moisture conservation technologies to facilitate growing of pulse crops in hostile environment of rice fallow can meet the growing demand of pulses in the country. Simultaneously, the extension system needs to be strengthened to sensitize the farming community through demonstration and other means of transfer of technology. Thus, introduction of pulses in rice fallow with appropriate production technology may usher in another green revolution in the backward, poverty-ridden and deprived region of the country.

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