Indian J. Genet., 76(4): 388-398 (2016)
DOI: 10.5958/0975-6906.2016.00058.4

Utilizing untapped potential of rice fallow of East and North-east India through pulse production

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(Received: October 2016; Revised: November 2016; Accepted: November 2016)

Abstract

Rainfed areas of the country- characterized by its complex nature, diverse and fragile ecosystem and distress prone production system - play a key role in country's food production and economy. It is estimated that about 11.695 m ha in India remains fallow after rice harvest, of which around 82% lies in the Eastern India and the rest falls in three southern states *viz*., Tamil Nadu, Karnataka and Andhra Pradesh. These areas have a vast potential to cultivate low input and low water requiring upland pulse crops (such as lentil, chickpea, lathyrus, mungbean and urdbean). However, depletion of soil moisture content following rice harvest affects timely sowing and receiving in of poor returns out of these ecosystems. Lack of life saving/supplementary irrigation at critical stages causes further soil moisture scarcity and hampers plant growth and crop productivity *per se*. Conservation agriculture through zero tillage, crop residue retention and crop rotation involving suitable genotypes influence pulses crop in rotation after rice. Two cropping systems *viz*., relay cropping of pulses in standing rice, and crop rotation after harvest of rice have potential for popularization and adoption depending on agro-ecosystem involved. Yet, these constrained areas require an understanding of ecology, constraints analysis and situation specific remedies. Keeping these facts, some potential management considerations involving suitable pulses varieties, zero tillage, relay cropping, residue retention, mulching, seed priming, life saving irrigations and foliar sprays of nutrients were suggested that could help in improving pulses productivity under challenging rice fallow conditions.

Key words: Conservation agriculture, pulses, RCT, relay cropping, rice fallow, RUE, SWOT analysis

Introduction

Rainfed agro-ecologies in India contribute around 65% of the net sown area, 100% of the forest, 66% of the livestock and provide livelihood, income, employment and environmental security. About 84-87% of pulses/ minor millets, 80% of horticultural crops, 77% of oilseeds, 66% of cotton and 50% of cereals are cultivated under un-irrigated condition in the country. Thus, rainfed agro-ecologies are playing a major role in our food production and national economy. However, rainfed areas are characterized by its peculiarities such as complex nature, diverse and fragile ecosystem, under-invested, risky, ethno-economically unique and distress prone production system. A majority of this area (about 11.695 m ha) remains fallow after rice harvest, of which around 82% lies in the states like, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, West Bengal and North Eastern Hill states, and the remaining area falls in three southern states (Tamil Nadu, Karnataka and Andhra Pradesh). There exists a vast scope for expansion of these areas (rice fallows) under low input and low water requiring upland pulse crops. Pulses like, lentil and chickpea are the most candidate crops for these regions (Anon. 2013). There are a number of factors including protection from stray animals especially during rabi season which, in fact, lead to low adoption of pulses by the farmers. Here, receding moisture content in the soil profile after rice harvest could limit sowing of succeeding crops as these areas virtually ended up with drying, while some low-laying areas were still so wet that these areas could not be taken up for sowing immediately resulting in delayed sowing. Secondly, in absence of reliable source of irrigation (due to lack of tubewells, water harvesting structures including farm ponds), life saving irrigation could not be possible (Praharaj et al.

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Published by the Indian Society of Genetics & Plant Breeding, F2, First Floor, NASC Complex, PB#11312, IARI, New Delhi 110 012
Online management by indianjournals.com; http://epubs.icar.org.in/journal/index.php/IJGPB

2016a, b). Another important consideration is poor plant stand in rice fallows resulting in poor crop establishment, and above all, pitiable management of crop affects both biomass production and grain yield. These reasons could end up in realizing low crop yield and sometimes, returns were uneconomical as well and hence, low coverage of crops in rice fallows. Research evidence suggests that the crop residue retention/incorporation has favourable effect on soil properties (Praharaj et al. 2014; Praharaj 2014). Thus, resource conservation technology (RCT) dealing with conservation of soil moisture, build up of organic matter and improvement in both soil structure and microbial population could be an appropriate approach to address these problems (Praharaj 2013, 2014). In addition, if crop residues are retained on the soil surface in combination with suitable planting techniques, it may possibly alleviate terminal drought condition in pulses by conserving soil moisture and bring overall improvement in resource use and its optimum management. Hence, minimum soil traffic by adoption of appropriate technology involving no-tillage and management of crop residues could lead to favourable effect on soil microbiological properties that would further enhance the overall resource use efficiency (RUE) and productivity capacity of rice-fallows. Alternatively, wherever possible, suitable relay cropping practices could be taken up before harvesting of rice crop so as to avoid rapidly receding soil moisture (in standing rice crop until harvest). Here, suitable varieties, improved and efficient crop and weed management practices need to be followed for better management of rice fallows. This will in turn reduce cost of cultivation through savings in resources (like, labour, time and farm power) and improve input-use efficiency thereby making cultivation of rice fallows the most remunerative (the constraints/SWOT analysis of rice fallow is given in Table 1 and the rice fallow areas distributed over India are depicted in Fig. 1). Visualizing the potential of rice fallow in relation to productivity of crops, introduction of pulses in rice fallows with appropriate technologies may usher in pulses revolution in the time to come.

Non-availability of quality seed of recommended and improved varieties is yet another constraint so as to have a good crop under rice fallows. Farmer saved seed is generally low in both seed viability & vigour due to improper storage conditions like, high relative humidity and infestation by storage pests that results in poor germination, plant establishment and seedling vigour following sowing. Thus, there is a need to have strong locally seed production back up through large scale screening of appropriate varieties, establishment

Table 1. SWOT analysis of rice fallow areas in India

Description	Characteristics
Strengths	Huge rice fallow acreage (> 11.7 m ha) Adequacy in availability of cheap labour Possibility of higher yield realization and untapped yield potential of major pulses Feasibility and viability in growing pulses (technical & socio-economic considerations) Unexplored and unexploited soil fertility for successful crop husbandry High rainfall areas to conserve the water for irrigation
Weaknesses	Unavailability of quality seeds (replacement of seed/variety) Low mechanisation Unavailability of irrigation Acute abiotic stress (mid- & late season drought or popularly called, terminal drought besides soil constraints) Surplus marketable produce (usually low) Incidence of biotic stresses (pests & diseases) and awareness towards diagnosis and control Scattered land holding
Opportunities	Strong motivation of farmers to grow pulses and other low input but remunerative crops Augmentation in farm income Generation of additional employment Rising demand of pulses *vis-a-vis* other protein sources Possibility of reduction in import of pulses (import substitution)
Threats	Greater instability in production and productivity Unstable price risk (Market considerations) Differential zone/state/local (consumer) preferences (both towards cultivation and consumption of pulses)

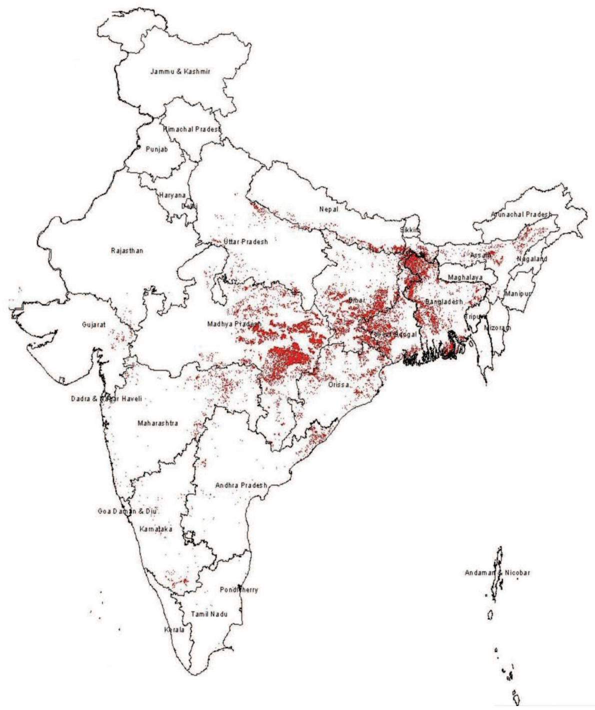


Fig. 1. Rice fallows in India, Source: Subbarao et al. (2001)

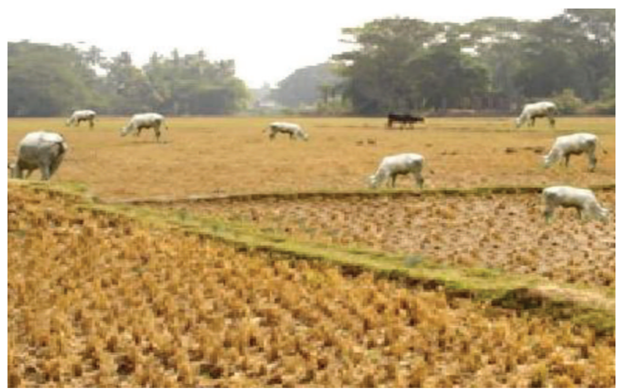
of seed chain (seed village, seed block and seed hub etc.,) and development of appropriate storage techniques/structures for seeds especially under high relative humidity condition (e.g. coastal belt of India).

Increase in pulse productivity is relatively low and unstable over the years; and is primarily attributed to several biotic and abiotic factors. Thus, measures resulting in horizontal expansion through crop diversification, intensification, crop substitution and introducing pulses in new niches like, rice fallows (with an estimated area of 11.695 m ha) have tremendous scope for realization of higher production and productivity so as to make the country self-reliant in pulses availability (Gumma et al. 2016). All this is possible through a suitable integration or synergy of appropriate technologies, particularly seed treatment with rhizobium and biocontrol agents for better initial establishment of crop besides other needful technological interventions. Therefore, sustainable intensification of existing crops/cropping systems (Yadav and Subbarao, 2001), especially of rice fallows, with low input requiring pulses, is the pre-requisite for meeting the projected demand of pulses in the country (22 million tonnes by 2020).

Scope

Rice fallows basically imply to those rainy season (June-September) sown rice areas which remains fallow during succeeding winter due to various underneath and complex factors. (A typical rice fallow land is depicted in Fig. 2). These include lack of irrigation, early withdrawal of monsoonal rains leading to soil moisture stress at planting time of winter crops, water logging and/or excessive moisture during November/December (due to winter rains following climate change), lack of appropriate varieties of winter crops for late planting, cultivation of long duration rice varieties in mono-cropping system, and socio-economic problems like, stray cattle, blue bulls etc.

(A)



(B)

Fig. 2. (A) Typical rice fallow land in eastern India; (B) Depiction of unhindered cattle grazing

Rice-fallow is a typical mono-crop rice based system existing in India since a long time. These areas are mainly concentrated (Table 2) in eastern (6.03 m ha) and central (5.09 m ha) India; while its areas in southern parts of the country is considerably low (0.51 m ha). Productivity of crops in rice fallows is quite low due to moisture stress during crop season, terminal drought, poor plant stand, poor quality seeds of improved varieties, weed menace, poor crop

Table 2. The extent of rice fallow areas in India

State	*Kharif* rice area(m ha)	*Rabi* fallow (m ha)
MP + Chhattisgarh	5.60	4.38
Bihar + Jharkhand	5.97	2.20
West Bengal	4.62	1.72
Orissa	3.88	1.22
Maharashtra	1.76	0.63
Assam	2.23	0.54
UP	6.26	0.35
AP	2.66	0.31
Others	7.20	0.30
Total	40.18	11.65

Source: Subbarao et al. (2001) and later on, rice fallow areas was revised to 11.695 m ha in India (Gumma et al. 2016)

management practices and biotic stresses.

Among the candidate crops for the rice fallows, lathyrus, lentil, urdbean, mungbean and peas, requiring low input, hold the most favoured alternative for intensification of rice-fallow production system. In India, these crops occupy a few million hectares (>1.0 m ha) under rice fallows, and have prospects for further expansion (to 3-4 m ha) with strategic crop management and technological interventions. Through innovative resource conservation practices, abiotic stresses under rice fallow conditions can be adequately mitigated and thus, resource-use efficiency (RUE) in pulses in rice fallows can be enhanced. However, working in these constrained areas needs a detailed understanding of the rice-fallow ecology, location specific constraints analysis and remedies applicable to specific situation. Keeping these in consideration, therefore, some potential management strategies could help in improving pulse productivity under challenging rice fallow conditions.

Holistic crop management strategies involving zero tillage, relay cropping, residue retention, mulching, seed priming, farm pond establishment, shallow dug wells, electricity, diesel pumpsets for life saving irrigation (Praharaj et al. 2016 a,b) and micronutrient application, can substantially improve the survival of pulses and its performance in rice-fallows. Small but viable *in situ* technologies for example, retention of 20-30 cm rice stubbles could maintain/conserve *in situ* soil moisture for longer time over residue removal (Bandyopadhyaya et al. 2016). Similarly, spraying of herbicide (Quizalofop-p-ethyl @ 100g/ha) to check stubble regeneration or sprouting could help further in conservation of soil moisture for longer time (Anon. 2013).

Classification of rice fallows

In India, rice is cultivated across the length and width of the country occupying about 43.38 million hectares area with production and productivity of 104.31 m t and 2404 kg/ha, respectively (Anon. 2013, 2015). Grown under both agro-ecological conditions of irrigated and rainfed areas in the country, the crop is subjected to different crop duration with variable productivity levels. Again, poor yields of mainly *kharif* rice are due to many constraints right from water availability during crop growth to production/protection constraints that involve both mitigating abiotic and biotic stresses. Nevertheless, since the crop is mostly transplanted under puddled conditions, the yield levels are fairly good provided other serious constraints are not becoming limiting. The major hitch starts only after rice cultivation as about 30% of the area under rice production during *kharif* in India remains fallow in the subsequent *rabi* due to number of biotic, abiotic and socioeconomic constrains. On the basis of soil and agro-climatic conditions, rice fallows may be classified into 4 sub-groups *viz*., rice fallows of northeast region, central region, coastal peninsula and north east hill region.

Northeast region

The agro-climate of the region is characterized by hot dry sub-humid climate with hot summers and cool winters. The area receives mean annual rainfall of 1200-1500 mm with increasing intensities towards eastern side. The region comprises eastern Uttar Pradesh, Bihar, Jharkhand, Odisha and West Bengal. This region is constrained on many accounts so far as profitable crop production in these areas is concerned. Here, soils are deep alluvial and calcareous in nature. Soils are generally deficient in organic carbon (OC), P and Zn. Excessive moisture or water logging is common in low lands during the start of winter (October/November). Winter is severe and stray cattle after harvest of rice are serious threat to the next crop in rotation. The length of growing season (LGS) ranges between 180-210 days in northern part while eastern and far eastern part have 240 days. Traditionally, lentil and lathyrus are grown after rice under relay (paira) cropping except in Odisha (grown with blackgram and horsegram due to high humidity) where mungbean performs well due to mild winter. In addition, the small seeded varieties of lentil, mungbean, urdbean, lathyrus and peas may find prominence under utera (relay) cultivation in states of Chattisgarh, Jharkhand, Bihar and West Bengal. The region offers great scope for utilizing some of the fallows for pulse production.

Central region

This is transition between hot dry sub-humid and moist humid, with dry summers and cool winters. The region covers Chhattisgarh, Madhya Pradesh and Maharashtra which receives around 1000-1200 mm of rainfall. Soils are generally clayey (*vertisols*) which become hard and develop deep cracks on drying and poor in soil nutrients. Early withdrawal of rains and soil moisture stress is observed at planting of winter crops. In standing rice fields, seeds of lathyrus and lentil are traditionally broadcasted. Here, winter is mild to severe.

Coastal peninsula

This is characterized by dry sub-humid with hot summers and very mild winters. Coastal areas of Andhra Pradesh, Tamil Nadu and Karnataka are covered under this region. The mean annual rainfall ranges from 1000-1200 mm with soils are deep and clayey. Excessive soil moisture and mild winter are the main characteristics of the region favouring in urdbean and mungbean cultivation. The region receives bi-modal rains.

Northeastern hills (NEH Region)

The agro-climate of the region is characterized by humid ecosystem with hot summers and cool winters. The area receives mean annual rainfall of 1600-2000 mm in Central Brahmaputra valley. The region comprises NEH states including Assam. So far as NEH states is concerned, shrinkage in land holding, rising population pressure and increasing food/pulse demand and above all, poor soil health are the key impediments for enhancing pulses productivity and production in this region. Thus, there was a relatively lower growth in production of pulses in NEH region due to many underlying intricate issues right from soil/ climate related constraints to technological and extension oriented tribulations. Poor soil health due to acidic pH (high rainfall causing leaching of most of the cations), aluminum toxicity, undulated topography and sloppy terrains often leads to unfavourable microclimate hampering adequate growth and development in upland crops especially pulses. In addition, the small seeded varieties of lentil, urdbean and peas may find prominence under utera (relay) cultivation in states of Assam and other NEH states (Anon. 2016).

Agroecology and production constraints

Production constraints in rice fallows are many (Pande et al. 2012). As a result of deterioration in soil structure and other management issues in such soils, pulses productivity in rice fallows is generally poor. Both soil and water are the two major limiting factors that have a bearing on stagnated pulse production in rice fallows over the years. Soil moisture is the most critical constraint for cultivating *rabi* crops in rice fallow areas. Growing of *rabi* pulses solely depends upon the availability of soil moisture in the field after rice harvest. After harvesting of rice crop low moisture content in the soil followed by fast decline in water table with the advancement of *rabi* season results in mid-and-terminal drought at flowering and pod filling stages which adversely affects the productivity of pulses in rice fallows. A typical drying pattern in such soils is given in Fig. 3. Terminal drought and heat stress could result in forced maturity and reduced grain yield by 50% in

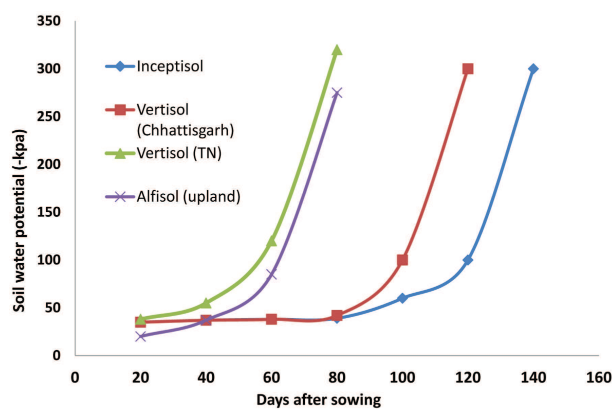


Fig. 3. Typical drying pattern in different rice fallow situations (Source: Anon. 2014) (Inceptisol in West Bengal and Uttar Pradesh; Alfisol in NEH region)

the tropics. This is more acute in absence of rainfall during *fall* or winter (Ali et al. 2014).

Besides the inherent constraints, other important attributes that affect rice fallow production including seed germination, seedling emergence and crop establishment involves disruption of soil structure, soil water deficit, poor aeration and mechanical impedance of the seed zone. In majority of soils, soil hardiness is the most limiting factor. Soil hardiness in the puddled rice fields deteriorates the hydraulic properties of the soil, which negatively affects the soil moisture distribution and root growth of deep rooted pulses (Ali et al. 2014). 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 and thus, sub-soil resources in rice fallows remain unutilized. Soil hardiness combined with low soil organic matter content as in most tropics and subtropics adds to the problem hampering suitability of such soils to profitable cultivation.

Two systems *(relay crop* or *crop rotation*) are mostly practiced in such soils. Pulses on account of low input requirements, short duration, ability to establish with surface broadcast in standing rice fields (relay cropping) and soil fertility restoration property are ideal for rice fallows (Anon. 2016). Traditionally, lathyrus and lentil are sown after rice under relay cropping in low land rice fields of Bihar, eastern U.P. and Chhattisgarh, and urdbean/mungbean in coastal peninsula (Ali et al. 2014). Under relay (paira) cropping, the situation is different from that of discrete crop rotation. In the former where there is no time lag while in the latter time lag often does more harm than good. Plant population in case of former is often low due low seed rates, poor contact of seed with soil, seed rotting as well as dryness of soil in patches. The system becomes more amenable to weed growth and crop loss due to it. Because of little or no land preparation, weeds do come and hand weeding is practically impossible in standing rice and even after rice harvest due to drudgery or difficulties in such operation (Satyanarayana et al. 1997). Other obnoxious weeds such as *Cuscuta* -a parasitic weed- is also associated with pulses (urdbean/mungbean) in such situations.

In case of latter (crop rotation), ploughing is followed just after harvest of rice to remove stubbles thereby sowing of *rabi* pulses are often delayed and germination will also be affected due to formation of large size clods. This is again followed by rapid evaporation of moisture from surface soils resulting in water stress at later growth stages of pulses (chickpea, lentil and blackgram etc.). Besides these, soil acidity (eastern India and NEH region) and alkalinity (and/or salinity as in lower and middle Gangetic plain) puts forth unfavourable soil reaction that leads to restricting or excess availability of certain nutrient in such soil in comparison to neutral soils. This unfavorable soil reaction restricts the growth of the crop further due to alteration in dynamics of availability of nutrients, microbial activity and other imbalance made in the rhizospheric environment of crop and beyond.

Due to anaerobic conditions in rice cultivation, many of the beneficial microbial organisms including rhizobia could not survive and their population goes on decline resulting in low efficiency and fixation through biological N fixation (BNF). Pulses do experience high incidence of insect pests and diseases especially under the prevailing situations of rice fallow condition as these situation are not considered as normal (soil-plant-atmospheric). For example, *Helicoverpa* is reported to be a potentially severe pest/ problem in chickpea under eastern states viz., Chattisgarh, Jharkhand and Madhya Pradesh. Diseases including root-knot nematodes are also observed as a severe problem. Besides this, powdery mildew is a serious disease of *rabi* planted urdbean and mungbean; while rust and *Fusarium* wilt are common in lentil.

"To sum up on production constraints in rice fallow under existing ecology, lack of varieties, poor plant stand, weed menace, less or no use of fertilizers and terminal moisture stress pose limitation to optimum performance by the crop. Besides this, prevalence of some diseases (like, powdery mildew in urdbean and mungbean, rust and fusarium wilt in lentil, and Botrytis grey mold and colar rot in chickpea) cause yield losses in east and northeast India. Other constraints include delayed planting, poor crop husbandry practices and socio economic issues prevailing in the region."

Utilizing untapped potential of rice fallow

Improved agronomic technologies or technological interventions could possibly help in utilizing untapped potential of rice fallow. Resource conservation through use of its technology (RCT) could render higher soil moisture conservation, organic matter build-up and improvement in both soil structure and microbial population in these stressed soils. Crop cover, if retained on the soil surface in combination with suitable planting techniques, could alleviate terminal drought condition in pulses by conserving soil moisture and bring overall improvement in resource management. This in combination with minimum soil traffic (no-tillage and minimum soil disturbance) could lead to favourable effects on soil properties that further enhance the overall resource enhancement and productivity capacity in rice-fallows. This will enable reduction in cost of cultivation by resource savings (in terms of labour, time and farm power) besides enhancing input-use efficiency and farm income.

In case of NEH region of the country during *rabi* season due to excess moisture owing to seepage from surrounding hillocks in rice fallows, the productivity of pulses remains very low. Here, field drainage could improve pulse productivity and bring substantial area under pulse production. Three resource conservation components (reduced tillage, use of soil cover and crop rotation that includes efficient weed control practices) could render better crop growth and realization of higher yield. Under paira (utera) system of production, two approaches of RCTs viz. reduced or no-tillage and retention of crop residue on soil surface are now in vogue. Seeds of pulses are broadcasted in standing rice field without any tillage. Further, 20-25% crop residue as stubbles are retained in the field. Under other (rotational) system where pulse is sown after harvest of rice with land preparation, zero till seeding may be advocated as it facilitates advance planting by a week, saves energy and labour. Zero till planting has also been popularized recently in chickpea and lentil in eastern Uttar Pradesh.

Concerted efforts have since been made to address the productivity issues of rice fallow system through screening suitable varieties, adoption of appropriate planting methods, foliar nutrition and adequate crop production/protection practices. Therefore, rice fallow initiative builds on past successes, refining and packaging improved technologies to address different problems (Anon. 2013). The details of technological interventions are given herein as under for enhancing productivity of pulses in rice fallow.

Choice of appropriate crops/varieties

It all depends upon *fall* temperature, soil texture and soil moisture. In eastern plains, small seeded lentil varieties such as WBL 77, KLS 218, NM1, and DPL 15 with resistance to rust perform well. Chickpea varieties viz., Pusa 372, PG 186, and Udai are recommended for this region. The newly developed lathyrus varieties Ratan, Parteek, Mahateora have low ODAP content and suitable for rice fallows. Here also, small seeded varieties perform better than large seeded due to better contact with soil, less rotting and thus, better plant stand. These interventions are now found prominence in Chhattisgarh, Jharkhand, Bihar, West Bengal and Assam. This in fact, can be reinforced with short duration and HYVs of rice that could vacate the field at the best by the end of October. In low land situation, lentil is more suitable over chickpea. Because of short duration, crop hardiness and low water requirement, lentil could be preferred over chickpea. Therefore, rice-lentil could be made more popular (with stable yields) in the lowland of Eastern Uttar Pradesh, Bihar, Jharkhand and West Bengal. In coastal region due to higher relative humidity and warm condition, powdery mildew could also be severe. It had been a deadly disease in urdbean and mungbean which had been known to restrict its spread until the development of powdery mildew resistant varieties like, LBG 17, LBG 602 and LBG 623 of urdbean; and those of mungbean *viz*., Pusa 9072, NARM-1, NARM-2 and NARM-18. LBG 17, the first powdery mildew resistant variety with yield potential of 1.5 t/ha, has revolutionized *rabi* urdbean cultivation in rice fallows of coastal peninsula (Anon. 2013).

In a latest programme on *promotion of pulses in NEH region*, a two-years (2014-16) study on varietal screening revealed that chickpea, IPC 97-67 and PUSA 372; lentil, DPL 62; fieldpea, AMAN at most of the locations while TRCP 9 at Assam and Tripura locations, and mungbean, HUM 12 and IPM 2-14 were promising and needs to be promoted under NEH conditions (Anon. 2016).

Introducing short duration varieties of pulses

These are important in the context of escape mechanism for terminal moisture and heat stress. Relevant traits of a particular crop have to be identified for a successful breeding programme. Making availability of good quality seeds with >90% germination is a must. There is need to introduce fast growing and wide canopy coverage type pulse genotypes to minimize evaporation loss from soil surface.

Introducing water efficient genotypes

Some of targeted pulse crops could be screened for introducing the better water efficient varieties amenable to higher yield under drought or stress condition. In pulses, water efficient crop in order of decreasing water requirement is as under: pea > chickpea > lentil > lathyrus, whereas the water requirement of summer mungbean and urdbean are greater than that of peas.

Enhancing seed germination

Priming of desired seed along with optimum seed rate 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% higher seed rate ensures desired plant stand. However, if the seeds are primed - a cost cutting exercise- reduction in seeds rate is there. In priming, pulses seeds are soaked in water ranging from 4-8 hours depending on crop/cultivar.

Pelleting of seeds

The desired agro-chemicals involving with super phosphate, rhizobial culture and plant protection chemicals has been reported to improve establishment, nodulation and grain yield in trials conducted under various AICRP and other net work programmes. However, efficacy and economics of this practice under rice fallow conditions are to be assessed/refined. The pelleting will definitely help the crop to survive better under moisture stress situation like that in rice fallows.

Foliar nutrition

Seed pelleting and foliar application of nutrients are practiced as application of fertilizers under relay cropping is not feasible. A large number of FLDs under AICPIP and other net work programmes showed that foliar application of 2% urea at flowering and pod formation significantly improved yields of mungbean, urdbean and lentil under rainfed conditions by increasing leaf N content which made them photosynthetically more active (Anon. 2008; Ali and Kumar 2009). Seed pelleting with micronutrients like, Zn is also recommended. Now, Mo deficiency is rampant especially in Central India (growing of soybean-wheat without adequate replenishment in nutrient supply to soil) where, soil application (1-1.25 kg ammonium molybdate/ha), foliar application (0.1% Mo) or seed inoculation (1 g Mo/kg of seed) were found to be effective (in case of Mo deficient soils).

Timely planting

In rice fallows, planting is generally delayed. Under relay planting, seeds should be broadcasted 2-5 days (sometimes one week) before harvest of rice. Zero till drill (ZTD) should be used wherever feasible when planting is done after harvest of rice. Timely planting in presence of adequate soil moisture is the key to realize higher productivity potential in pulses. Timely planted crop takes care of residual soil moisture efficiently, and robust root growth of the crop could resist soil moisture stresses that might come in the latter crop growth stages.

Timely plant protection

Post-emergence herbicides are not effective due to inherent low soil moisture content and in fact, are commercially unavailable. Inter-cultivation is again difficult due to hardness of soil. Hence, hand weeding or hand pulling of weeds is only option which should be done at an early stage. Besides control of weeds, insect pests and diseases should also be promptly controlled. Seed dressing with fungicides like, carbendazim should also be made. A better practice of *Tricoderma viridae* at 8-10g/kg seed could effectively protect germinating seeds against rotting or any anticipated damage to young seedling.

Supplementary and life saving irrigation

One of the approaches for effective on-farm management of allocated precious water is the use of single life saving or supplementary irrigation during post rainy or fall months which would possibly sustain productive potential of crop through alleviation of moisture stress. In presence of farm pond or natural reservoir, further saving in water use could also be possible through use drip- and sprinkler irrigation as a water saving measure even under dry and hot summer where both water and fertilizer could be applied precisely to the crop at its pick of demand ensuring direct benefit to plants (Praharaj et al. 2016a). Few agro-technologies could reinforce this by way of technologically up-scaling and/or providing a sound back up for better water delivery and its usage. This includes precision land leveling, no-till systems, FIRB planting systems, crop diversification and its residue management etc which have shown incredible potential for lowering water use and/or increased water productivity (WP) and its use efficiency (WUE). In the era of deficit rainfall/dry or dryland farming further amalgamated with rapid and visible climate change, there is a greater need to apply need based critical inputs at the point of interception to improve resource use efficiency (RUE) along with higher productivity of pulse crops (Praharaj et al. 2016b). Therefore, improved tactical water management in pulses could play a strategic role in sustainable intensification of a given food production systems in India against a backdrop of widespread natural resource degradation/ vagaries of climate (Praharaj et al. 2016a,b).

Wherever other competitive crops like linseed, sesame are in place in rice fallows, intercropping of these crops with pulses with suitable farm implements will open up another opportunity to harvest more crop/ unit area (Praharaj and Blaise 2016). One or two rows of short duration pulses could suitably be included between two wide placed row/strip crops which could provide extra farm income besides acting as biological N fixers. The major consideration for such combination is compatibility between the crops/genotypes in question that could eliminate mutual competition for resources.

Research and developmental needs

Strategic research and developmental efforts are further boon to enhancing productivity in rice fallows. Research is underway to continuously and sustainably screen suitable germplasms to adopt and adapt under a specific agro-ecosystem. For example, high yielding and disease resistant (powdery mildew) varieties of urdbean and mungbean have been developed for coastal peninsula region of the country. Similarly, specific disease endemic areas need immediate attention to curb its further spread. With use of quality seed, quality inputs and quality management, these areas can be exploited to a large extent. Besides these, there are some potential districts as suggested by Ministry of Agriculture (Anon. 2009) where special efforts are needed to bring additional area under cultivation (Table 3). It is expected that if at least 3 m ha of rice fallow could be covered under cultivation, this would provide at least 1.5-2 m tonnes of additional grain production in pulses at the existing productivity level. The R & D issues concerning rice fallows include the implementation of followings achievable recommendations.

Table 3. Some of the potential areas available in different states for cultivation of pulses in rice fallow

State	Potential area (m ha)	Potential districts
Chhattisgarh	0.88	Bilaspur, Dhamtari, Kanker, Jamshedpur, Raipur, Durg, Rajgarh,Kabirdham, Korba, Mahsamud and Rananadgaon
Madhya Pradesh	0.53	Annupur, Chhatarpur,Damoh, Dindori, Raisen, Jabalpur, Katni, Satna, Shahdol, Seoni, Mandla, Narsingpur
Odisha	0.37	Baleshwar, Sundergarh, Mayurbhanj, Kalahandi, Bolangir, Puri, Cuttack
West Bengal	0.52	Bankura, Purulia, Medinapur, West Dinajpur, Malda, Jalpaiguri, Bardhaman
Assam	0.16	Marigaon, Naogaon, Lakhimpur, Kokrajhar, Nalbari, Kamrup, Barpeta, Darrang, Cachar, Goalaghat, Johrat, Tinsukia

Source: Anon. (2013)

Fresh mapping of rice fallows

A consolidated effort is needed involving all the stake holders to delineate areas covered under actual rice fallow for planning and successful utilization of these unutilized areas. The assistances involving satellite imagery and remote sensing tools for fresh mapping is necessary. Satellite and remote sensing tools may be used for this purpose.

Consolidating all R & D activities on rice fallow

Existing research and developmental outcomes needs to be consolidated at farm/village/block/district/agro-ecosystem or state level for successful implementation of future action plans and appropriate modification in existing plans.

Implementation of model pilot projects on holistic basis

Seeing is believing. Therefore, model projects should be organized in farmer's field for convincing and popularizing technologies.

Continual addressing of constraints in rice fallows

Assessing a constraint *in situ*, and addressing it then and there facilitates early adoption and spread of the proven technological interventions. A constant and sustained endeavour in addressing common issues also encourages a greater success.

System mode approach

Adoption of popular and agroecology based farming system involving 2 or more enterprises leads to yield sustainable farm incomes. Animal component in any system is the key to sustainability. Utilization of rice fallows will also lead to saving of 30% crop residues towards feeds.

Large scale mechanization

Large scale mechanization involves use of machines for increasing efficiency and reducing drudgery. Large machines can take up of more areas which can be possible through land consolidation. However, in undulated lands under hilly terrains and in small holdings of marginal and small farmers, there is a need for small equipments (operated under the local condition and) capable of increasing efficiency. These essentially reduce drudgery and increase ease in inputs handling and its application.

Scaling-up and scaling-out crop management practices

Innovative and efficient technologies or best management practices (BMPs) evaluated and refined on farms need to be both up-scaled and out-scaled so as to penetrate in more areas and to more farmers for enhancing total output/efficiency of the system.

Crop specific information on area expansion and related monitoring

Individual crop(s) depending on ecologically efficient zones needs to be expanded precisely. For this, help from modern information tools or GIC maps are very essential for acquiring related information necessary for monitoring/forecasting purpose.

The knowledge and research gaps identified for analysis on pulses production in rice fallows shows the need for concrete action in both short-terms and long-terms. Research also should focus on evolving medium duration drought escaping varieties of pulses and short duration varieties of rice to facilitate early sowing of *rabi* crops on the residual soil moisture. There is continuous need to assess and refine technologies that help in seed germination in low soil moisture regime and appropriate soil moisture conservation technologies. Development and promotion of moisture conservation technologies to facilitate growing of pulse crops in hostile environment of rice fallows is the need of the hour. Simultaneously the other stake holders including an efficient extension system need to be strengthened to sensitize the farming community through demonstration and other means of technology transfer. There is urgent need for creation of basic infrastructures like, approach roads, custom hiring centres for mechanisations, seed go-downs and marketing infrastructure etc. Thus, introduction of pulses in rice fallows with appropriate production technologies may usher in another green revolution in the backward, poverty-ridden and deprived region of the country.

Declaration

The authors declare no conflict of interest.

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