



Rice fallows in the eastern India: Problems and prospects

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ABSTRACT

Rice (*Oryza sativa* L.) is the most important crop during the *kharif* in the Eastern India, covering an area of ~26.8 million ha and accounts for ~63.3% of the total rice acreage. Out of which, ~11.7 million ha area in rice production system remains fallow during the succeeding winter season due to several limitations. Efficient utilization of these fallow lands may improve productivity and sustainability of the regions. Soil properties of the region suggests that short duration pulses, i.e. chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), lathyrus (*Lathyrus sativa*) and oilseeds, viz. safflower (*Carthamus tinctorius*), linseed (*Linum usitatissimum*) and mustard (*Brassica campestris*) can be grown successfully in rice-fallows with supplemented life saving irrigation. Around 3 million ha extra land under pulses and 1 million ha land under oilseeds can be brought in, with suitable policy interventions. If the location specific constraint to produce the crop are alleviated, these unutilized lands might be converted into the productive lands with crop appropriate planning. This review deals with the problems and prospects of the rice-fallows in the eastern India.

Key words: Eastern India, Oilseeds, Pulses, Rice-fallow

Rice-fallow areas are those *kharif* paddy grown areas that were kept fallow in *rabi* season. The main reasons for leaving the lands fallow during the winter season are lack of irrigation, late harvesting of long-duration high yielding rice varieties, moisture stress at sowing during the *Rabi* crops due to early withdrawal of monsoon, waterlogging and excessive moisture in November/December, and nuisance like stray cattle and blue bulls (Ali and Kumar 2009). Rice fallow (~11.7 million ha) is a mono-crop rice-based production system in India and mostly (82%) is concentrated in the eastern states, i.e. Chhattisgarh, Jharkhand, Upper Assam, Bihar, eastern Uttar Pradesh, Odisha and West Bengal (Pande *et al.* 2012a, Kumar *et al.* 2018). Intensification of existing agricultural systems is need of the hour to take care of the rising demand of food grain production in the country (Kumar *et al.* 2016). In this perspective, there is an enormous opportunity to increase the total cropping area through strategic research in rice-fallows (Kar and Kumar 2009). However, including the second crop in rice-fallows is a great challenge as post-rainy season often confront a series of abiotic and biotic stresses (Kumar *et al.* 2018). Fast depletion of the soil-moisture after rice harvest, lack of irrigation facilities, poor access to extra

early-duration varieties of pulses/oilseeds, late harvesting of rice, uncertainty in rainfall event, poor soil structure and problems of stray cattle, are some of the major constraints in cultivation of winter crops in rice-fallows (NAAS 2013, Kumar *et al.* 2018). Thus, it is a great challenge to the researchers, policy maker and stakeholder for extensive use of rice fallow areas in the eastern India.

Climatic variability

Agro-climate condition of the eastern region is categorized by hot-dry, sub-humid with hot summers and cooler winter. Mean annual temperature ranges between 24–26°C. Mean summer (April–June) temperature varies from 29–32°C rising to a maximum of 37–42°C in April/May. Mean winter (December–January/February) temperature varies from 16–18°C and dropping to minimum of 8–10°C. The region receives annual rainfall of 1200–1500 mm and increases towards the eastern side to 1600 mm. *Kharif* season is humid with excess water of 200–300 mm and potential evapo-transpiration (PET) ranges between 1400–1700 mm (Bandopadhyaya *et al.* 2015). Cropping activities start with commencement of rains and it ranges between 180–210 days in the region except more than 240 in West Bengal. Soils of the regions have subterranean, weakly drained and fine loamy in texture.

Distribution of rice fallow areas

As per the recent estimates, ~22.3 m ha of suitable rice-fallow areas exist in the South Asia, with 88.3 % in India, 0.5% in Pakistan, 1.1% in Sri Lanka, 8.7% in Bangladesh, 1.4% in Nepal, and 0.02 % in Bhutan (Gumma *et al.* 2016).

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These fallow areas are suitable for intensification with a short duration (≤ 3 months), low water consuming grain legumes, i.e. chickpea, lentil, blackgram, greengram, and oilseeds, viz. linseed and safflower to improve the smallholder farmer's incomes and the soil health (Fig 1). Rice–fallow areas are extensively spread in rainfed ecology of the regions. Soils are mainly deep alluvial and neutral to acidic in nature. Lentil and lathyrus are mostly grown in *utera* before harvesting of rice for utilization of the residual moistures in Bihar and West Bengal (Gupta and Bhowmick 2005, Rautaray 2008). Major districts falls under rice–fallows in the eastern India are Lakhimpur, Jorhat, Sibsagar, Dibrugarh, Golaghat, Karbi, Nagaon, Maringon (Assam); Kishanganj, Gaya, Aurangabad, Jamui, Nawada, Banka, Katihar, Bhagalpur (Bihar); Ranchi, Purbi/Paschim Singhbhum, Hazaribagh, Gumla, Sahibganj, Deogarh, Palamau, Dumka, Dhanbad (Jharkhand); Surguja, Jashpur, Raigarh, Durg, Bilaspur, Bastar (Chhattisgarh); Koraput, Kalahandi, Sambalpur, Sundergarh, Bhadrak, Cuttack, Puri, Dhenkanal, Mayurbhanj (Odisha); Purulia, Bankura, Birbhum, Bardhaman, Medinipur, Murshidanad, South–24 Parganas, Maldah, West Dinajpur, Coochbihar (West Bengal); Ghazipur, Bhadohi, Maharajganj, Bahraich, Balrampur, Gonda, Siddharthanagar, Mirzapur, Chandauli, Sonbhadra, Lakhimpur Kheri, Pilibhit, Etawah (Eastern Uttar Pradesh) (NAAS 2013, Annual Report DPD 2016–17). As per the estimates of the Expert Group on Pulses, potential pulses area under the rice fallows is 2.46 million ha (Fig 2), which is mainly concentrated in districts of eastern states like Bilaspur, Dhamtari, Kanker, Raipur, Jashpur, Durg, Rajgarh, Kabirdham, Korba, Mahasamund and Rananadgaon (Chhattisgarh); Baleshwar, Dhenkanal, Sundergarh, Mayurbhanj, Kalahandi, Bolangir, Kheonjar, Puri and Cuttack (Odisha); Bankura, Purulia, Medinapur, West Dinajpur, Malda, Jalpaiguri, Bardhaman and Birbhum (West Bengal); Marigaon, Naogaon, Lakhimpur, Kokrajhar, Bongaigaon, Nalbari, Kamrup, Barpeta, Darrang, Cachar, Goalaghat, Jorhat, Dibrugarh, Tinsukia and Sonitpur (Assam) (Annual Report DPD 2016–17).

Challenges of rice fallow

The total geographical area of the eastern India is 73.66 Mha, which accounts for 22% of total geographical area of the country (Bandopadhyaya *et al.* 2015). The net cultivated area in this region is only 45% (33.6 M ha). This region

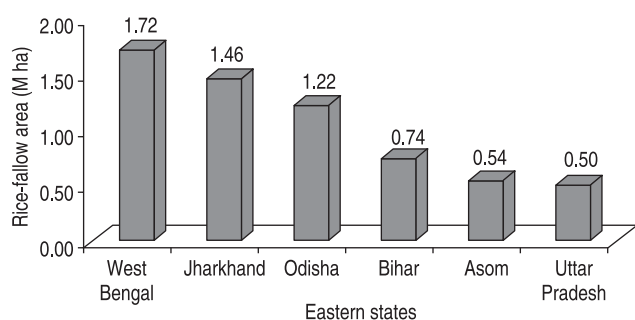


Fig 1 Existing area under the rice–fallows in eastern India (Annual Report DPD 2016–17).

contributes to 34.6% of total national food production. The foodgrain productivity in this region is the highest in West Bengal followed by eastern Uttar Pradesh, Bihar, Assam, Odisha, Jharkhand and Chhattisgarh. Cropping intensity in the Eastern states ranges from 115% in Chhattisgarh to 177% in West Bengal. This region is inhabited by 38% of the total national population (Census of India 2011) but the agricultural development is much below its potential levels (Bandopadhyaya *et al.* 2015). As a consequence, employment prospects in farming segment are restricted, compel to a mass of people to stay under the poverty and malnutrition. The per capita accessibility of cultivated land in regions is the lowest (0.15 ha) in the country (Kumar *et al.* 2016). Majority of the farm possessions are marginal to small and extremely fragmented, which hampers in implementation of mechanized farming in this region. Region receives 1100–1200 mm annual rainfall that is much enough to meet water necessity of different crops. Much spatial and temporal variation is found in the rainfall pattern and distribution that cause volatility in the farming process. Rice is the main crop and grown as mostly as transplanted during rainy season, for which puddling operation is done to create the favourable environments. However, puddling creates a slurried soil through damage of macro-pores, aggregates and resulted in lowered the bulk density (Cassman *et al.* 1995). These soils frequently dried out, builds up crack at the end of post-*kharif* leading to unavailability of soil moistures for support the winter crops. However, ploughing of these soils after harvesting of rice creates big clods with higher breaking strength, decrease yields of subsequent crop, perhaps due to the restricted root growth (Kar and Kumar 2009). Nonetheless, the resource-poor farmers of these regions are not able to meet expense of irrigation and fertilizers to produce their crop during *rabi*. Thus, growing of 2nd crop after harvest of *kharif* transplanted rice depends on the efficient use of residual soil moisture.

Through the appropriate study, plan and expansion efforts on these fallow lands may be brought it in second cropping through efficient use of residual moistures. After

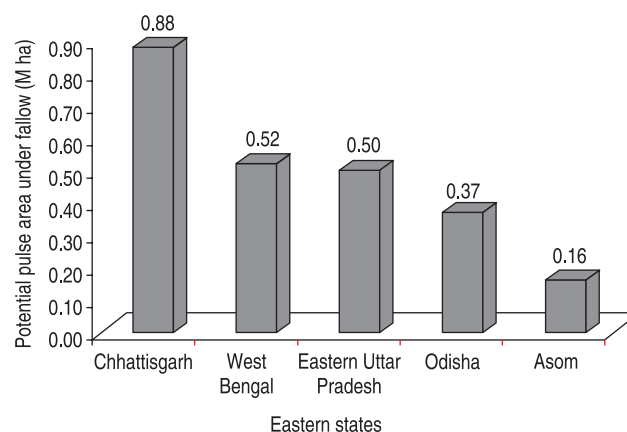


Fig 2 Potential pulses area under rice–fallows in eastern India (Annual Report DPD 2016–17).

harvesting of rice, climatic situations of unutilized land in these regions are appropriate for growing of short-duration cultivars of lathyrus, lentil, chickpea, safflower, linseed and mustard. However, conventional rice-pulse relay systems are being followed in Odisha, West Bengal, Chhattisgarh and Jharkhand. But a poor crop establishment of pulses in relay cropping is major yield-limiting factor in the region (Kumar *et al.* 2018). After understanding the system ecology, it has been observed that poor seed-soil contact; low soil-moistures and severe infestation of weeds are the major constraints to guarantee the ideal plant population of pulses in rice-fallows (Kumar *et al.* 2016). In lowland soil having higher soil moistures; lentil and lathyrus are suitable for *utera* cropping as compared to chickpea (Mishra *et al.* 2016, Mishra and Kumar 2018). Residual soil moisture at rice harvesting is normally enough to raise the pulses/oilseed crops in the region (Kumar *et al.* 2018).

Despite of the immense scope, extensive use of rice-fallow for cultivation of pulses/ oilseed crops is mostly restricted because of the several biotic, abiotic and socio-economic constraints (Panda *et al.* 2000). Among the abiotic factors, low soil moisture content and rapid soil-moisture depletion frequently led to drought situation at flowering and harvesting (Pande *et al.* 2012a). Still if crop is managed well with residual soil moisture; short of winter rain at grain filling stage often led to the complete crop failures (Kumar *et al.* 2016). Lack of irrigation facilities and poor soil moisture, thus constitute main limiting factor for production of pulses/ oilseed in rice-fallows. Site-specific nutrient deficiency (P, Zn, S, B, Mo), soil acidity and low soil organic carbon (SOC) directly affect pulses/oilseeds production in rice-fallows (Pande *et al.* 2012b). In fact, poor water-retention capacities are directly associated with lowers SOC. Further, the poor soil-physical properties, disturbance of the soil structure, soil-water deficits, meagre porosity and mechanical impedance of seeding zones create adverse situation for crop establishment in rice-fallows. Soil hardness in puddle rice field get worse physical properties of soil that badly affect moistures allocation and rooting patterns. Hostile environment in puddle rice in rice-fallows land generate the probable risk to microbes and nutrients uptake of following crop.

- *Soil moisture stress and lack of irrigation:* Although, rice-fallow areas receive normal to high rainfall during rice (*Kharif*) season, but most of rain water is lost due to high runoff and low moisture storage capacity of soils. Soil compaction after puddle rice restrict water infiltration, development of deep and wide cracks in the soils after rice harvest helps in fast depletion of stored soil-moisture through evaporation. Soil moisture stress at sowing of fallow crops results in poor plant stand (Kumar *et al.* 2018). Even if crop is established well with residual soil moisture, lack of winter rains towards reproductive stage often leads to complete failure of the crops (Ghosh *et al.* 2016). Available soil moisture gets exhausted at that time and crop reaches to flowering stage resulting in terminal drought and

heat stress (Kumar *et al.* 2018).

- *Shortage of superior cultivars and quality seeds:* Crops cultivars especially suitable for this fallow lands had not developed, thus, available varieties with relatively higher yields are being suggested (Kumar *et al.* 2018). Lack of suitable quality seeds of short-duration varieties of pulses/oilseeds for rice-fallows is also one of the major constraints (Mishra and Kumar 2018).
- *Long duration rice varieties:* In rice-fallows areas farmers used to grow the long duration rice varieties that mature in 160–165 days. This causes in delayed in sowing of subsequent of pulses/oilseeds, resulting in poor yields due to terminal drought. Pande *et al.* (2012a) elicited that more than 90% farmer's viewed lack of suitable crop varieties is the main bottleneck in rice-fallows.
- *Severe weed menaces:* Weeds pose severe difficulty in *utera*, because crops are grown without cultivated soil (Ali *et al.* 2014). Excessive weed infestation in general and problems of parasitic weed (*Cuscuta* spp. in pulses and oilseeds) and lack of selective post-emergence herbicides to control these weeds in pulses and oilseeds are other challenges in these areas. Manual weeding is tough due to quick moistures loss from soil surfaces (Kumar *et al.* 2018).
- *Soil acidity:* It is an important constraint responsible for lower productivity of pulses in the eastern region. About 50% of total land and ~80% of cultivated soils are acidic in nature (Kumar *et al.* 2016). Basically, pulses are sensitive to acidity and directly impacting biological nitrogen fixation (BNF), microbial diversity, plant-nutrient accessibility and toxic effect to the root (Choudhary *et al.* 2014). Strongly acidic soil has been noticed in rice-fallows of Chhattisgarh and Assam (Kumar *et al.* 2016).
- *Terminal drought:* Since post-rainy season crop is taken on residual soil moisture in rainfed condition, terminal drought badly affects crops yield (Kumar *et al.* 2016). Drought fastens the leaf senescence and lessens net photosynthesis and translocation from leaf to budding grains. Build up of poor biomass frequently does not sustain grain formation (Singh *et al.* 2017). Terminal drought and temperature apprehension consequence in strained ripeness and trim down yield by 50% (Reddy 2009).
- *Poor crop management:* Winter crop in these fallow are considered as bonus cropping (Ali and Kumar 2009). In view of risk concerned for growing of 2nd crops due to limitation of soil-moistures as well socio-economic hindrance, the farmers do not give more attention in crop management i.e. selection of suitable cultivars, seeding rate, crop protection, *Rhizobial* treatment, foliar feeding of nutrition and farm mechanization (Singh *et al.* 2017).
- *Socio-economic constraints:* Poor-economic condition and low purchasing capability induces farmers to leave field unused after rice harvest. Besides, fragmented land

holding, shortage of labour, non-availability of inputs, limited access to institutional credit, lack of market, lack of knowledge among farmers on water-conservation techniques, poor extension service directly or indirectly discourages the farmers for taking 2nd crop (Joshi *et al.* 2002). Animal grazing or free grazing by *neelgai*, monkeys and boars causing severe damage in Bihar to pulses is another potential threat to in rice–fallow (Panda *et al.* 2012a).

Scope for cultivation of pulses and oilseeds in rice fallows

About 11.7 million ha area remains fallow after rice harvesting, of which ~82% (9.73 million ha) area lies in Eastern states (Kumar *et al.* 2018). Thus, introduction of lentil/lathyrus/chickpea/linseed/safflower/mustard in these areas through suitable agricultural production techniques might usher in 2nd Green Revolution in such diffident, poverty and under privileged region (Singh *et al.* 2017). Normally, available water storage ability of the soil in following paddy harvest ranges between 150 to 200 mm (Das *et al.* 2017). Research finding reveals that these unutilized areas can be converted into 2nd cropping by utilizing the residual soil moistures during *rabi* (Das *et al.* 2014). Similarly, oilseeds, viz. linseed and safflower can be grown under the moisture stress condition (Kumar *et al.* 2018, Mishra and Kumar 2018). With appropriate crop varieties and agricultural practices, productivity of these pulses and oilseeds can be improved in rice–fallow (Kumar *et al.* 2018).

Pulses/oilseeds are considered as main crop for strengthen of these fallows area (Table 1). Special advantages with pulses crop that being short-duration, resilient and low-input requiring in nature, suggest an incredible prospect to use of residual soil moistures (Kar *et al.* 2004, Kar and

Kumar 2009). It has distinct character of biological nitrogen fixation (BNF), profound root growth, prospective to set up by means of broadcasting of the seeds in standing paddy field. It is best fitted in these areas due to cost-effective approaches (Pande *et al.* 2012b). In addition, biotic factors as well as grounds harsh hammering the pulses in these fallow lands. Therefore, strategic oriented option to be work out to manage adverse challenge of nature. More focused research should be carried on maximizing the productivity in rice–fallow with inclusion of suitable pulses and oilseeds. In India, pulses are grown on ~24–26 Mha land with yearly production of 17–18 MT (Singh *et al.* 2017). At present, because of large gap between supply and demand of pulses, prices of pulse in country had imported a huge quantity. So as to meet up the rising needs of pulses, it should be included as an integral part in rice–fallow with the dual advantage of area expansion and sustainable production. Similar case is associated with oilseeds too. Hence, promotion of pulse/oilseed crops in these unutilized lands would improve the sustainability of paddy cultivation in addition to attractive productivity and augments the incomes of farming community of regions (Reddy and Reddy 2010). For efficient utilization of rice–fallow with inclusion of pulses/oilseeds, location-specific and economic viable technique are required to identify through proper understanding of system ecology and constraints.

Initiated research and development programmes on pulses and oilseeds

Scheme intervention had great impacts on exploiting of these unutilized fallows for growing of pulses and oilseeds and acceptance of the recent technology by resources-poor farming community. Around one-third of land is presently unutilized after paddy harvest; it can be transformed into

Table 1 Suitable crops and varieties for rice–fallow areas of the eastern India

Crops	Varieties	States
Lentil	HUL 57, KLS 218, Narendra Masoor, Arun, DPL 15, DPL 62, Vaibhav, Pusa Masoor, IPL 316, IPL 01, IPL 406, Ranjan, K 75	Assam, West Bengal, Bihar, Odisha, eastern Uttar Pradesh, Chhattisgarh and Jharkhand
Lathyrus	Ratna, Prateek, Mahateora	Tal area Bihar, Chhattisgarh and West Bengal
Pea	Arkel, Azad pea, Rachna	Jharkhand, Chhattisgarh and eastern Uttar Pradesh
Chickpea	GCP 105, Pusa 372, JG 11, JG 14, JG 16, Pant G 186, Rajas, Pusa 547, Pusa 256, Vaibhav, GCP 105, GNG 1581	Chhattisgarh, West Bengal, Bihar and Jharkhand
Mungbean	SML 668, Pusa Vishal, Samrat	Odisha, Chhattisgarh, Jharkhand and Bihar
Urdbean	Navin, T 9, ADT 3, ADT 4	Odisha and Jharkhand
Mustard	Pusa Bold, Kesri Gold	Eastern Uttar Pradesh, Bihar and Jharkhand
Groundnut	JL 24, ICGS 1, TAG 24	Bihar, Odisha and Assam
Safflower	PBNS 12, Manjira, Bhima	Eastern Uttar Pradesh, Bihar and Jharkhand
Linseed	Sweta, Uma, Shekhar, Indu, RLC 133, RLC 138, RLC 143, SLS 79, JLS 95, BAU 06-03, BAU 2012-1, BAUP 101	Eastern Uttar Pradesh, Bihar, Jharkhand, Assam
Toria	TS 36, TS 38, TS 61, M 27	Assam, Bihar and Jharkhand

Source: Modified from Ghosh *et al.* (2016)

productive farming, and 3 million ha of additional land under pulses and 1 million ha oilseeds can be brought with appropriate policy-intervention. Promotion of pulses mainly lentil, lathyrus and chickpea in rice-fallows with support of National Food Security Mission (NFSM) has shown a positive impact in the region. NFSM on Pulses, and National Mission on Oilseed and Oil Palm Project (NMOOP) are implemented in the Eastern states. Due to limited areas in oilseeds/pulses spread of resources over larger area and change of beneficiary frequently, impact of these programmes was not much visible. Therefore, a differential approach is required for improving the profitability of rice-based cropping system through intensive cultivation of pulses and oilseeds under the rice-fallows.

Rice-fallows has immense potentials for growing of extra early-duration pulse/oilseed crops. Nonetheless, modest effort had used in these area with suitable technological support. In AICRP on MuLLaRP, inadequate effort on managing and expansion of early-duration HYVs of lathyrus and lentil earlier conceded in this region. Recently, Department of Science and Technology (DST)-sponsorship project had implemented in Jharkhand to tackle the problems of rice-fallows. Parallel efforts are being completed in the National Fund for Basic, Strategic and Frontier Application Research in Agriculture (NFBSRA) Project of ICAR on extenuating abiotic stress and improving resources use efficiencies in pulses under these fallows. National Mission on Food Security (NFSM), Department of Agriculture and Cooperation (DAC), Ministry of Agriculture, Government of India had funded unique project to global institute on rice-fallow. International Crop Research Institute for Semi-Arid Tropics (ICRISAT) launched NFSM-funded Project on “Enhancing chickpea production in rainfed rice fallow land of Chhattisgarh and Madhya Pradesh” in collaboration with National Agricultural Research System (NARS) for 2008–12. Another project on “Enhancing lentil production for food, nutritional security and improved rural livelihood” was also approved by International Centre for Agricultural Research in Dry Areas (ICARDA) during 2010, which is being implemented in Assam, Bihar, eastern Uttar Pradesh and West Bengal in association with NARS. Likewise, unique project on “Enhancing grass pea production for safe human food, animal feed and sustainable rice-based production system in India” was supported by the NFSM to ICARDA, and is being launched in Bihar, Chhattisgarh, eastern Uttar Pradesh and West Bengal. On the other hand, varietal assessment and production of seeds are most important mandates, whereas managing soil and crops aspect remained untouched in these project. Small seeded of pulses find eminence in *utera*. Consortium Research Platform (CRP) on CA was initiated by the ICAR with broad objectives of development, adaptation and refinement of location specific CA practices for enhancing productivity of rainfed eco-systems and results revealed that soil and water are the two major restraining attributes responsible for lower production of crops in these fallows.

Strategies for production of pulses and oilseeds

Pulses and oilseeds are largely grown in similar agro-ecologies and considered as companion crop for mitigating the adverse weather situation. Pulses have additional advantage of their soil enriching capabilities and supplement good quality fodder in rice-fallow. Key interventions i.e. demonstration of improved production technologies with cluster approach, augmenting availability of quality seed, seed priming and treatment with *rhizobium*/fungicide, application of micronutrients, insect-pests management and protective irrigation will be supported for visible impacts in rice-fallows. Resource conservation technologies (RCTs) may be suitable impend to tackle exertion in these fallows area. After harvesting of rice, lower soil moistures content subsequently quick turn down in water table with the progression of winter result in mid and terminal drought at reproductive phases affects yield. Therefore, if the crop residue is retained on soil surface combined with appropriate establishment methods, it might be lessen the fatal stress by protecting soil moistures. ZT with minimum disturbance of the soil and retaining crop residues might be favourable impacts on soil property that further enhance overall productivity in rice-fallows. This helps in reducing the cost of cultivation and improved input-use efficiency. Fodder scarcity for livestock during *rabi* is also an important issue in rice-fallows. Improving cropping intensity of rice-fallows may inturn, help in meeting out fodder requirement during lean period. Simple technologies like seed priming, spraying of 2% urea and DAP and micronutrient at vegetative stages increase productivity to remunerative level for resources-poor farmers (Kumar *et al.* 2018).

- *Water harvesting and storage:* In spite of heavy rain in *kharif*, moisture become foremost restrictive factors for raise the second crops in *rabi* as most of overflow is washed out. Thus, there is essential to construct arable farm ponds and community water reservoir in such areas with support of Governmental agencies. It will provide as vital means for life-saving irrigations during *rabi*. For obtaining optimum productivity in rice-fallows, it is necessary to have proper soil moistures at sowing and facility of water for at least one life-saving/ supplemental irrigation at the most critical stages. Since, plenty of water in these areas is lost during rainy season through runoff; there is a need to harvest this excess rainwater and store in small farm-ponds or reservoirs to provide life-saving irrigation to succeeding fallow crops. Construction of farm-pond or community water reservoirs to harvest excess rain-water during rainy season is a feasible strategy to provide life saving irrigation to successive pulse/oilseed crops in the rice fallows. Excess run-off available to extent of 300–400 mm, which can be harvested in silpaulin-lined pond to make available critical irrigation. This helps in increase the overall land productivity. In higher rainfall areas of north eastern hilly (NEH) states, technological options have been identified for two contrasting conditions of abiotic stresses, i.e. excess soil moisture at rice

harvesting in land-locked areas and valleys of hill and fast depleting the soil moisture in upland, terraces and plains (Das *et al.* 2014).

- *Use of resource conservation technologies (RCTs):* RCT such as ZT/RT, 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 monetary 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). Similarly, retention of rice stubble/mulching and ZT sowing of pulses significantly enhanced productivity of pulses in rice fallows (Ghosh *et al.* 2016). Retaining 30% rice residues on soil surface and ZT sowing with Happy Seeder increased yields of succeeding lentil, chickpea, safflower, linseed and mustard by 3.1, 11.7, 19.1, 14.4 and 12.3%, respectively (Unpublished results, CRP on CA Project at ICAR RCER, Patna). Similarly, utera cropping performed better than ZT (with or without mulch), and produced the maximum seed yield due to advantage of early sowing and better utilization of residual soil moistures. Among different crops, lathyrus followed by linseed and lentil recorded the maximum yields and profits (Mishra *et al.* 2016). ZT after rice harvest also facilitates timely planting of winter pulses, and helps to escape negative effects of terminal drought and rising temperature in spring–summer in rice–fallows. Results of the farmers participatory trials on ZT lentil and chickpea in Eastern–IGPs during 2009–10 showed that using ZT with reduced seed rate (30 kg/ha for lentil and 80–100 kg for chickpea), deeper seed placement (5–6 cm for lentil) improved crop establishment, crop productivity and reduced wilts incidence (Singh *et al.* 2012). A survey on farmers' participatory adoption of ZT seeded lentils in rice–fallows (200 ha) of Nawada, Bihar showed that ZT planting of lentils together with the suitable improved agronomic packages resulted in higher yields (13 %) and a reduced cultivation cost by ₹ 3800/ha, thereby increasing farm profitability of ₹ 10,000/ha (Singh *et al.* 2012). In lowlands having high moistures after rice harvest, draining excess water at physiological maturity of rice by providing drainage channels at appropriate intervals creates a favourable soil condition for ZT of winter pulses (Layek *et al.* 2014). But in case of a dry soil at rice harvest, NT along with standing stubbles/residue retention @ 5 t/ha along with life saving irrigations could give a reasonable lentil yields (Das *et al.* 2013). Mulching with paddy straw/water hyacinth was found to increase productivity of groundnut sown after rice harvest (Chaudhary *et al.* 2014). At Indian Institutes of Pulse Research Kanpur, ZT–drill for small farmers having low purchasing power was developed for line sowing in rice–fallow, which helped in moisture retention as least disturbances of soil occurred. Use of NT drill, seeding was performed timely at reduced cost. Experiences from several location in
- IGPs showed that ZT farmers saves on preparatory operation by ₹ 2500/ha and reduced diesels of 50–60 l/ha (Sharma *et al.* 2005).
- *System mode of crop production:* In order to efficient utilization of soil moistures and maximize the system productivity of rice–fallows, long-duration rice varieties need to be replaced with short to medium duration varieties for early harvesting and timely sowing of succeeding crops. Even for para/utera (relay) cropping, where seeds broadcasted in standing rice 10–12 days before crop harvest, rice fields need to be properly levelled for maintaining uniform soil moisture to facilitate uniform seed germination. Mechanical transplanting or line transplanting of rice gives higher yield of fallow paira crops (Mishra and Kumar 2018).
- *Suitable crops and varieties:* Suitable accessibility of superiority seed is regularly a most important limitation for late sowing and reduced yield of winter crops in rice–fallow. Therefore, community based seed multiplication plan needs to be launched with suitable dispensation and storeroom facilities. National/State seed corporations have to toughen their actions in such area for helping the farming community. Growing early to medium duration rice varieties (Prabhat, Naveen, Swarna Shreya) enables the farmers to advance sowing of succeeding crops for efficient utilization of stored soil moistures. Residual moisture left in soil at rice harvest is often sufficient to support the short duration crops. In eastern region, short-duration varieties of pulses like lentil, lathyrus, chickpea, field peas, mungbean, urdbean and oilseeds such as mustard, groundnut, linseed, and safflower could be cultivated profitably in rice–fallows under ZT or utera. In low land areas with excessive soil moisture, lentil and lathyrus can be grown successfully as utera cropping. Small-seeded varieties of pulses are better than large-seeded. In Jharkhand and Chhattisgarh, cultivation of bottle gourd was also found promising with limited irrigation facility. Lentil cultivars Pusa Masoor 5, Vaibhav, HUL 57, KLS 218 and Arun; chickpea C 235, Pusa 256, JG 14 and Vardan; linseed Uma (1.21 t/ha), RLC 143, BAU 06-03 and RLC 138; grasspea Ratan and Prateek have been found promising in the rice–fallows (Unpublished results, CRP on CA Project at the ICAR RCER, Patna. In another studies, linseed was found most productive/remunerative at Pusa, Bihar under the rice–fallows. Among the winter crops, safflower was most remunerative followed by blackgram, lentil, mustard and Niger in rainfed condition. Kar and Kumar (2009) reported that safflower as the most remunerative crop in rice–fallow areas in Odisha. Extensive trapping of the rice–fallows needs short-duration and hardy pulses varieties that can efficiently avoid terminal drought. Pulses genotype with fast growing and wide canopy coverage could minimize the evaporation losses from soil surface. Besides, growing early to medium duration rice varieties enables the farmers to advance sowing of pulses/oilseed for utilizing residual moistures

efficiently. Thus, there is urgent need for developing an extra early-duration cultivar of oilseed/pulses for fallows areas (Mishra and Kumar 2018).

- *Seed priming and optimum seeding rate:* It is an important cost effective technology to obtain better crop stand and high yields of pulses in rice–fallows (Ali *et al.* 2005). Seed priming i.e. overnight seeds soaking with water or nutrient solution before sowing is an important low–cost technology to improve the germination and seedling emergence. It is recommended to increase seed rate by 20–25% to have a desired plant population in rice–fallows (Bhowmick *et al.* 2005). Lathyrus is mostly grown on residual soil moisture as utera cropping in rice–fallow areas (Gupta and Bhowmick 2005, Mondal and Ghosh 2005). But lower yields especially in utera system are major problem associated with these crops (Bhowmick *et al.* 2005). Even there is a limited scope for agronomic manipulation under rice–utera system although it has potential for increase cropping intensity in considerable areas that remain idle after aman rice (Rautaray 2008). Pre-sowing soaking of seeds with $\text{KH}_2\text{PO}_4/\text{Na}_2\text{HPO}_4/\text{water}$ has been reported to improve the seed germination, seedling vigor and root growth early, resulting in good establishment, better drought tolerance and more crop yield (Solaimalai and Subburamu 2004). Bhowmick *et al.* (2014) conducted a field trial at Pulses and Oilseeds Research Station, Murshidabad, West Bengal during *rabi* season to evaluate the different levels of seed priming (water soaking, 2% KH_2PO_4 solution and sprouted seeds) along with varying levels of foliar nutrition (water spray, 2% urea/DAP/KCl spray) using crop lathyrus cv. Ratan. Results revealed that use of sprouted seeds had the highest seed yield (1021 kg/ha) followed by seed soaking in 2% KH_2PO_4 (964 kg/ha). Planting 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 techniques for augmenting the production of lathyrus under utera cropping in the rice-fallows (Bhowmick *et al.* 2014).
- *Seed treatment and foliar plant nutrition:* Pulses seed should be treated with fungicides followed by Rhizobium, phosphate solubilizing bacteria (PSB) and vesicular-arbuscular mycorrhizae (VAM) fungi and *Trichoderma* inoculation before sowing for disease free plant and better nodulation. Besides, foliar nutrition may be a useful option particularly for areas, whereas the soil application of fertilizers often leads to locking/loss of nutrients. With this technique, nutrients can reach to the site of food synthesis directly, leaving no wastage and thereby, requirement of fertilizer may be cut short from a huge bulk to a handful (Bhowmick 2008). Foliar spraying of $\text{KNO}_3/\text{Ca}(\text{NO}_3)_2$ at 0.5% significantly improved productivity of pulses (Sarkar and Malik 2001, Layek *et al.* 2014). Amongst the foliar sprays, Bhowmick *et al.* (2014) reported that application of 2% urea at pre-flowering stages had the maximum seed yield (1040 kg/ha) and followed by 2% DAP spray (983 kg/ha). Apart from the moisture stress, winter crops in rice–fallow experiences uneven degrees of nutrient stresses. Because of poor-physical condition of the soil and low native Rhizobium in typical rice–fallows, nutrient mobilization is substantially reduced (Ali *et al.* 2014). Deficiency of micronutrient is also very common and supplementary application of these inputs especially Mo is necessary in acidic soil of rice–fallows. In acid soils, application of lime/seed priming with Mo was found to be most effective (Kumar *et al.* 2016).
- *Pest management:* Diseases namely root rot, powdery mildew and yellow mosaic and insects like pod borer cause heavy damage to pulse crops in rice–fallow areas. For management of insect-pest and diseases, integrated pest management (IPM) strategy involving seed treatment with fungicides and bio-control agent *Trichoderma*, selection of disease tolerant varieties and spraying of need-based fungicides/insecticides will be useful. Taking after IPM like bird perches, spray of NPV/chemical pesticides useful for controlling the pod-borer in pulses. Genotypes having resistant to wilt in chickpea and rust in pea/lentil should be promoted. Small-sized lentil cv.WBL–77, KLS–21, NM–1 and DPL–15 have resistance to rusts is performed well in the eastern India. To check seed-borne diseases, seeds treatment with suitable fungicides/insecticides/plant growth promoting rhizobacteria is required. Seed treatment with *Trichoderma*+carboxin/alternately carbendazim+thiram for root rot, colour rots/wilt in chickpea, lentil, mungbean/urdbean is useful for pulse production.
- *Weed management:* Similarly, integrated weed management (IWM) strategies including crop residue mulching, ZT–sowing, application of post-emergence herbicides like quizalofop for grassy weed control and need based manual weeding should be adopted (Kumar *et al.* 2016). Effective post-emergence herbicides are not accessible in rice–fallows. Intercultural operations are additionally troublesome, as soil turns out to be hard. In this way, hand-weeding is main choices that must be done at early stages of crop growth (Ali *et al.* 2014). Actually suitable post-emergence herbicides are not available for pulses/oilseeds and carry out intercultural operation is hard owing to compactness of soil, manual weeding is only alternative that have to be completed at initial stages of crops (Singh *et al.* 2017). Use of imazethapyr @ 100 g/ha has been found relatively efficient in pulses (groundnut/urdbean/mungbean) at initial stages of crop growth against the narrow-leaved weeds (Ali *et al.* 2014). Application of glyphosate/paraquat to check growth of rice stubbles that causes significant moisture losses in rice–fallows is required before sowing of winter crops (Kumar *et al.* 2018). Application of quizalofop @ 50 g/ha at 15–20 days

after sowing (DAS) has also been found effective in checking the regrowth of rice as also the grassy weeds (Kumar *et al.* 2016).

- *Soil-moisture conservation:* In rice-fallows, effective moisture conservation practice can mitigate the moisture related stress and terminal drought. The approaches of RCTs that prevent rapid soil moisture losses (Kar *et al.* 2004), improves SOC and bio-physical properties (Gangwar *et al.* 2006) could be strategic approaches in rice-fallows (Ali *et al.* 2014). To better utilizing the residual soil moisture, pulses/oilseeds need to be sown immediately after rice harvest. ZT prevents soil moisture loss and advances planting by seven days (Mishra *et al.* 2016). Kar and Kumar (2009) reported that RT increase pulses (lathyrus/lentil/chickpea) yield 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). Fundamental principles of CA, NT and residues retentions on surface had followed in utera (Ali *et al.* 2014). A multi-location trials at Kanpur (UP), Kalyani (WB) and Raipur (Chhattisgarh) revealed that retention of rice stubbles/mulching and NT sowing of pulses (chickpea, lentil, lathyrus) had significantly enhanced productivity in relay cropping by maintaining higher soil moisture and improves soil attributes in rice-fallow areas of the eastern India (Ali *et al.* 2005).
- *Crop establishment techniques:* Mishra *et al.* (2016) evaluated the performance of three winter pulses, viz. lathyrus (Ratna), chickpea (JG-14) and lentil (HUL-57) were evaluated under ZT and ZT with straw mulch @ 5 t/ha (ZTM). Results revealed that ZTM was recorded to increase yields of pulses. Similarly, ZTM in rice-fallow had significantly higher rice equivalent yield (2.03 t/ha), system rice equivalent yield (6409 kg/ha) compared to ZTM and ZT. A longterm field experiment initiated by Kumar *et al.* (2018) and results revealed that ZT-DSR had maximum rice yield (5.14 t/ha) followed by CT-TPR (5.05 t/ha). In general, productivity of succeeding crops was higher after ZT-DSR. Among winter crops, chickpea (1559 kg/ha), lentil (1515 kg/ha) and safflower (1761 kg/ha) out yielded in ZT-DSR than that to UPTR and CT-puddle. Comparatively superior yield was recorded with 30% residues retention. System productivity had higher with chickpea (5799 kg/ha), lentil (5408 kg/ha) and safflower (5325 kg/ha). Conserving soil moistures in conventional system through increasing stubbles height; get better yield of winter crops in rice-fallows. Higher yields of pulses subsequent to paddy harvesting in RT had reported by Kar and Kumar (2009). Incorporation of residues/retaining residues on soil surface is recognized to have numerous benefits on soil excellence (Blanco-Canqui and Lal 2008). Retaining crops residue on soil surfaces seem to be good option than incorporating as it helps in reducing erosion and evaporation, evade the short-term association of nutrition and suppress weeds. Under NT, residues retention had significant effect in soil sealings, crust formation and same time bringing over-all enhancement in resource managing (Bandopadhyaya *et al.* 2016). Marginal and small land-holders in budding countries like India face by way of trading-off in manage residues. Residues are separated entirely for utilize as bio-fuel or farm animals feed or graze (Ghosh *et al.* 2010). Although, residue had high values and still little quantity is retained subsequent to harvest, increase over year and changing in farmer to manage residues since a durable asset on soil qualities (Das *et al.* 2018). Information on residues retentions coupled with appropriate sowing like utera helps in mitigation terminal drought in pulses/oilseeds through protect soil moisture and sinking evaporation in these fallow (Layek *et al.* 2014). Therefore, suitable skill of the cost effective conservation tillage and resilient cropping are feasible option to growing lentil, lathyrus and chickpea in fallow land. Therefore, transplant of paddy at right timing with early-duration varieties might sustain the moistures deficits and terminal drought. Retaining paddy stubble of dissimilar habit possibly will modify features soil surface, influences thermal property of soil by sinking evaporations, which render additional water availability to the crops (Cutforth and McConkey 1997).
- *Planting strategy:* In rice-based systems, productivity of succeeding winter crops is influenced by the crop establishment methods due to late harvest of HYVs transplanted rice, particularly in eastern parts of the country, which delays sowing of succeeding winter crops and resulting in lower crop yields and input-use efficiency (Mishra and Singh 2011). In rice-fallow areas, crop sowing is normally late. In utera system seed have to be broadcasted 10–15 days before harvesting of paddy (Mishra *et al.* 2016). ZT seed-cum-ferti drill/Turbo Happy Seeder should be used wherever feasible for planting in these area. There is compulsory to use early/medium duration rice cultivar for appropriate planting of Rabi crop (Table 1).
- *Ensure well-timed accessibility of crucial input:* Usually, post-rainy season crops are grown on residual soil moistures with traditional cultivars devoid of using crop nutrition, bio-fertilizers, pesticides and agro-chemicals owing to non-availability. However, yields are driving force for land growth that is subjected with improved practices. Therefore, attention needs to be sited on well-timed accessibility of this required crucial input in these areas.
- *Rural credits facility and marketing infrastructure:* Underprivileged socio-fiscal condition and purchasing power of farmer also force them to leave 2nd cropping subsequent to paddy towards denial inputs used. Thus, subsidy on farms input, credit and crop insurance schemes must implement. Market plays a keys responsibility in motivate farmers for producing crops.

- *Safeguard from stray cattle*: Neelgai/stray cattle cause serious damages to fallow crops and therefore, farmers discourage to growing *rabi* crop in these areas. However, suitable policy is compulsory to deal with these menaces.

Future research and prospects

Considering the importance of rice–fallow as a potential platform for cultivation of pulses/oilseeds, more intensive research is needed to address the soil, water and crop management challenges in this fragile ecology. Detailed understanding of the soil–profile moistures, depletion pattern, soil resistance, soil–plant relationship and bio–physical properties in rice–fallow is essential for strategic constraints management. Intensive research should address for improving relay-based system particularly in rice–fallow of Eastern India. In relay system, suitable machinery needs to be designed for sowing and residue retention. Research should also more focus on developing, deploying suitable pulses/oilseeds crops varieties, identifying low-cost moisture-conservation practice and rapid dissemination of available rice–fallow are lacking in the eastern India. Therefore, location-specific strength, weakness, opportunities and threats and constraint analysis largely help to formulate the location specific management strategies in rice–fallow area of the Eastern India.

Conclusion

Rice–fallow offer a great opportunity to maximize area of pulses and oilseeds with adoption of improved agro-techniques. Soil-moisture conservation and mitigation of abiotic stresses are two major strategies required for successful trapping of rice–fallow. for better use and understanding, intensive research is needed to understand the rice–fallow ecology for strategic crop management. Location-specific, extra early duration, drought-tolerant varieties of pulses/oilseeds are vital. If these location-defined constraints are managed, these unutilized lands may be transformed for growing of suitable pulses/oilseed crops by appropriate crops planning, the poverty and malnutrition in the region may be eradicated to a great extent.

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