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Intensifying rice (*Oryza sativa*) based cropping system through pulses and oilseeds in North-East India

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ABSTRACT

Cultivation of pulses and oilseeds in north eastern region (NER) of India assumes greater significance in view of high deficits in production for nutritional security. A field experiment was conducted for two consecutive years 2013-14 and 2014-15 to study the possibility of growing three crops in a year in the valley land rice (*Oryza sativa* L) ecosystem by following conservation tillage and cultivation of short duration pulses/oilseed crops and to study their impact on system productivity, water use efficiency, net return and soil fertility. While, the average rice yield (4.78 t/ha) was significantly higher under the rice-pea-greengram system, the system rice equivalent yield (13.61 t/ha) was the maximum under rice-pea-French bean followed by (12.55 t/ha) rice-pea-blackgram as compared to rice-fallow (4.64 t/ha) systems. Higher cultivated land utilization index was recorded under rice-lentil-greengram (0.97) and rice-lentil-blackgram (0.93) than other systems. The highest net returns were realized under rice-pea-French bean (₹ 118392/ha) followed by rice-pea-black gram system (₹ 110267/ha) over a low net returns (₹ 39040/ha) from rice-fallow. The soil organic carbon, available N and soil microbial properties were substantially enhanced due to inclusion of legumes in rice based system and the highest value of these properties were evident under rice-pea-greengram followed by rice-pea-blackgram systems. Thus, inclusion of short duration legumes like lentil and pea in winter season and green gram, blackgram or French bean in summer season under conservation tillage can enhance the cropping intensity to 300%, improve soil health and enhance system productivity and income by two to three times in NER.

Keywords: Cropping intensity, Conservation tillage, Hill ecosystem, Pulses, Short duration crops

In India, rice (*Oryza sativa* L) is mainly grown in *kharif* (June–November) and most of the rice fallow area remain uncultivated (fallow) in the *rabi* (December to March) (Das *et al.* 2019). This is mainly due to prevalence of low moisture or insufficient irrigation availability to grow vegetable crops, *boro* rice or wheat. In the north eastern region (NER) of India, rice is the major cereal crop with cultivated area of about 3.5 m ha with an average productivity of 2 t/ha (FAO 2016). Most of the rice growing areas remain fallow in the NER due to scanty winter rainfall and non-availability of irrigation water, lack of short duration cultivars, thus cropping intensity remains low (134%). The cultivation of pulses and oilseeds in NER under rice fallows assumes greater significance in view of the increasing demand for pulses/oilseeds and their role in soil fertility buildup. Retention of adequate amount of crop residues on the soil surface in combination with suitable planting techniques and adoption of conservation tillage may alleviate terminal moisture stress by conserving soil moisture and judicious resource use (Das *et al.* 2019). The winter crops like lentil, pea and *toria* are short duration in nature and generally attain maturity and harvested in the month of February/March. Thus, appreciable time gap is available in-between April to mid-July for growing some short duration summer legumes like greengram, blackgram and French bean which can be befittingly grown and harvested before transplanting of rainy season rice in July/August. This is possible only when suitable planting techniques, short duration varieties and right time of sowing are adopted. Appropriate inclusion of these summer legume crops in cereal/oilseeds rotation is an important aspect of N and C management in fragile soils of NER (Prasad and Nagarajan 2004). Thus, a field experiment was conducted to study the potential of achieving 300% cropping intensity by integrating short duration legumes and oilseeds in a single year under rice based cropping system in NER.

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MATERIALS AND METHODS

The field experiment was conducted under rainfed

conditions during 2013–14 and 2014–15 at lowland rice field of the ICAR Research Complex for NEH Region, Umiam, Meghalaya, India. The topography of the experimental site was mostly lowland valley (950 amsl, 25°30´ N latitude and 91°51´ E longitude) surrounded by hillocks and also characterized by a subtropical climate. The area received a substantial amount of rainfall annually (2450 mm, decadal average). However, the amount of rain received during November to March is very scanty. Daily mean temperature during the monsoon season (June to October) ranged from 23–32°C. The average rainfall received during experimental years was 2217 mm. The maximum and minimum temperature recorded were 30.8°C and 6.5°C, respectively. The soil of the experimental field was a *Typic Paleudalf*, clay loam in nature, acidic (*p*H 5.3) with low available soil nitrogen (N) (253.7 kg/ha), phosphorous (P) (11.2 kg/ha) and medium in available potassium (K) (259.9 kg/ha).

The experiment was laid out in a complete randomized block design (CRBD) and replicated thrice. The gross and net plot size was 5.0 m × 4.0 m and 4.0 m × 3.2 m, respectively. Different crops like lentil, pea and *toria* (*Brassica compestris* L.) were included in succession of rice in winter season and blackgram, greengram and French bean were raised in summer season. The 10 treatment combinations tested were T_1: Rice-fallow, T_2: Rice-lentil-greengram, T_3: Rice-lentil-black gram, T_4: Rice-lentil-French bean, T_5: Rice-pea-greengram, T_6: Rice-pea-blackgram, T_7: Rice-pea-French bean. T_8: Rice-*toria*-greengram, T_9: Rice-*toria*-blackgram, and T_{10}: Rice-*toria*-French bean.

Twenty-day-old seedlings of rice (cv. Shahsarang 1) were transplanted manually at 20 cm × 20 cm square spacing in the 2nd week of July using two seedlings/hill and a recommended fertilizer dose of 80 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. The harvesting of *kharif* rice was done manually by leaving about 20 cm standing stubbles in the field during the 1st week of November. The rice fields were drained at physiological maturity to cultivate the succeeding crops. The winter crops, viz. pea (var. Arkel), lentil (var. IPL 406) and *toria* (var. TS-27) were sown under no-till system in last week of November by opening a narrow furrow in between two rows of rice by using a manual furrow opener and seeds were covered with soil and farmyard manure (FYM) mixture (2:1 ratio) to give a good contact with soil. While the legumes lentil and pea were grown with 30:60:40 kg N:P_2O_5:K_2O/ha, the *toria* was grown with 60:60:40 kg N:P_2O_5:K_2O/ha. The winter crops were raised with residual soil moisture and no irrigation was provided. The winter crops were harvested in the end of March manually. The summer season crops like greengram, blackgram and French bean were sown under no-till system in the month of April with a spacing of 50×10 cm and harvested in 1st week of June. While the greengram and blackgram were grown with 30:60:40 kg N:P_2O_5:K_2O/ha, the French bean was grown with 50:60:40 kg N:P_2O_5:K_2O/ha. As there was good amount of rainfall received from April to June in the region, almost no irrigation was required for the pre-*kharif* summer crops. Only lifesaving irrigation was given during establishment stage of summer crops with about 2 cm water.

Rice equivalent yield (REY) for cropping systems were estimated by multiplying the actual grain yield of rice and fallow crops with their respective minimum support price (MSP) and dividing the same with market price of rice and expressed as t/ha. Total system yield was obtained by adding yield of all component crops in a system and expressed as t/ha. Production efficiency was obtained by dividing total system yield with total duration of component crops in a system and expressed as kg/ha/day. Water-use efficiency (WUE) was computed by the following formula suggested by Taha and Gulati (2001) and expressed as kg/ha/mm. Cultivated land utilization Index (CLUI) was calculated by summing the products of land area to each crop, multiplied by the actual duration of that crop divided by the total cultivated land time, i.e. 365 days. Composite soil samples were collected from the each plot after completion of two cropping cycles from 0-15 cm depth to determine soil chemical and biological properties. Freshly collected soil samples were used for soil microbial biomass carbon (SMBC) determination by chloroform fumigation extraction method. For SMBC, root debris or visible organic residues were removed from sample before weighing. Soil dehydrogenase activity (DHA) was determined in air dried soil samples as per the method described by Casida *et al.* (1964). The experimental data pertaining to each parameter of study were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by "F" test. Standard error of means (SEm+) and critical difference (CD) at 5% probability (P=0.05) were worked out for each parameter studied to evaluate differences between treatment means.

RESULTS AND DISCUSSION

Grain and straw yield of rice: The average grain yield of rice grown over two years (Table 1) was highest under the rice-pea-greengram cropping system followed by rice -pea-blackgram and rice - lentil-greengram. As legumes are known to fix N biologically from the atmosphere and enhance the soil fertility, the average yield of rice under rice-legume cropping systems (rice-winter and summer legume) were higher than those under rice-non-legume-legume systems. Although French bean is a legume crop, but it's considered as a shy-nodulating crop and fix very less amount of N in soil. Hence, the rice-*toria*-French bean cropping system gave significantly the lowest yield of rice. However, inclusion of legumes in rice based system did not enhance the rice yield significantly as compared to rice fallow. The highest straw yield of rice was recorded under rice-pea-greengram followed by rice-pea-blackgram systems.

Yield of crops in succession (winter and summer season crops): Among the different crops grown after rice in winter season in succession, significantly higher green pod yield of pea was recorded under rice-pea-greengram cropping system (Table 1), which was at par with pod yield obtained from rice-pea-blackgram. The lowest pea pod yield was obtained

Table 1 Crop yields and rice equivalent yield as influenced by different cropping systems (pooled mean of 2 year)

Treatment	Grain yield of rice (t/ha)	Stover yield of rice (t/ha)	Grain yield of winter crops lentil/ pea/*toria* (t/ha)	Stover yield of lentil/pea/ *toria* (t/ha)	Grain yield of summer crops (GG/BG/FB) (t/ha)	Stover yield of GG/BG/ FB (t/ha)	REY of cropping system (t/ha)
Rice	4.64	6.99	0.00	0.00	0.00	0.00	4.64
Rice-lentil-greengram	4.73	7.16	1.28	4.22	0.66	3.19	10.14
Rice-lentil-blackgram	4.72	7.07	1.26	4.15	0.64	2.94	9.48
Rice-lentil-Frenchbean	4.63	7.22	1.23	4.01	5.14	7.12	10.87
Rice-pea-greengram	4.78	7.49	4.22	6.11	0.74	3.48	12.33
Rice-pea-blackgram	4.74	7.35	4.16	6.16	0.67	3.28	12.55
Rice-pea-Frenchbean	4.66	7.22	3.78	5.81	5.35	7.34	13.61
Rice-*toria*-greengram	4.61	7.01	1.15	4.16	0.60	3.00	9.77
Rice-*toria*-blackgram	4.44	6.57	1.08	4.18	0.55	2.52	8.77
Rice-*toria*-Frenchbean	4.38	6.47	0.95	4.06	4.51	6.94	9.53
SEm±	0.09	0.30	0.19	0.19	0.07	0.11	0.38
LSD (P=0.05)	0.28	0.89	0.55	0.57	0.20	0.32	1.12

GG: Greengram, BG: Blackgram, FB: French bean (for green pod), REY: Rice Equivalent Yield

under rice-pea-French bean system which may be due to lesser amount of N fixation through French bean in soil as compared to greengram and blackgram. Similarly, the lowest seed yield of *toria* was recorded under rice-*toria*-French bean cropping system as compared to rice-*toria*-greengram and rice-*toria*-blackgram (Table 1).

The highest French bean green pod yield was recorded under rice-pea-French bean system followed by rice-lentil-French bean (5.14 t/ha), may be due to enhanced soil N availability due to fixation of N by pea and lentil. *Toria* being a non-legume crop incapable of N fixation in soil and competes for available N in soil, there by impacting growth of succeeding crop, i.e. French bean. The higher stover yield of lentil, pea and *toria* was observed under rice-pea-blackgram, rice-lentil-greengram and rice-*toria*-blackgram, respectively than others. Similarly, the highest stover yield of greengram, blackgram and French bean was obtained from systems involving rice-pea-green gram, rice-pea-blackgram and rice-pea-French bean, respectively than others. This might be due to cultivation of two successive legumes in the system and subsequent enrichment of soil fertility due to biological N fixation (Das *et al.* 2019).

Rice equivalent yield, total system yield, production efficiency and cultivated land use index: Significantly higher REY of winter crops were obtained from rice-pea-blackgram, rice-pea-French bean and rice-pea-greengram and summer crops were obtained from rice-pea-French bean and rice-lentil - French bean as compared to other systems.

Table 2 Production efficiency, cultivable land utilization index, economic returns (pooled mean of 2 years) and soil properties at 0-15 cm after two cropping cycles

Treatment	Production efficiency (kg/ha/day)	CLUI	Net return (₹/ha)	SOC (g/kg)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	DHA (µg TPF/ h/g soil)	SMBC (µg C/g dry soil)
Rice	35.69	0.36	39040	20.3	247.8	12.2	208.9	2.93	203.2
Rice-lentil-greengram	40.59	0.97	75882	21.2	273.5	15.2	242.1	3.36	245.0
Rice-lentil-blackgram	40.96	0.93	65714	21.5	276.9	15.3	238.9	3.43	241.1
Rice-lentil-French bean	56.31	0.91	79692	21.0	257.7	13.8	239.2	3.28	227.3
Rice-pea-greengram	43.20	0.91	104833	21.7	281.8	15.1	246.8	3.56	252.1
Rice-pea-blackgram	42.35	0.90	110267	21.6	277.2	15.0	243.2	3.62	249.3
Rice-pea-French bean	58.95	0.86	118392	21.8	259.6	14.4	235.5	3.40	233.0
Rice-*toria*-greengram	31.40	0.90	68618	20.6	268.3	13.8	240.4	3.30	235.3
Rice-*toria*-blackgram	30.55	0.88	52733	20.7	264.0	13.5	239.3	3.42	236.3
Rice-*toria*-French bean	44.84	0.87	55657	20.8	256.2	13.5	232.4	3.20	227.1
SEm±	1.25	0.005	5683	0.2	6.9	0.47	8.1	0.07	6.4
LSD (P=0.05)	3.72	0.01	16884	0.6	20.6	1.41	24.0	0.22	18.9

CLUI, Cultivable land utilization index; DHA, dehydrogenase activity; SMBC, soil microbial biomass carbon.

In general cropping systems involving pea as winter crop had higher total system REY than others (Table 1). The highest system REY was recorded under rice-pea-French bean (13.61 t/ha) followed by rice-pea-blackgram (12.55 t/ha) and rice-pea-greengram (12.33 t/ha). Thus, it's evident that growing of winter crops like lentil, pea, *toria* and summer legumes like greengram, blackgram and French bean after rainy season rice following suitable agronomic management practices enhances the system REY by two to four times with relatively higher REY under rice-winter and summer legumes systems than rice-winter *toria*-summer legumes..

The highest total system yield was also obtained from rice-pea-French bean (13.79 t/ha) followed by rice-lentil-French bean (11.01 t/ha). Cropping systems with French bean as summer season crop had significantly higher production efficiency than other systems (Table 2). The production efficiency registered under rice-pea-French bean and rice-lentil-French bean cropping systems were 65.2% and 57.78% higher than rice–fallow system, respectively. The two years average results revealed that cropping systems namely rice-lentil-greengram (355 days), rice-lentil-black gram (340 days) and rice-lentil-French bean (333 days) took significantly longer duration to complete life cycle of crops than rice-pea-blackgram (328 days), rice-pea-French bean (313 days), rice-*toria*-French bean cropping systems (317) and rice-fallow system (130 days). Thus, the Cultivated Land Utilization Index (CLUI) (Table 2) achieved under rice-lentil-green gram and rice-lentil-blackgram were significantly higher than other systems, which implies that the land is more efficiently being used under these cropping systems involving lentil as component crop as compared to other systems. It was observed that cropping systems like rice-pea-French bean and rice-*toria*-French bean comprising French bean could be easily fitted in the cropping pattern with fallow period of about 50 days in a year (Layek *et al.* 2018).

Water use efficiency (WUE): The highest WUE was achieved under rice-pea-French bean system, followed by rice-pea-blackgram as compared to rice fallow (Fig 1). The consumptive use of rainfall and residual soil moisture by the crops in succession significantly enhanced the WUE as compared to growing of rice alone. Higher yield of French bean and pea in the cropping systems tested than other crops also contributed to higher WUE than other systems. Adoption of no-till cultivation practices along with adequate residue retention promoted timely sowing and soil moisture conservation in component crops leading to improved growth and higher WUE than rice-fallow system (Das *et al.* 2019).

Economic returns: Rice-pea-French bean and rice-pea-blackgram enhanced the net return by almost three times as compared to rice-fallow system (Table 2). In general, B:C ratio (Fig 1) of all the cropping systems were more than 1.5, the highest being noted with rice-pea-blackgram (2.01) followed by rice-pea-French bean (1.99), but these systems were statistically at par with rice-fallow (1.93). Higher net returns and B:C ratio with rice-pea-French bean and rice-pea-blackgram systems were mainly due to higher production potential and fair market price of pea, French bean and blackgram than other crops.

Soil properties: Most of the systems having legume components significantly enhanced the soil fertility parameters especially the available N status in the soil (Table 2). Significantly higher SOC concentration was observed under rice-pea-French bean followed by rice-pea-greengram and rice-pea-blackgram systems as compared to rice-fallow. Rice-pea-greengram enhanced the SOC concentration substantially over rice fallow system, which might be due to incorporation of leguminous plant residues and subsequent improvement in soil organic matter and soil properties (Das *et al.* 2019). The maximum available N was registered under rice-pea-greengram followed by rice-pea-blackgram systems. Inclusion of legumes in cropping systems has an impact on available N supplementation by fixing atmospheric N. Legume crop residues are rich in all nutrients than other crop residues with narrower C:N ratio (<30:1), which decompose rapidly and release N for uptake by succeeding crop (Kumar and Yadav 2018). While the maximum soil available P was registered under rice-lentil-blackgram system, maximum soil available K was recorded under rice-pea-greengram system. Legumes release organic acid anions such as citrate and malate and other compounds from their roots, which might influence better P availability

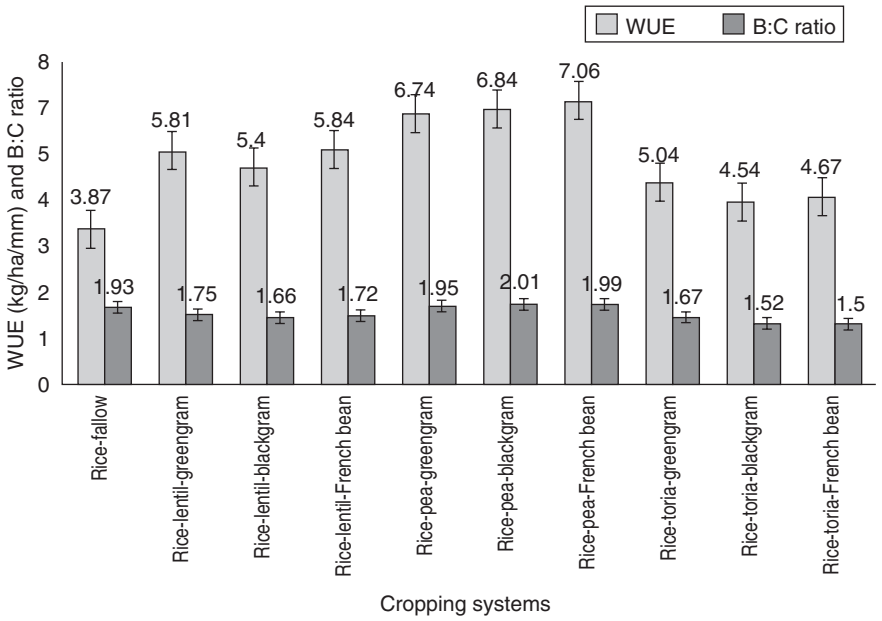

Fig 1 Water use efficiency (WUE) and benefit: cost (B:C) ratio of different rice based cropping systems (pooled mean of two years).

on soil (Krishnappa and Aftab Hussain 2014). While the maximum DHA was recorded under rice-pea-blackgram cropping system, the maximum SMBC was recorded in soil under rice-pea-greengram cropping system. Higher SMBC was observed under rice-legume system than mono cropping of rice in the 0–15 cm layer, probably because of surface accumulation of crop residues under no till condition leading to increase in SMBC and sequestration of SOC (Das *et al*. 2018).

The outcome study revealed that there is ample scope of growing pea/lentil in winter season and French bean/ blackgram/greengram in summer (pre-*kharif*) in rice fallow areas, thus, providing opportunity for achieving 300% cropping intensity in valley ecosystems of NER India. Inclusion of French bean and pea in cropping system gives higher equivalent yield, and WUE, whereas, inclusion of efficient nodulating crop such as greengram, blackgram, lentil and pea was found more promising for improving soil health..

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