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Crop and varietal diversification for enhancing productivity and profitability of rice fallow system in eastern Himalayan region

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ABSTRACT

Rice fallow is predominant system in eastern Himalaya, a reason for low agricultural productivity in the region. In north eastern regions of India, farmers grow rice crop during rainy season (June to November) and keep the land fallow after rice harvest in the post-rainy season (November to May) due to inadequate irrigation water availability and insufficient rainfall. There was an urgent need to develop location specific crop diversification plan suitable to existing conditions with appropriate crops and their varieties. Crop diversification is also required to mitigate the effect of climate change. Moisture conservation practices like zero tillage and residue retention as mulch reduce carryover time between two crops and ensure moisture availability in the soils for low water requiring crops. Therefore, attempts were made to develop suitable crop diversification options under rice fallow areas with promising cultivars of oilseed and pulse crops. A field experiment was conducted to assess productivity, profitability and soil health of rice fallow land under diversified sequential cropping pattern. The results reveal that inclusion of pea, lentil and rapeseed with minimum tillage and mulching under rice fallow system recorded highest net return (₹ 71.28×10^3, ₹ 72.65×10^3 and ₹ 29.26×10^3, respectively). Seed productivity enhancement was 47.5, 61.7 in rapeseed, 31.0, 52.1 in pea and 39.0, 56.0 in lentil under minimum tillage, and minimum tillage with mulching over farmers' practice. Improved management practices (minimum tillage and mulching) also recorded remarkable net return of 69.3, 66.6 and 84.8% over farmers existing practices in rapeseed, pea and lentil crops, respectively. The soil fertility status after harvest of the crops improved in the agro-technique with minimum tillage and mulching.

Key words: Crop diversification, Crop growth rate, Improved varieties, Mulching, System productivity, Zero tillage

One of the key challenges of 21st century is to devise ways of producing sufficient amounts of food while protecting both environment and economic well-being of rural communities. Due to nonutilization of fallow lands in rice fallow system in north-eastern Hill, India, the cropping intensity (134%) is low. Rapeseed, lentil and pea are important low input crops, which are potential options for crop diversification to achieve enhanced productivity of rice based cropping systems in north-eastern Hill, India (Das *et al.* 2017). Consequently, attention is now being directed toward development of crop production systems with improved resource use efficiencies and more benign effects on the environment (Foley *et al.* 2011). Rotation systems have been used for millennia to maintain soil fertility and productivity and to suppress pests, and can increase yields even in situations where substantial amounts of fertilizers and pesticides are applied (Bennett *et al.* 2012). Rotation systems also foster spatial diversity, since different crops within the rotation sequence are typically grown in different fields on a farm in the same year. Under the present system of sole cropping, small farmers are unable to address their diversified domestic needs to sustain normal living from their limited land, water and economic resources. This necessitates going for appropriate alternative and more efficient production systems such as multi cropping (inter/relay cropping) which can ensure proper utilization of resources to obtain increased production per unit area and time on a sustainable basis (Trenbath 1986, Rathore and Bhatt 2008). Therefore, the present experiment was undertaken to evaluate productivity and profitability of rice fallow land through diversified sequential cropping system with special reference to soil health as the region is still 33% deficit in foodgrain production and has cropping intensity of 136%.

MATERIALS AND METHODS

A field experiment was conducted at the Research farm of the institute during winter season of 2014-15 and

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2015-16. The farm is located at 24.49° N latitude, 93.55° E longitude with an altitude of 760 m amsl, with an average annual rainfall of 1450-2000 mm. Due to varied level of altitude and slopes the climatic situation of the region varies from subtropical to semitemperate condition (prevailing at higher altitudes). The winter season (November to February) can be characterized by low temperature, heavy dew fall and occurrence of frost. The temperature varies from 0°C in winter to 36°C in summer. In general, the soil of the experimental sites was sandy loam in texture, acidic in reaction (pH 5.2), medium to low in nitrogen (117± 2.8 kg/ha), medium in phosphorus (14.3 ± 0.67 kg/ha) and low in potassium (170 ±8.9 kg/ha). The experiment consisted of three diverse crops (rapeseed, lentil and pea) in rice fallow lands with three varieties of each crop, rapeseed (M-27, TS-36 and TS-38), lentil (PL-4, DPL-15 and HUL-57) and pea (Rachna, Azad and Makhayatmubi) and three agro-techniques; Farmers' practice (FP= control), Minimum Tillage (MT), Minimum Tillage + Mulching (IM= Improved management practices). Total nine treatment combinations for each sequential crops were laid out in RCBD with three replications. The fertilizer dose for rapeseed and mustard was 50-60-30 kg N, P_2O_5 and K_2O/ha along with 2 t/ha of FYM; lentil 30-60-40 kg N, P_2O_5 and K_2O/ha along with 2 t/ha of FYM and pea 30-60-40 kg N, P_2O_5 and K_2O/ha along with 2 t/ha of FYM. However, the dose of fertilizers was reduced to half in case of farmers' practices as farmers use very less amount of fertilizers. The remaining crop management practices were followed as and when required for the crops. After harvest of rice crop, the collected straw was used for mulching the succeeding crops as per treatments @ 5 t/ha. The crops were sown in the last week of October during both the years and all the agronomic and plant protection measures were followed as and when required as per treatment. The crops were harvested at maturity. The price of different commodities was considered as per prevailing market rate and economics for all the crops were calculated. To compare the treatment means for each year separately, standard analysis of variance (ANOVA) was performed and pooled data are given in the tables. Least significant difference (LSD) of the treatment means was compared at the 5% probability level ($P \leq 0.05$).

RESULTS AND DISCUSSION

Biomass accumulation and growth analysis: Different varieties of rapeseed and mustard, M-27, TS-36 and TS-38 were influenced differently in rice fallow land in terms of plant height, root length, number of branches, crop growth rate, root growth rate and ultimately on the yield of seed (Fig 1 and Table 1). Among all the varieties of rapeseed and mustard, TS-36 recorded the highest yield (774.9 kg/ha) which was influenced by higher plant height (65.05 cm), root length (8.03 cm) over TS-38 and M-27 (Table 1). The maximum plant height (72.7 cm) was recorded in crop receiving minimum tillage with mulching and TS-36 rapeseed-toria variety which was higher ($P \leq 0.05$) than the plant height of TS-36 under farmers' practice. Similar was the trend in plant height of M 27 under farmers' practice and improved management technique. Root length of TS-36 and M-27 was also significantly higher under minimum tillage with mulching than in farmers' practice. The growth analysis in terms of CGR and RGR also revealed that better biomass accumulation and higher growth rate was noticed in TS-36 and M-27 under IM and among rapeseed-toria varieties there was no difference in CGR but significantly higher RGR was recorded in TS-36 over M-27 even under IM (Table 1). Improved moisture conservation and less weed incidence in initial period, better ambience in terms of temperature moderation and higher uptake of nutrients ensuring better plant nutrition are the reasons for higher crop growth and biomass accumulation under minimum tillage with mulching (Shekhawat *et al.* 2012, Premi *et al.* 2013 and Shekhawat *et al.* 2016). The effect of pea varieties on growth and biomass were influenced significantly in

Table 1 Effect of varietal diversification and agro-techniques on yield attributes and seed yield (kg/ha) of rapeseed in rice-rapeseed cropping system (2 years mean)

Treatment	Plant height (cm)	Root length (cm)	Number of branches	CGR (g/pl/day)	RGR (g/pl/day	Seed yield (kg/ha)	Straw yield (kg/ha)
FP + M-27	49.20	5.60	2.33	0.27	0.01	390.8	820.0
FP + TS-36	56.85	5.60	2.33	0.31	0.07	415.5	1,585.3
FP + TS-38	58.49	5.60	3.00	0.60	0.11	450.8	1,339.3
MT + M-27	61.27	6.73	2.67	0.54	0.01	714.33	1,421.3
MT + TS-36	65.60	7.85	3.00	0.57	0.07	764.0	1,694.6
MT + TS-38	59.58	7.85	3.00	0.91	0.10	808.0	1,366.6
IM + M-27	69.97	7.85	3.00	1.00	0.08	974.67	1,612.6
IM + TS-36	72.70	10.65	3.00	1.00	0.13	1145.33	1,913.3
IM + TS-38	72.16	7.852	3.00	0.91	0.08	1015.67	1,421.3
SE(m) ±	0.41	0.11	0.17	0.01	0.002	51.13	16.12
CD (P=0.05)	1.2	0.34	0.53	0.05	0.01	154.61	48.73

(FP) Farmers' practice, (MT) Minimum Tillage, (IM) Minimum Tillage + mulching rice fallow lands (Table 2). Among all the pea varieties, Makhayatmubi (*local*) recorded the highest plant height (104.2 cm), root length (10.9 cm), number of branches (2.6) and resulted in highest green pod yield (2228.63 kg/ha) which was superior over the other pea varieties, Rachna and Azad (Fig 1 and Table 2). Field pea cultivars e.g. Rachna, Makhayatmubi and Azad performed differently under different management practices, under rice-field pea system field pea cultivars recorded higher (P≤0.05) plant height and root length under IM (minimum tillage and mulching) over farmers' practice. Root length was highest (18.0 cm) in Azad variety under IM. Among all the field cultivars Rachna and Makhayatmubi had more number of branches, which is also an important yield attributing trait. Because of better growth and biomass accumulation higher CGR was recorded in Rachna, Makhayatmubi and Azad under IM. Minimum tillage created favourable rhizospheric conditions for better root nodulation in field pea and improved moisture supply, and nutrient uptake which may be the reason for better growth and biomass accumulation under minimum tillage with mulching (Rautaray 2005, Aleksandras and Satkus 2012, Yeboah *et al.* 2012).

Three varieties of lentil, viz. PL-4, DPL-15 and HUL-57 were evaluated for their performance in rice fallows and the result reveals that among all the varieties, HUL-57 showed higher plant height (53.9 cm), number of branches (6.4), root length (9.17 cm) and crop growth rate (0.5 g/plant/day) and significantly higher grain yield (Fig 1 and Table 3). HUL-5, DPL-15 and PL-4 lentil cultivars recorded higher plant height and root length under minimum tillage with mulching. It is also evident that IM resulted in better growth and root development (Table 3). Significantly higher root length was noticed in IM in PL-4, DPL-15 and HUL-57 lentil cultivars compared to these parameters under farmers' practice. Irrespective of management practices, HUL-57 resulted in better growth and biomass accumulation compared to PL-4 and DPL-15 (Table 3). DPL-15 and HUL-57 were observed with higher CGR even under minimum tillage without residues and highest CGR was in HUL-57 under IM. In rice-lentil system mulching with minimum tillage resulted in better moisture conservation and subsequently resulted in higher moisture availability to lentil crop at critical growth stages. Kumar *et al.* (2011) and Tomar and Singh (1991) also reported that mulching and reduced tillage had favourable effects on the plant growth environment and associated photosystems due to improved soil properties.

Yield and yield attributes: The rapeseed and mustard variety, TS-38 had higher number of branches (3), crop growth rate (0.9 g/plant/day) and seed yield (758.16 kg/ha). The pooled data over the two years experiments reveals that growing of rapeseed variety, TS-36 with minimum tillage and mulching recorded the highest yield (1145 kg/ha). This may be due to more availability of soil moisture and nutrients in the root zone of the crop which resulted in higher crop yield (Sarangi et al. 2010). Mohanty et al. (2002) reported 2.8% increase in soil moisture content till top 20 cm soil depth due to rice straw mulching. This technology can be recommended for rice fallow terrace lands of NEH hill region for cultivation of rapeseed and mustard.

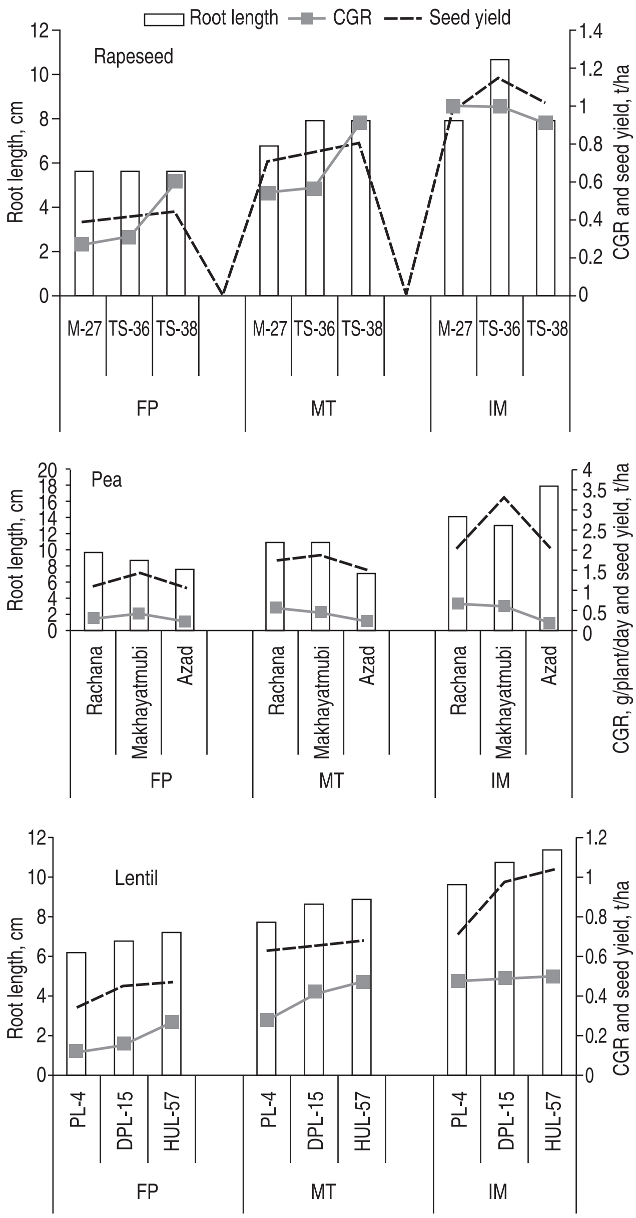

Fig 1 CGR, root length and seed yield of rapeseed (toria), pea and lentil in rice based cropping system.

Three varieties of pea were studied with three different agro-techniques and the result reveals that the crop receiving minimum tillage and mulching recorded the highest green pod yield (2506.3 kg/ha) over the other pea varieties under the study. This may be due to higher in plant height, root length, number of branches and crop growth rate of the pea varieties receiving minimum tillage and mulching. This might be due to sustainability and stability of the local variety, Makhayatmubi (local) under moisture stress condition in rice fallow lands.

This may be due to suitability of the lentil variety, HUL-57 in rice fallow lands**.** The pooled data over the two years experiments reveals that growing of lentil variety, HUL-57 with minimum tillage and mulching recorded in highest plant

Table 2 Effect of varietal diversification and agro-techniques on yield attributes and seed yield (kg/ha) of pea in rice-pea cropping system (2 years mean)

Treatment	Plant height (cm)	Root length (cm)	Number of branches	CGR (g/pl/day)	Seed yield (kg/ha)	Straw yield (kg/ha)
FP + Rachana	94.5	9.8	2.2	0.30	1145.0	2,472.0
FP + Makhayatmubi	61.2	8.7	2.2	0.43	1435.9	2,851.0
FP + Azad	47.0	7.6	1.1	0.23	1,086.6	1,738.6
MT + Rachana	98.7	10.9	2.2	0.57	1,781.9	2,703.7
MT + Makhayatmubi	124.6	10.9	2.2	0.46	1,902.5	2,672.8
MT + Azad	50.2	7.1	1.1	0.23	1,534.7	2,302.0
IM + Rachana	109.3	14.2	3.4	0.67	2,085.7	2,686.5
IM + Makhayatmubi	126.8	13.1	3.4	0.62	3,347.5	2,920.0
IM + Azad	57.9	18.0	2.2	0.19	2,085.7	2,720.0
CD	5.1	0.55	0.2	0.08	64.4	82.2
SE(m)	1.6	0.18	0.06	0.02	21.3	27.2
SE(d)	2.3	0.26	0.09	0.03	30.1	38.4
CV	3.4	2.87	5.07	11.70	1.9	1.7

(FP) Farmers' practice, (MT) Minimum Tillage, (IM) Minimum Tillage + mulching

height (63.07cm), number of branches (7.53), root length (10.56cm), crop growth rate (0.49 g/plant/day) and finally resulted in the highest (908.2 kg/ha) grain yield (Fig 1). This may be due to higher soil moisture content below the mulches due to reduction in soil surface evaporation and weed intensity (Shirgure *et al.* 2003). In rice-linseed cropping sequence, normal tillage with rice straw mulching @ 3.5 t/ha applied just after linseed sowing, recorded significantly higher seed yield over without mulch treatment also reported by Kalita *et al.* (2005).

Soil fertility dynamics under different interventions: Soil fertility status, available soil organic carbon, nitrogen, phosphorus and potassium were assessed after harvest of pea-rice, lentil-rice and rapeseed-rice cropping system with improved agronomic interventions of minimum tillage and maintaining crop residue mulch on soil (Table 4), it was revealed that available OC, N, P_2O_5 and K_2O was positively influenced with the improved agro-techniques, minimum tillage and mulching. The available OC, N, P_2O_5 and K_2O were increased by 23.5%, 15.7%, 39.6% and 12.3% in pea-rice, 12.2%, 19.5%, 32.20% and 13.9 % in toria-rice and 21%, 6%, 11.9% and 25.8% in lentil-rice, over farmers' practices (Table 4). Rautaray (2005) reported that the mean response of *rabi* crops (toria, lentil, etc.) in rice-based cropping system with mulching was significant with 16% increase in yield. The findings are in conformity with Kanwarkamla (2000) and Ali *et al*. (2012). They reported that cultivation of legume crops were viewed more as a soil fertility improver than as independent crops grown for their grain output. This is because legume crops are sufficient in N supply.

Economics of crop diversification: The economics of

Table 3 Effect of varietal diversification and agro-techniques on yield attributes and seed yield (kg/ha) of lentil in rice-lentil cropping system (2 years mean)

Treatment	Plant height (cm)	Number of branches	Root length (cm)	CGR (g/pl/day)	Grain yield (kg/ha)	Straw yield (kg/ha)
FP + PL-4	30.8	3.4	6.2	0.12	344.6	1,250.5
FP + DPL-15	33.0	3.4	6.8	0.16	456.0	1,300.4
FP + HUL-57	35.2	4.5	7.2	0.27	470.0	1,320.2
MT + PL-4	41.8	5.7	7.7	0.28	627.0	1,345.0
MT + DPL-15	59.4	6.8	8.6	0.42	655.5	1,358.4
MT + HUL-57	60.5	6.8	8.9	0.47	684.0	1,480.3
IM + PL-4	60.5	7.9	9.6	0.48	712.5	1,400 .8
IM + DPL-15	62.7	6.8	10.7	0.49	974.7	1,360.4
IM + HUL-57	66.0	7.9	11.37	0.50	1,037.4	1,500.3
SE(m)	0.75	0.14	0.16	0.01	17.04	4.69
CD (P=0.05)	2.29	0.44	0.48	0.02	51.4	14.15

Table 4 Effect of different agro-techniques on soil fertility status after harvest of rice-rapeseed, field pea and lentil cropping system (2 years mean)

Treatment	Rapeseed				Field pea				Lentil			
	OC (%)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	OC (%)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	OC (%)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
FP	0.98	114.60	15.43	393.33	0.85	171.00	15.63	326.57	0.80	217.80	26.70	310.10
MT	1.01	126.39	17.77	407.33	1.01	189.00	21.13	345.03	0.87	225.33	28.70	354.77
IM	1.10	136.99	20.40	448.00	1.05	198.00	21.83	366.40	0.97	231.00	29.90	390.23

(FP) Farmers' practice, (MT) Minimum Tillage, (IM) Minimum Tillage + mulching

diversified cropping system with rapeseed, lentil and field pea was estimated (Table 5) and revealed that IM resulted in higher gross, net return and B:C ratio. Inclusion of pea and lentil in the rice fallow system resulted in maximum net profit in terms of highest net return (Fig 2 and Table 5) and compared to the farmers' practice the minimum tillage and MT along with mulching resulted in higher profitability. Existing farmers' practice, though low costing produced comparatively lesser income and even less than cost of cultivation. Diversification option with rice-lentil system resulted in highest net return >80% over farmers' practice. Similarly, improved practice out yielded existing practice by generating up to 70% and 67% higher returns in rice based diversification options by including rapeseed and pea crop during *rabi* season. The higher productivity, along with better market price of rapeseed, lentil and pea, and relatively low cost of production was the reason for higher profitability. Though cost of cultivation was comparatively higher in minimum tillage with mulching but due to higher growth and productivity under IM it resulted in higher net return, B:C ratio and profitability. Field pea incurred more cost in minimum tillage and mulching compared to rapeseed-toria and lentil. This was due to high prices of seed, pest and disease management in field pea. The highest net return was recorded in lentil under IM, closely followed by field pea however, distinct difference was recorded in rapeseed-toria due to its lower seed yield. Maximum net return per ₹ (B:C ratio) was in IM which includes minimum tillage with mulching in all crops but among the crops, field pea had highest B:C ratio (3.5). Almost similar B:C ratio was noticed in field pea under MT and lentil in IM. Because of comparatively lesser profit, lowest B:C ratio was in rapeseed crop. Profitability was highest in field pea under IM and it was higher even under MT compare to lentil and rapeseed-toria (Table 5).

Table 5 Economics of varietal diversification and agro-techniques in rice-based cropping system in hill terrace of Manipur (2 years mean)

Treatment	Mean yield (kg/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net profit (₹/ha)	B:C ratio	Crop profit-ability (₹/ha/day)
R and M						
FP	419.0	11982.0	20951.7	8969.7	1.7	209.5
MT	762.1	18964.0	38105.5	19141.5	2.0	381.1
IM	1045.2	22989.0	52252.8	29263.8	2.3	522.5
Pea						
FP	1222.5	19486.0	48900.0	23827.0	2.5	543.3
MT	1739.7	25073.0	68254.8	39281.8	2.7	758.4
IM	2506.3	28973.0	100253.2	71280.2	3.5	1113.9
Lentil						
FP	423.5	16786.0	33882.7	11059.7	2.0	260.6
MT	655.5	22823.0	52440.0	26067.0	2.3	403.4
IM	908.2	26373.0	72656.0	72656.0	2.7	558.9

(FP) Farmers' practice, (MT) Minimum Tillage, (IM) Minimum Tillage + mulching

The study revealed that crop diversification under rice fallow system by inclusion of oilseeds and pulse crops, not only enhances overall system productivity but also improves soil health and farm profitability. The suitable agro-climatic conditions in NEH India can be perfectly harnessed for improued resource-use efficiency with better economics through crop diversification. It is also imperative to development package of effective crop diversification in rice fallow system in North Eastern Hill the region must be made self-reliant and surplus in foodgrain production. This will also help in abandoning the age old faulty practice of shifting cultivation. Therefore, from the above study can be concluded that the agro-technique minimum tillage and mulching, along with promising cultivars of pea

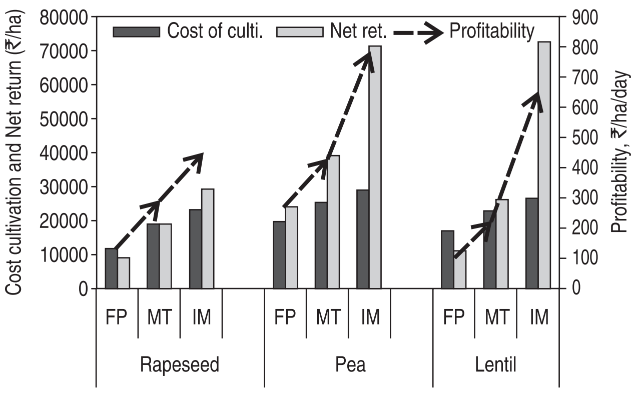

Fig 2 Comparative economics of rapeseed, pea and lentil in farmer's practices, minimum tillage and minimum tillage and residue under rice based cropping system.

(Makhayatmubi), lentil (HUL-57) and rapeseed (TS-36) is suitable for higher crop productivity in rice fallow lands of hill terraces of NEH region.

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