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Research Communication

Improving soil health and water productivity of lentil (*Lens esculentum*) sown after lowland rice (*Oryza sativa*) through appropriate variety and rice residue management

EMDOR SHYLLA[1], ANUP DAS[2], RAMKRUSHNA G.I[3], JAYANTA LAYEK[4] AND P.K. GHOSH[5]

College of Post Graduate Studies, Central Agricultural University, Umiam, Meghalaya 793 103

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ABSTRACT

A field experiment was conducted during rainy and winter seasons of 2012–13 in lowland at ICAR Research Complex for NEH Region, Umiam, Meghalaya to identify suitable rice (*Oryza sativa* L.) and lentil (*Lens esculentum* Medik.) cultivars and appropriate rice residue-management practices (RRMPs) for enhancing productivity of rice–lentil system and improving soil health. The results revealed that there was no significant effect of rice cultivars on productivity of lentil. However, the yield of lentil was significantly influenced by lentil cultivars and RRMP. Lentil variety 'IPL 406' recorded significantly higher yield (1.82 t/ha), water-use efficiency (9.46 kg/ha-mm) and water productivity (3.30 kg/m^3) compared to that of 'DPL 81'. Amongst RRMPs, mulching recorded significantly higher lentil yield (1.87 t/ha), water-use efficiency (9.75 kg/ha/mm) and water productivity (3.40 kg/m^3) compared to 20 cm standing stubble and residue removal. Irrespective of rice and lentil cultivars, mulching recorded about 26.7% and 18.7% higher lentil yield than residue removal and 20 cm standing stubble respectively. Available N and K were higher when 'DPL 81' grown after rice cultivar 'Shahsarang 1' as compared to that under Mendri. Significantly higher available N, K and soil organic carbon were recorded under mulching than 20 cm standing stubble and straw removal. The dehydrogenase activity and soil microbial biomass carbon were significantly higher under mulching than removal and 20 cm standing stubble. Thus, growing of lentil 'IPL 406' under mulching @ 5 t/ha after high-yielding varieties of rice 'Shahsarang 1' is a viable option for enhancing productivity and WUE under rainfed lowland conditions.

Key words : Pulses, Rainfed agriculture, Rice paddies, Rice fallow, Rice-lentil cropping system, Water productivity

Cropping systems in the North Eastern Region (NER) of India (about 26.2 m ha) total geographical area) are predominantly rice-based with exception in Sikkim, where maize is the main food crop. Rice cultivation in the NER of India is exposed to different biotic and abiotic stresses, i.e. drought, floods, soil acidity, pests and diseases, thus resulting in a very dismal condition in rice productivity and production of the region which in turn reflects a lower per capita consumption as well. Rice is the major staple food crop of the region occupying 3.5 m ha, which accounts for about 7.8% of the country rice area and 6.5% of the production. The valley lowlands generally remain saturated after rice harvesting mainly due to releasing of water from the surrounding hillocks. Any tillage practice in a saturated or wet soil disturbs the soil structure and makes sowing of arable crop very difficult. Thus, management of moisture stress (excess and scanty condition) becomes an essential aspect for cultivation of arable crops in lowland rice fallow areas.

Pulses are the ideal crops that can occupy the area vacated by the rainy-season rice (Kumar *et al*., 1994) which leads to increased cropping intensity, productivity per unit area and farmers income (Das *et al.,* 2014). Lentil is a drought-tolerant pulse crop and can also be grown in high-rainfall areas and lowlands during dry season with adequate water management practices. Draining of excess water during physiological maturity of rice (about 10 days

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[2]**Corresponding author Email**: anup_icar@yahoo.com
[1]M.Sc. (Agron.) Student, [2]Senior Scientist (Agronomy), [3,4]Scientist (Agronomy) Division of Crop Production, ICAR RC for NEH Region, [5]Director, Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh 283 002

before harvesting) is an adaptation option for cultivation of pulses in high-rainfall mid-hills ecosystems of eastern Himalayan region (Das *et al.,* 2014). Because of its adaptation to intercropping and relay cropping, lentil occupies a unique place in cropping systems in northern, eastern, and central India. Water productivity (WP) of rainfed mono-cropped rice is very low which can be substantially improved by inclusion of pulses in the system. Retention of residues of previous crops can conserve soil moisture for succeeding crop grown during dry/winter season leading to improved water-use efficiency (WUE). However, the area and production of lentil are very low in NER than other states of India. Thus, cultivation of lentil or any pulse crop after rice would enhance the cropping intensity, pulse production, availability of high-protein food and in the long run improve the soil health due to N-fixation. With this background, the present study was conducted to evaluate the impact of rice and lentil cultivars on lentil yield and WP and to assess the impact of cultivars and rice residue-management practices (RRMPs) on soil-quality parameters.

The field experiment was conducted during 2012–13, at the lowland Agronomy field of the Indian Council of Agricultural Research (ICAR) Research Complex for NEH Region, Umiam (25^{o}41' N, 1^{o}54' E, 950 m above mean sea-level), Mehgalaya. The total rainfall received during lentil-growing season was 55.1 mm, where the highest rainfall was in March (44.9 mm) and no rainfall received during December–January. The total evaporation recorded during the entire lentil period (winter crop) was about (330.4 mm), in which the highest evaporation was recorded in March (99.9 mm) and the lowest in December (40 mm). Mean maximum temperature was recorded during May (30.09^{o} C) and the lowest in January (10.86^{o}C). Average relative humidity was 38.80% in the mornings and 24.84% in the evenings. The experimental soil is a *typic plaeudalf*, poorly drained soil. The experimental soil was low in *p*H (5.07–5.3), high soil organic carbon (24 g/kg) medium in available nitrogen (N) (248.7 kg/ha), low in phosphorus (P) (28.6 kg/ha) and high in potassium (K) (155.5 kg/ha) content. The experiment was laid in a split-split-plot design with 2 main-plots consisting of 2 rice cultivars in rainy season (Local long duration-'Mendri' and a HYV medium-duration-'Shahsarang 1'), 2 sub-plots with two lentil cultivars in the winter season ('DPL 81'-early duration with high biomass and 'IPL 406'-medium duration with high biomass) and 3 sub-sub-plots, comprising 3 RRMPs (20 cm standing stubble, mulching @ 5 t/ha and residue removal), replicated thrice. Rice was transplanted on 10 July, 2012 with all the recommended agronomic practices. 'Shahsarang 1' was harvested on 14 November, while Mendri on 26 November 2012. Excess water was drained out at physiological maturity of rice for favorable soil moisture to facilitate sowing of succeeding lentil crop. Glyphosate 41% @ 3 ml/litre water was applied to control weeds before sowing of lentil. After harvesting of rice, furrows were opened using a manual furrow opener between 2 rice lines. The recommended doses of fertilizers (20 : 60 : 40 kg N : P_2O_5 : K_2O/ha) and seeds were placed in the furrows and covered with soil : farmyard manure mixture (2 : 1 ratio) for better seed soil contact. Sowing of lentil after 'Shahsarang 1' (HYV rice) was done on 6 December 2012 (as the field was vacated early due to its shorter duration) and after Mendri on 12 December 2012. Rice straw mulch was applied 20 days after sowing @ 5 t/ha. The 20 cm standing stubbles were maintained at the time of rice harvesting. The residues were completely removed in case of control by harvesting close to the ground. Urea 2% spay was given in lentil before flowering for better growth and development. All other agronomic practices were followed for rice and lentil as recommended. The observations on rice and lentil yields were recorded at harvest following standard procedure. The soil samples at lentil harvested were obtained from 0–15 cm depth and analyzed for soil available, available N, P, K, soil microbial biomass carbon (SMBC) and dehydrogenase activity (DHA) following recommended analytical procedures.

'Shahsarang 1' far exceeded 'Mendri' for grain yield (Table 1, 2), however, 'Mendri' recorded higher straw

Table 1. Effects of rice, lentil cultivars and rice stubble-management practices on seed yield, water-use efficiency and (WUE) water productivity (WP) of lentil

Treatment	Biomass (t/ha)	Seed yield (t/ha)	WUE (kg/ha-mm)	WP (kg/m^3)
Rice cultivars				
'Shahsarang 1'	8.4	1.7	8.4	3.1
'Mendri'	6.6	1.6	7.7	2.9
SEm±	0.06	0.006	0.1	0.01
CD (*P*=0.05)	0.39	NS	NS	NS
Lentil cultivars				
'DPL 81'	7.5	1.5	7.3	2.7
'IPL 406'	7.4	1.8	8.9	3.3
SEm±	0.07	0.01	0.1	0.02
CD (P=0.05)	NS	0.05	0.3	0.1
Rice residue-management practices				
20 cm SS	7.4	1.6	7.6	2.8
Mulching	8.6	1.9	9.1	3.4
Residue removal	6.4	1.5	7.5	2.8
SEm±	0.06	0.02	0.1	0.1
CD (*P*=0.05)	0.18	0.08	0.4	0.2

SS, Standing stubble

yield compared to 'Shahsarang 1'. The soil organic carbon was found to be significantly influenced by lentil cultivars as well as by RRMPs (Table 2). Higher soil organic carbon was recorded under 'IPL 406' (2.60%) and mulching (2.62%) as compared to 'DPL 81' (2.44%) and no mulching (23.9%). Mohammad *et al.* (2012) also reported similar findings, where total soil organic content was higher under residue retention than removal. Higher concentration of soil-available N, P and K was recorded under mulching as compared to no mulch (Table 1). This might be due to addition of some nutrient when the residues decompose gradually. Similar findings were reported by Alvarez *et al*. (1995) which stated that crop residues retained on soil surface decompose slowly and have a greater N-immobilization potential or lower rate of net N release than incorporated residue. Sharma *et al*. (2010) observed that the enhanced conservation of moisture in the soil profile due to mulching resulted in greater available N. Similarly, Prasad *et al*. (2010) also reported increase in available P and K in soil due to addition of crop residues (Sønsteby *et al.,* 2004).

Higher dehydrogenase activity (DHA) was recorded under mulching followed by 20 cm standing stubble than no mulch (Table 2). The increase in DHA indicated increased microbiological activity as a consequence of the addition of crop residues and the presence of leguminous plants (Garci *et al.,* 1997). The soil microbial biomass carbon (SMBC) was the highest under mulching, followed by 20 cm standing stubble (Table 2). This is in line with the finding of Saha *et al*. (2009), who noted the highest SMBC in zero tillage with residue retention than that under residue removal. The water-use efficiency (WUE) and water productivity (WP) were significantly influenced by lentil cultivars and RSMP. Higher WUE was recorded with 'IPL 406' compared to 'DPL 81'. Among the RRMPs, the highest WUE was recorded under mulching compared to residue removal. The increase in WUE of lentil under mulching than residue removal was 21% (Table 1). The WUE increased as a result of soil water being used for crop growth rather than in evaporation. The increase in yield of the crop is a direct indication of the efficiency of the practices to conserve and improve the water available to the plants and also improve the WUE of the crop. Wang (2006) reported that zero tillage combined with crop-residue retention improves soil physical condition and increases crop yield and WUE.

Significantly higher seed yield was obtained under mulching, being 18% higher than residue removal (Table 1). The higher seed yield might be owing to use of straw mulch that enhanced the inherent moisture-retention capacity as well as nutrient-supplying capacity of the soil, which in turn improved seed yield. Ghosh *et al*. (2009) reported that mulching had positive effect on the yield of succeeding mustard crop and registered maximum seed yield. Addition of crop residue and subsequent decomposition released nutrients that helped in increasing the yield of all the crops, leading to their higher yield as compared to no mulch. Liu *et al*. (2002) observed that mulch increased soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield. Various mulch-

Table 2. Effect of rice, lentil cultivars and rice stubble-management practices on soil chemical and biological properties at 0–15 cm soil depth

Treatment	Soil organic carbon (g/kg)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)	SMBC (μg/g)	DHA (μg TPF/hr/g)
Rice cultivars						
'Shahsarang 1'	24.8	267	31.2	178.8	158.5	2.05
'Mendri'	25.5	234	28.1	1650	157.3	2.03
SEm±	0.1	0.25	0.12	1.42	0.11	0.003
CD (P=0.05)	NS	1.51	0.73	8.67	NS	NS
Lentil cultivars						
'DPL 81'	24.4	255	28.1	177.3	157.1	2.03
'IPL 406'	26	246	31.3	166.5	158.7	2.05
SEm±	0.004	0.43	0.21	0.95	0.36	0.004
CD (*P* =0.05)	0.016	1.69	NS	3.15	NS	NS
Rice residue-management practices						
20 cm SS	25.4	257	30.4	170.6	159.9	2.05
Mulching	26.2	264	29.6	186.7	161.1	2.11
Residue Removal	23.9	229	28.9	158.4	152.8	1.97
SEm±	0.01	1.24	0.24	1.82	0.35	0.004
CD (*P* =0.05)	0.03	3.71	NS	5.46	1.06	0.01

SS, Standing stubble; SMBC, Soil microbial biomass carbon; DHA, dehydrogenase activity ing practices helped in the conservation of a notable amount of moisture in the root zone profile; this enhanced root proliferation and availability of nutrients to crop roots. As a result, grain yield under mulched plot attained higher values than no mulching.

Thus, it can be concluded that, lentil cultivar 'IPL 406' gave significantly higher yield than 'DPL 81'. The application of straw mulch helped in conserving soil moisture and improving the soil chemical and biological properties and ultimately gave higher productivity than residue removal. The WUE and WP were recorded the highest under rice cultivar 'Shahsarang 1', lentil cultivar 'IPL 406' and mulching. Thus, cultivation of 'IPL 406' after 'Shahsarang 1', under rice-residue mulching is a viable option for higher lentil productivity, soil moisture conservation, WUE, WP and soil health improvement in lowland rice fallow under zero tillage.

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