



Influence of rice (*Oryza sativa*) habit groups and moisture conservation practices on soil physical and microbial properties in rice + lathyrus relay cropping system under rice fallows in Eastern Plateau of India

R N SINGH¹, C S PRAHARAJ², RAHUL KUMAR³, S S SINGH⁴, N KUMAR⁵ and UMMED SINGH⁶

Indira Gandhi Krishi Vishwa Vidyalaya, Raipur, Chhattisgarh 492 012

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ABSTRACT

The study involving bio-physical aspects of popular rice (*Oryza sativa* L.) + lathyrus relay system for conserving natural resources and deriving the best benefits out of them was carried out in a *vertisols* at Indira Gandhi Krishi Vishwa Vidyalaya, Raipur (India) during 2011-14. The study location comes under tropical sub humid climate that receives an annual precipitation of 1582 mm. Two rice habit groups (a tall local rice Masuri maturing at 140 days *vis-à-vis* a dwarf HYV of rice Swarna with 110 days duration) were combined with two moisture conservation practices (retaining rice stubble height up to 15 cm versus 30 cm) for growing two contrasting varieties of lathyrus (early high biomass accumulating Ratan *vis-à-vis* medium high biomass Prateek). The study showed that soil moisture depletion pattern was relatively lower in case of residue retention at a higher cutting height, i.e. 30 cm in comparison to 15 cm with better and higher crop cover in the former. At later stages of lathyrus, faster moisture depletion was observed in case of lathyrus Ratan over that in Prateek. Yet, maximum soil moisture depletion was recorded under Prateek especially under long rice habit group since it stayed for long as compared to 'Ratan'. Similarly, bulk density (BD) was increased slightly with both time and soil compaction as a result of tillage or soil traffic. Soil strength indicated higher order variation (0.13 to 0.19) which could explain relatively higher sensitivity of soil strength to relay cropping situation in comparison to BD. However, marginal changes did occur in respect of soil porosity (47- 50%), pH (6.6 to 7.2) and EC (0.12 to 0.14 dS/m) at 15 cm profile depth. Moreover, as a result of slow depletion of soil moisture storage (SMS) following stubble retained at 30 cm height, soil organic carbon (SOC) status was greatly enhanced under it. Similar small increments in respect of soil fertility attributes such as soil available N (193.4 to 210.4 kg/ha), soil-P (10.3 to 12.2 kg/ha), soil-K (465.4 to 475.4 kg/ha), Cu (2.2 to 2.5 mg/kg), Fe (6.9-7.6 mg/kg), Zn (0.69-0.84 mg/kg) and Mn (6.2-6.9 mg/kg) after the harvest of rice were observed with diverse treatment combinations. Similarly, soil microbiological properties such as *Rhizobium*, dehydrogenase activity, crop growth and nodulation did affect following treatment imposition. Besides these, weed dynamics and the resultant yield attributes and grain yield were favoured especially in those treatments where soil moisture is conserved (higher SMS) and availability of it was extended over a period of time. Therefore, the study carried out in a lentil relayed with diverse rice habits showed that efficient management of soil and land resources was crucial for realizing higher output through adequate soil cover with better soil health.

Key words: Microbial dynamics, Residue retention, Rice fallow, Rice + lathyrus relay system, Soil physical properties

Rice fallows occupies an acreage of 7.81 million hectares (Mha) in India which mostly remains fallow in winter/summer after harvest of rice crop. Although a large

number of abiotic factors related to soil and water are responsible for low or stagnated pulse production in rice fallows especially falling under Eastern Plateau and Hill Zone (EPHZ, the agro-climatic Zone VII) during the last decade, yet hardy, relatively drought tolerant and low water requiring pulses like, lentil and lathyrus (Khesari) have been candidate crops under such a situation. In addition, recent lifting of the ban on lathyrus in eastern states and promotion of low (beta-N-oxalylamino-L-alanine) BOAA content varieties have added required thrusts to grow this crop under rice fallow situation. However, typically low moisture content in the soil after rice harvest followed by fast decline in water table with the advancement

¹Professor (Soil Science) (e mail: rnsinghikv@gmail.com), ³Senior Research Fellow (e mail: rahulsoiligkv@gmail.com), Department of Soil Science and Agricultural Chemistry, IGKVV, Raipur (Chhattisgarh). ²Principal Scientist (Agronomy) and Head (e mail: cspraharaj@gmail.com), ⁵Principal Scientist (e mail: nkumar.icar@gmail.com), ⁶Senior Scientist (e mail: drummedsingh@gmail.com), Division of Crop Production, ICAR-Indian Institute of Pulses Research, Kanpur (UP). ⁴Director (e mail: sssinghpatna@yahoo.co.in), ATARI, Zone II, Kolkata (WB).

of *rabi* season further leads to seasonal (midseason or terminal) drought at flowering and pod filling stages and thus, adversely affects the productivity of even lathyrus crop. The abiotic stress (especially terminal drought) increases leaf senescence, decreases net photosynthesis and translocation from leaf to developing grains. In addition, this hostile environment creates potential threat to microbial activity, nutrient availability, root growth (although root is mostly confined in top soil layer) and water and nutrients uptake (Bandyopadhyaya *et al.* 2016, Ali *et al.* 2014). The after-effect is that the sub-soil resources in rice fallows remains un or underutilized and prone to diverse loss with time.

Research evidence suggests that residue retention on soil surface has favourable effect on physical, chemical and biological properties of soil for which it calls for a quick appraisal on resource conservation technology (RCT) to address such recurrent constraints for sustainable crop cultivation (Bandyopadhyaya *et al.* 2016, Kovac *et al.* 2005). Resource conservation through minimum soil traffic involving reduced or no-tillage and conservation tillage could further boost the overall resource enhancement and productivity capacity of relatively newer agro-ecological niche especially rice-fallows. Conversely, on integration with suitable crop husbandry practices, these areas could be made green following utilization of residual soil moisture (Pratibha *et al.* 1996, Kar *et al.* 2004, Shirish *et al.* 2013). Here, the measures (such as tillage and residue retention and even varietal interventions for both rice and pulses) that could help in alleviating soil moisture depletion, organic matter build-up and improvement in soil structure and microbial population could further act in strengthening soil fertility besides realizing potential productivity from these field crops/soils (Praharaj 2014, Praharaj *et al.* 2014, Singh *et al.* 2016).

Besides the constraints observed inherent to rice fallows including growing of profitable (second) crop cultivation in rotation with rice, suitable strategies for alteration in sowing windows could be a boon for conserving natural resources and higher productivity realization. Therefore, advancing sowing time of *rabi* pulses by at least by 7-10 days before rice harvest so that the crop could come up well using congenial microclimate (optimum soil temperature and moisture dynamics) at rice harvest (Pratibha *et al.* 1996, Kar *et al.* 2004) would be a possibility. In addition, different rice habit groups offer differential productivity pattern offering further complementation to existing productivity of the system. Harnessing this opportunity in rice-pulse system could further scale-up the productivity of *rabi* pulses without jeopardizing rice yields (Patil *et al.* 2013, Anonymous 2016). With this analogy, since Eastern Plateau and Hills pose constant impediments for enhancing agricultural productivity and farm income, an attempt was, therefore, made for suitably manipulating the microenvironments favouring higher productivity through dilution or deceleration of physical factors following improved agronomy. Hence, the current experiment was

planned at IGKV, Raipur of Eastern Plateau region of India in EPHZ in a rice + lathyrus relay cropping system.

MATERIALS AND METHODS

For evaluating the harvest activity through retention of rice stubbles on soil moisture and microbial population dynamics under differential rice and lathyrus habit groups, an experiment was conducted at Indira Gandhi Krishi Vishwa Vidyalaya (IGKV), Raipur (located at 21°13.906' N and 81°41.976' E) during 2011-14 for three consecutive years. Situated in the central India's sub tropical humid region of Chhattisgarh under Eastern Plateau region of India, the soil of the experimental site is clayey loam with 7.7 pH, 0.60% SOC (with low soil-N availability), 9.8 kg/ha available P, 197.3 kg/ha available K and 1.35 Mg/M³ BD. The crop cycle recorded an annual maximum and minimum temperature of 42.3 and 11.6°C, respectively. The climate of the location comes under tropical sub humid receiving an annual precipitation of 1582 mm.

Eight treatment combinations comprising two rice habit groups (a local tall rice 'Masuri' with 140 days duration *vis-à-vis* a dwarf HYV of rice Swarna with 110 days duration); and two varieties of lathyrus (early high biomass accumulating variety Ratan *vis-à-vis* medium high biomass variety Prateek) in vertical factor (strip); while two moisture conservation practices (retaining rice stubble height up to 15 cm (a farmers' practice), 30 cm) in horizontal factor (strip) were laid out in thrice replicated strip plot design. Thus, interaction effect could be possible to study through the intersecting plots of both the strips and factors. Lathyrus was sown during last week of October after rice harvest and was harvested during mid February. Normal agronomic practices were followed in rice-lathyrus relay cropping system. In addition, common crop husbandry practices such as seed treatment with PSB and *Rhizobium* at sowing, and 2% urea spray were given to lathyrus at pod development stage.

Observations on crop parameters such as plant population, nodule number and its dry weight, specific leaf weight, relative water content in leaves, root and shoot weights, yield attributes and grain yield were recorded as per the standard procedure. Besides this, population of weed and its dry weight was also recorded using a square meter quadrat. The details of observation on soil moisture content (SMC) was taken periodically after lathyrus sowing so as to record the depletion pattern in moisture content in soil as growth and development progress with time. From soil moisture dynamics, water use and water use efficiency was also calculated. Soil moisture determinations were made from the soil samples taken from 0 - 100 cm depth at different soil profile following standard procedures.

Soil physical parameters, *viz.* bulk density and soil strength was measured using core sampler and penetrometer. Soil pH was measured in a 1:2.5 soil water suspension (McLean 1982). Likewise, nitrogen content in the sample was analyzed by micro-Kjeldahl method (Piper 1966). The phosphorus and potassium content was estimated by

taking 1 g sample in a digestion flask with 10 ml tri-acid mixture (HNO_3 : HClO_4 : H_2SO_4 : : 9:3:1) and digestion was carried out on a hot plate at 180-200°C until dense white flume of H_2SO_4 and HClO_4 were evolved (Jackson 1973). The digested materials were used for estimation of P and K content (Black 1965). The Organic C was estimated by Walkey and Black (1934). Micronutrients (Zn, Fe, Mn, Cu) were estimated by tri-acid digested material using Atomic Absorption Spectrophotometer.

For determination of soil biological parameters, rhizosphere soil samples were collected carefully by uprooting the root system and placed in a cool box for transport and stored at 4°C. Soil diazotrophs were measured by viable plate count technique and soil dehydrogenase activity (SDA) with iodinitrotetrazolium chloride following normal procedures. Nodulation, root studies, stress physiological observations (specific leaf weight, relative water content), weed dynamics, yield attributes and yield data were recorded following standard procedure.

RESULTS AND DISCUSSION

Dynamics of soil moisture storage

Alteration in soil moisture storage is indicative of availability of moisture in relation to time and quantity. In the present investigation, periodic soil moisture content under rice + lathyrus relay cropping system indicated a very high soil moisture content in neutral pH clayey loam soil with medium soil organic carbon (SOC) under a standing rice crop readying to maturity/harvest. It was apparent that at the time of sowing of lathyrus, SMC in plot could go up to 47.4 to 49.4% (beyond the maximum water holding capacity of soil). It followed a declining trend as the rice crop traversed through maturity thereby opening up soil surfaces to demands made for both evapo-transpiration (ET) and crop uptake (lathyrus). Critical constants for available water content at different soil profile depth are given in Table 1.

Not only the lathyrus varieties but also the treatments involving residue retention influenced dynamics of soil moisture content. SMC observed at 7 days interval revealed the apparent depletion pattern with both time and constraints imposed. However, soil moisture depletion pattern was relatively lower in case of residue retention at a higher cutting height, i.e. 30 cm in comparison to 15 cm especially in upper soil profile depth (Bandyopadhyay *et al.* 2016). This was obviously due to better and higher crop cover in the former. In the later stages of plant growth and within the varieties, faster moisture depletion was observed in the plot where lathyrus 'Ratan' was grown, as it developed higher biomass early in the season as compared to medium high biomass variety 'Prateek'. Nevertheless, as per quantitative water use/consumptive use of water by different lathyrus varieties evaluated, maximum soil moisture depletion was recorded under 'Prateek' especially under long rice habit group since it stayed for long as compared to 'Ratan'.

When comparison was made for total soil moisture

Table 1 Available water content (AWC) at different soil depths in experimental vertisols

Soil depth (cm)	WHC (cm^3/cm^3)	Field capacity (cm^3/cm^3)	Permanent wilting point (cm^3/cm^3)	Available water content (cm^3/cm^3)	Total water content (cm/m profile)
0-2.5	0.7	0.47	0.24	0.23	0.575
2.5-5	0.7	0.47	0.24	0.23	0.575
5-7.5	0.7	0.47	0.24	0.23	0.575
7.5-10	0.7	0.47	0.24	0.23	0.575
10.12.5	0.71	0.47	0.24	0.23	0.575
12.5-15	0.71	0.47	0.24	0.23	0.575
15-30	0.66	0.43	0.22	0.21	3.05
30-40	0.64	0.42	0.21	0.21	2.10
40-60	0.66	0.39	0.20	0.19	3.80
60-100	0.67	0.39	0.18	0.21	8.40

AWC /100 cm soil profile : 20.8 cm/m

content up to 100 cm soil depth, higher SMC was recorded in Ratan (21.8 cm) under dwarf rice with its residues at a cutting height of 30 cm than that in tall rice (cut at a height of 30 cm and under Ratan with SMC of 21.6 cm). Here the lowest SMC was analyzed under Prateek followed after tall rice with its stubbles height of 15 cm. Similar was the case for other soil profile depths, wherein maximum soil moisture depletion up to 20-30 cm soil depth was recorded in tall rice habit group with stubble maintained at a height of 15 cm especially in Ratan which eventually fell below wilting point during later part of vegetative period (end of November) in comparison to dwarf rice habit with stubble height of 15 cm. Therefore, tall habit group proved its inefficiency in terms of SMC and extended water availability (Bandyopadhyay *et al.* 2016, Mondal *et al.* 2012). The reasons attributed to such an inefficiency are relatively long duration of tall rice varieties depleting more moisture in comparison to dwarf rice.

On total water use measured in terms of consumptive water use, maximum water used was recorded under tall rice habit group which was cut at a height of 15 cm under Ratan lathyrus followed by dwarf rice habit group retained at a height of 15 cm. Hence, the period and content of water availability was less to succeeding crop of lathyrus in rotation. The minimum water use was observed under tall rice habit group when it was cut at a height of 30 cm in 'Prateek'. Therefore, soil moisture depletion was more in tall variety as compared to dwarf rice as observed up to the root zone of 0-40 cm. As rice crop is mainly a surface feeder, the differences in SMC in lower depths beyond the depth of effective root activity (> 40 cm) could be marginal.

SMC and soil moisture storage is a unique characteristic dependent upon soil texture (soil mineralogy dependant), soil organic matter content and other management factors (mulches, crop rotation, conservation tillage dependant, etc, (Kovac *et al.* 2005). These conditions altered the resultant SMC at a particular time/space which could also

influence seed germination, seedling emergence and crop establishment. Due to disruption in soil structure also, the effect could be soil water deficit, poor aeration and mechanical impedance especially in the seed zone. Hence, an effective strategy by way of *in situ* early sowing of succeeding crop (relayed sown crop) ensures extended period of availability of adequate soil moisture that further enhances plant establishment and crop performance (Pratibha *et al.* 1996, Kar *et al.* 2004). This could also happen in the backdrop of high yielding dwarf rice variety without curtailing its duration (and realizing the potential yield of rice). This dual benefits of relay cropping of pulse in a dwarf rice was also inevitable in the present investigation (Patil *et al.* 2013).

Soil physical and chemical properties

Pulses *per se* - a soil building crop- improves soil properties through BNF, leaf fall and root biomass. This could be cumulated over time following crop rotation involving pulses. In the present case, some of the associated physical and chemical soil properties were modified or improved following cultivation of the rice + lathyrus relay cropping system. Although bulk density (BD) –a measure for soil compactness - observed at 0-15 cm depth in different treatments showed slight variation in the range of 1.33 to 1.35 Mg/m³, the same as a whole was increased slightly

Table 2 Changes in bulk density and soil strength in rice-lathyrus relay cropping sequence after harvest of the latter

Variety	Bulk density (g/cm ³)			Soil strength (MPa)		
	0-15 cm	15-30 cm	Mean	0-15 cm	15-30 cm	Mean
<i>Rice cultivars</i>						
Local (Tall)	1.33	1.34	1.34	0.13	0.17	0.17
Improved (Dwarf)	1.34	1.35	1.35	0.17	0.19	0.18
<i>Lathyrus cultivars</i>						
Prateek	1.34	1.34	1.34	0.15	0.19	0.19
Ratan	1.33	1.34	1.33	0.15	0.17	0.16

Table 3 Dynamics in soil chemical properties under rice-lathyrus relay cropping sequence after harvest of the pulse (15 cm soil profile depth)

Treatment	pH	EC (dS/m)	OC (%)	Available nutrient (kg/ha)			Available micronutrient (mg/kg)				
				N	P	K	Cu	Zn	Mn	Fe	
<i>Rice cultivars</i>											
Local (Tall)	6.75	0.13	0.78	196.8	10.7	470	2.35	0.76	6.70	7.05	
Improved (Dwarf)	6.88	0.14	0.74	206.5	11.3	465	2.40	0.78	6.55	7.45	
<i>Management practices</i>											
Farmer's practice	6.73	0.13	0.73	202.5	10.7	468	2.38	0.76	6.60	7.23	
30 cm residue retention (Improved practice)	6.90	0.13	0.79	200.8	11.3	466	2.38	0.78	6.65	7.28	
<i>Lathyrus cultivars</i>											
Prateek	6.75	0.12	0.74	204.2	10.7	464	2.40	0.72	6.60	7.08	
Ratan	6.88	0.14	0.78	199.1	11.4	471	2.35	0.82	6.65	7.43	

with both time and soil compaction as a result of tillage or soil traffic (Table 2). However, soil strength -another quantitative characteristic for soil compaction -recorded after harvest of rice under relay cropping of lathyrus indicated higher order variation (0.13 to 0.19). This could explain relatively higher sensitivity of soil strength to relay cropping situation in comparison to BD.

Closely related to soil strength, hydraulic conductivity (HC) of different treatments determined by Guelph *in-situ* permeameter that precisely measured *in situ* HC varied between 2 to 5 ml/hr. However, marginal changes did occur in respect of soil porosity (47 to 50%), pH (6.6 to 7.2) and EC (0.12 to 0.14 dS/m) at 15 cm profile depth under different factors or strips irrespective of pre- and post-harvest soil analysis. This interactive effect of treatments indicated more or less soil resilience to possible alteration in consequence of growing of rice-lathyrus relay cropping. Moreover, as a result of slow depletion of SMC under stubbles retained at 30 cm height, soil organic carbon status was greatly enhanced under the said treatment (Table 3) which was more evident under tall rice (in comparison to dwarf rice due to soil cover for more time due to standing rice crop) and 30 cm residue retention (compared to farmer practice) which was also evident in both varieties of lathyrus (Table 3). Thus, soil organic carbon plays a critical role in resource conservation and may be due to which possibility of higher carbon sequestration could be a reality under pulses inclusion cropping systems (Venkatesh *et al.* 2013, Mishra *et al.* 2012, NAAS 2013).

Similar small increments in respect of soil fertility attributes were also observed following lathyrus cultivation in rice fallow. The mean effects (Table 3) indicated that the differences observed in respect of soil available N (an interactive effect of 193.4 to 210.4 kg/ha), soil-P (10.3 to 12.2 kg/ha), soil-K (465.4 to 475.4 kg/ha) after the harvest of rice were nominal to influence residual or cumulative effect on diversified crop attributes. Similar was the case for other essential micronutrients also (an interactive effect of 2.2 to 2.5 mg/kg Cu, 6.9 – 7.6 mg/kg Fe, 0.69-0.84 Zn and 6.2-6.9 mg/kg Mn). These ranges were observed in

different combination of treatments imposed on the crop (not the mean effect *per se* as in Table 3).

Soil microbial properties

Microbiological analysis (Table 4) of pre-sowing composite soil samples (taken before lathyrus planting) revealed that maximum rhizobial population (an interactive effect of 7.83×10^4 CFU/g of soil) was observed in the plots where Ratan was grown after tall rice habit group combined with retention of 30 cm stubble as compared to Prateek under dwarf rice category with retention of similar stubble height. The lowest rhizobia population (7.17×10^4 CFU/g of soil) was analyzed under tall rice with a stubble height at 15 cm. This was evident due to the above factors described as above (more with higher residue retained at 30 cm height). Similar to rhizobia population, maximum population of *PSB* (an interactive effect of 4.33×10^5 CFU/g soil) was also counted in 30 cm stubble under tall rice group and in lathyrus Ratan followed by tall rice group with stubbles retained at 30 cm under Prateek; and the lowest population of these N fixers (3.63×10^4 CFU/g of soil) was recorded under Ratan with tall rice group where its stubbles were maintained at a height of 15 cm. On the contrary, in respect of population of other diazotrophs (mostly bacteria and other microorganisms that fix atmospheric N into more usable form non-symbiotically requiring more energy from symbiosis) under relay cropping system, dwarf rice habit group when retained at 30 cm height had comparatively higher population (an interactive effect of 3.3×10^5 CFU/g of soil) under Ratan followed by tall rice with the same stubble height and lathyrus variety (3.17×10^5 CFU/g of soil). The lowest diazotrophs count was recorded under tall rice stubbles retained at 15 cm height under Prateek. The reason for higher microbial biomass under residue retained at 30 cm height was attributed to more congenial microclimate favoured by shading effect and extended availability of soil moisture compared to that at 15 cm height.

Dehydrogenase activity (DHA) - a microbial oxidative activity in the soil environment (usually determined by measuring the amount of an artificial electron acceptor reduced by microbial activity) – is considered to be a fairly good measure of enzymatic activities undergone in the soil. In the above rice + lathyrus relay cropping system, the highest dehydrogenase activity was observed under dwarf rice stubble retained at 30 cm height especially under Ratan lathyrus (an interactive effect of $77.23 \mu\text{g TPF/soil/day}$) followed by that under tall rice habit with 15 cm stubble height under Prateek ($74.77 \mu\text{g TPF/soil/day}$); and the minimum activity was observed under dwarf rice retained at 15 cm height under 'Ratan' lathyrus. Therefore, depending on the constraints imposed, microbiology of rhizosphere was altered which in turn had an influence on BNF and crop performance (Venkatesh *et al.* 2013, Bandyopadhyaya *et al.* 2016).

Crop growth and nodulation

As a result of alteration in microclimate following imposition of constraints (*viz.* growing of diverse rice habit group, subsequent retention of crop residues and raising of relay cropping of lathyrus under rice fallow situation), both quantitative measurements in relation to crop growth parameters and its nodulation behaviour were changed. There was an intra-row or inter-row competition amongst the crop plants. As a result, maximum plant population (POP) was evident in 30cm dwarf rice stubble under Ratan lathyrus (an interactive effect maintaining a POP of $172/\text{m}^2$) followed by the same stubble height of 30cm under tall rice habit and Prateek ($161/\text{m}^2$); and the lowest number of plant were counted (with highest mortality) in the plot where 15 cm tall rice stubbles was retained under lathyrus Ratan ($141/\text{m}^2$).

Similar to POP, highest number of nodules per plant was recorded under dwarf rice with 30 cm stubble height of under variety Ratan (an interactive effect resulting in 20

Table 4 Influence of rice and lathyrus cultivars and management practices on soil microbial dynamics, plant population, nodulation and specific leaf weight of lathyrus

Treatment	Rhizobium (10^4 CFU/g soil)	PSB (10^5 CFU/g soil)	Diazotrophs (10^5 CFU/g soil)	Dehydrogenase activity ($\mu\text{g TPF/g soil/24 hr}$)	Plant population* (m^2)	Nodule/ plant	Dry weight of nodules (mg)	SLW (g/ cm^2)
<i>Rice cultivars</i>								
Local (Tall)	7.46	3.96	2.85	75.83	155	16.0	7.86	0.20
Improved (Dwarf)	7.36	4.08	2.78	74.45	161	18.0	8.36	0.21
<i>Management practices</i>								
Farmer's practice	7.29	3.77	2.45	73.94	155	16.0	7.70	0.19
30 cm residue retention (Improved practice)	7.54	4.28	3.16	76.34	161	18.0	8.49	0.22
<i>Lathyrus cultivars</i>								
Prateek	7.3	4.00	2.77	75.66	158	17.0	8.05	0.19
Ratan	7.53	3.83	2.85	74.63	158	17.0	8.18	0.22

*Plant population was not significant

nodules/plant) followed by the same (dwarf rice stubbles retained at 30 cm height) under Prateek. As a result, higher dry weight of nodules per plant was observed in dwarf rice stubble maintained at a height of 30 cm under variety Ratan (9.13 mg/plant) followed by the same condition (dwarf rice with stubble height 30 cm) under variety Prateek. Yet, the lowest number of nodules (15/plant) was recorded under tall rice stubbles retained up to the height of 15 cm especially under Prateek. The minimum dry weight was evident under 15 cm tall rice stubble and Ratan lathyrus (7.43 mg/plant under the treatment combination).

On the same manner, higher values of specific leaf weight (SLW) - an index of crop physiological activity - recorded in lathyrus Ratan grown under dwarf rice habit group with 30 cm stubble (0.33 mg/cm²) (Table 4) followed by that under lathyrus Prateek (0.23 mg/cm²). To the contrary, the lowest SLW was recorded under tall rice stubble maintained at 15 cm height (0.13 mg/cm²). Similar to SLW, relative water content (RWC) recorded at 30 day intervals was consistently higher in Ratan under 30 cm standing stubble in dwarf rice followed by the same under Prateek. Evidently, the lowest SLW was recorded in lathyrus Prateek grown under 15 cm tall rice stubble (Table 4).

Other important growth attributes, viz. root shoot ratio and root volume were influenced as per treatment(s) imposed, and the specific parameter in question (Table 5). For example, maximum root shoot ratio was observed in dwarf rice stubble with 15 cm stubble height in lathyrus Ratan (0.62) followed by that in Prateek under tall rice with stubble height of 15 cm (0.57) and the minimum was recorded in lathyrus Prateek under dwarf rice habit group with stubble height maintained at 30 cm.

On the same fashion, the highest root volume was recorded under dwarf rice group with 30 cm rice stubble variety Ratan (1.4 cm³ × 10⁻³) followed by 30 cm rice stubble height (1.30 cm³ × 10⁻³) in lathyrus Prateek. However, the lowest volume of roots was recorded in Prateek under 15 cm rice stubble maintained under tall rice habit group

(0.97 cm³ × 10⁻³). Therefore, not only different rice habit group but also tillage and soil cover (residue retained) did influence resource conservation (of soil moisture for an extended period, Gangwar *et al.* 2006). This could be useful for higher resource saving and enhanced input use efficiency (Praharaj *et al.* 2014, Bandyopadhyaya *et al.* 2016, Mondal *et al.* 2012)

Weed population

Another resource depleting phenomenon is of weed menace as it drains out the existing resources, be it light, space, time or even inputs (that includes both natural and added resources). In the present investigation, the maximum weed population (31/m²) was recorded in Prateek under dwarf rice stubbles kept at a height of 15 cm followed by stubbles of tall rice cut at 15 cm height (30). Because soil cover and depletion of resources for nourishment of weeds, the lowest weed population was noticed in Ratan under dwarf rice habit variety (Table 5) cut at 30 cm stubble height (22). Therefore, for a holistic crop management strategy, both biotic and abiotic constraints did limit crop performance and subsequent yield formation (Mishra *et al.* 2012, Praharaj 2013, Praharaj *et al.* 2014, Praharaj *et al.* 2017).

Grain yield and yield attributes

The study also confirmed higher number of pods per plant (maximum) recorded in Ratan (39) under dwarf rice group where stubbles were cut at 30 cm height followed by that in Prateek (34) under both tall and dwarf rice where stubbles were cut at 30 cm height (Singh *et al.* 2016). The lowest number of pods/plant was recorded in Ratan (24) under dwarf category with 15 cm stubble height. As a result of this, the highest grain yield of lathyrus Ratan (interactive effect of 1689 kg/ha) was recorded in dwarf rice habit group with 30 cm cutting height followed by tall rice habit group Prateek (1406 kg/ha) with 30 cm cutting height. On the contrary, the lowest yield of 1156 kg/ha was recorded in tall rice habit group with stubble height of 15 cm (Table 5).

Table 5 Influence of rice and lathyrus cultivars and management practices on relative water content, root, weed dynamics and yield of lathyrus

Treatment	RWC (%)			Root attributes		Weed Dynamics		Pods/ plant	Grain yield (kg/ha)*
	Days after sowing (DAS)			Root volume (cm ³ ×10 ⁻³)	Root shoot ratio	Weed population	Weed DW(g/m ²)		
	30	60	90						
<i>Rice cultivars</i>									
Local (Tall)	67.57	68.58	69.37	1.11	0.54	26	9.5	31	1380
Improved (Dwarf)	68.65	70.03	70.75	1.26	0.53	25	9.2	33	1392
<i>Management practices</i>									
Farmer's practice	66.17	67.87	68.40	1.07	0.56	28	10.2	29	1366
30 cm residue retention (Improved practice)	70.05	71.00	71.72	0.29	0.50	23	8.6	34	1406
<i>Lathyrus cultivars</i>									
Prateek	67.97	69.12	69.92	1.21	0.52	27	10.1	32	1326
Ratan	68.25	69.75	70.20	1.16	0.55	24	8.8	31	1446

*CD (P=0.05) for Grain yield: Management practices (54.3) and variety (102)

The grain and straw ratio was similarly influenced and higher values were recorded in Prateek (0.67) under the dwarf rice with stubble height of 15 cm followed by Ratan (0.57) grown under same rice habit group/stubble height. The minimum values recorded in tall rice habit group with stubble height in 30 cm in Prateek (0.48) (Singh *et al.* 2016).

The study suggested that dwarf rice habit group of rice was found to conserve maximum water in comparison to tall rice habit group. Similarly, maximum water was conserved in medium biomass producing lathyrus Ratan over that in relatively high biomass producing cultivar Prateek. Consequent to higher moisture storage/availability and further utilization, yield attributes and grain yield were enhanced under dwarf rice habit group where 30 cm stubble height was maintained in comparison to tall rice habit group similar to farmer practice. Furthermore, rhizospheric microbial population and crop physiological attributes such as relative leaf water content etc were also influenced similarly as it was higher in lathyrus following after dwarf rice in comparison of that after tall rice. Therefore, growing suitable crop varieties and keeping minimum stubble height of rice for adequate soil cover and better soil health could be an efficient way for better management of soil and land resources besides realizing or stabilizing necessary gain in output from lentil relayed with diverse rice habits.

REFERENCES

- Ali Masood, Ghosh P K and Hazra K K. 2014. Resource conservation technologies in rice fallow. (*In*) *Resource Conservation Technology in Pulses*, pp 83-89. Ghosh *et al.* (Eds). Scientific Publishers, Jodhpur.
- Ali M and Kumar S. 2009. Major technological advances in pulses-Indian scenario. (*In*) *Milestones in Food Legumes Research*, pp 1-20. Masood Ali and Shiv Kumar (Eds). Indian Institute of Pulses Research, Kanpur.
- Anonymous. 2016. Annual Report on Promotion of pulses in NEH region, 2015-16. ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, 56 p.
- Bandyopadhyaya P K, Singh K C, Mondal K, Nath R, Ghosh P K, Kumar N, Basu P S and Singh S S. 2016. Effect of stubble length of rice in mitigating soil moisture stress and on yield of lentil (*Lens culinaris* Medik) in rice-lentil relay crop. *Agriculture Water Management* **173**: 91–102.
- Black C A. 1965. *Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Madison, Wisconsin, USA.
- Gangwar K S, Singh K K, Sharma S K, and Tomar O K. 2006. Alternative tillage and crop residue management in wheat after rice in sandy loam soils of Indo- Gangatic plains. *Soil Tillage Research* **88**: 242–52.
- Jackson M L. 1973. *Soil Chemical Analysis*. Printice Hall of India Pvt Ltd, New Delhi.
- Kar G, Singh R and Verma H N. 2004. Productive and profitable management of rainfed lowland rice through intensive cropping and efficient water use. *WTCER Bhubaneswar Research Bulletin s* 56.
- Kovac K, Macak M and Svancarkova M. 2005. The effect of soil conservation tillage on soil moisture dynamics under single cropping and crop rotation. *Plant and Soil Environment* **51**: 124–30.
- McLean E O. 1982. Soil pH and lime requirement. (*In*) *Methods of Soil Analysis: Part 2 – Chemical and Microbiological Parameters*, 3rd ed, pp 199–224. Page A L, Miller R H, Keeney D R (Eds.). American Society of Agronomy, Madison, WI.
- Mishra J P, Praharaj C S, Singh K K and Kumar N. 2012. Impact of conservation practices on crop water use and productivity in chickpea under middle Indo-Gangetic plains. *Journal of Food Legumes* **25**: 41–4.
- Mondal Koustav, Singh Kh Chandrakumar and Bandyopadhyaya P K. 2012. Soil moisture and root distribution patterns of lentil as affected by rice habit group in rice-lentil relay cropping system. National Seminar on Development in Soil Science, December 3-6, 2012, PAU, Ludhiana.
- NAAS. 2013. Improving productivity of rice fallows. Policy Paper No. 64, National Academy of Agricultural Sciences, New Delhi. 16 p.
- Patil Shirish S, Kelkar Tushar S and Bhalerao Satish A. 2013. Mulching: A soil and water conservation practice. *Research Journal on Agricultural Forestry Sciences* **1**: 26–9.
- Piper C S. 1966. *Soil and Plant Analysis*, Hans Publishers, Bombay.
- Praharaj C S. 2013. Managing precious water through need based micro-irrigation in a long duration pigeonpea under Indian Plains. *In International Conference on Policies for Water and Food Security*, Cairo, Egypt, 24-26 June, 2013, p 4.
- Praharaj C S, Ummed Singh and Kalikrishna Hazra. 2014. Technological interventions for strategic management of water for conserving natural resources. (*In*) *Proceeding of 6th World Congress on Conservation Agriculture –Soil Health and Wallet Wealth*, Winnipeg, Manitoba, Canada, 22-26 June, 2014, p 4-6.
- Praharaj C S, Ummed Singh, Singh S S and Kumar N. 2017. Micro-irrigation in rainfed pigeonpea-Upscaling productivity under Eastern Gangetic Plains with suitable land configuration, population management and supplementary fertigation at critical stages. *Current Science* **112**: 95-107.
- Praharaj and Chandra Sekhar. 2014. Water management strategies for pulse based cropping systems. (*In*) *Resource Conservation Technology in Pulses*, pp.199-212. Ghosh *et al.* (Eds). Scientific Publishers, Jodhpur.
- Pratibha G, Pillai K G, Satyanarayan V and Hussain M M. 1996. Tillage systems for production of black gram (*Vigna mungo*) succeeding rice crops. *Legume Research* **19**: 23–8.
- Singh N P, Praharaj C S and Sandhu J S. 2016. Utilizing untapped potential of rice fallow of East and North-east India through pulse production. *Indian Journal of Genetics* **76**(4): 388–98.
- Venkatesh M S, Hazra K K, Ghosh P K, Praharaj C S and Kumar N. 2013. Long-term effect of pulses and nutrient management on soil carbon sequestration in Indo-Gangetic plains of India. *Canadian Journal of Soil Science* **93**: 127–36.
- Walkely A and Black I R. 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29–37.