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Research Paper

Effect of irrigation and nitrogen management on rice (*Oryza sativa*) under system of rice intensification and its residual effect on lentil (*Lens culinaris*)

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ABSTRACT

A field experiment was conducted to study the effect of irrigation scheduling and nitrogen management on growth, yield, quality and relative economics of hybrid rice (*Oryza sativa* L.) (cv. 'PHB 71') under SRI and their residual effect on lentil (*Lens culinaris* Medik) (cv. 'HUL 57') on sandy-clay loam soil of Varanasi, Uttar Pradesh during rainy (*kharif*) and winter (*rabi*) seasons of 2014–15 and 2015–16. The experiment was laid out in split-plot design assigning 3 irrigation scheduling [irrigation at 2 days after disappearance of ponded water (DADPW), 5 DADPW and 8 DADPW] in the main-plots and 5 nitrogen management practices, [Recommended dose of nitrogen (RDN), RDN + *Sesbania aculeata* Poir as co-culture with rice, 75% RDN + *Sesbania aculeata* Poir as co-culture with rice, RDN + blue green algae (BGA) and 75% RDN+BGA] in the sub-plots, with 3 replications. Results revealed higher growth parameters, yield attributes and grain and straw yields (6.67 and 8.43 t/ha, respectively) under scheduling of irrigation at 2 DADPW as compared to 8 DADPW although it was statistically at par with scheduling of irrigation at 5 days after disappearance of ponded water. The magnitude of increase in grain and straw yield of hybrid rice under SRI by scheduling of irrigation at 2 DADPW over 8 DADPW was 14.0 and 10.3%, respectively on pooled basis. The NPK uptake by the crop and hulling, milling and head rice recovery of rice grain were found to be higher under scheduling of irrigation at 2 DADPW. Among the nitrogen management practices, RDN+BGA produced markedly higher leaf-area index (4.78), dry matter accumulation/hill (67.6 g), effective tillers/m^2 (262), panicle length (31.7 cm), grains/panicle (190), weight/panicle (5.64 g), 1,000-grain weight (24.8 g), grain yield (6.78 t/ha) and straw yield (8.66 t/ha) over other nitrogen management practices. The residual effect of scheduling of irrigation at 5 DADPW applied to rice exhibited higher value of pods/plant, 1,000-grain weight, yield of grain and stover of lentil as well as NPK uptake by the crop. Further, application of RDN (150 kg N /ha) along with BGA (12 kg BGA powder/ha) to rice recorded the highest pods/plant, 1,000-grain weight and grain and stover yield and NPK uptake by succeeding lentil.

Key words : Available NPK, Irrigation scheduling, Nitrogen, Rice, System of rice intensification

Rice is a main dietary component of the Indian population and supplies 31% of total calories required. India will need 112 million tonnes of rice in 2020, which is 7 million tonnes more than the present production as per Agricultural Policy Vision 2020 by Indian Council of Agricultural Research, New Delhi. Further, per capita water availability has declined from 5,000 m^3/annum in 1,950 to around 2,000 m^3 now and is projected to further decline to 1,500 m^3 by 2025 leading to far less water availability for agriculture (www.indiawaterportal.org). The water availability for agricultural use has reached a critical level as the country uses more than 80% of the surface water in this sector alone. Climate change has also brought an alarming situation to agricultural sector particularly of increasing scarcity of water, which threatens irrigated low-land rice production. Moreover, in Uttar Pradesh, rice is mostly cultivated in puddled fields with continuously ponded water and it is also one of the biggest users of world's fresh water resources. With current practices, the rice crop consumes large quantity of irrigation water, ranging between 1,500 and 3,000 mm/ha (Singh *et al.,* 2002). Various water-saving techniques have been developed for rice production systems, such as alternate wetting and drying (Belder *et al*., 2004), saturated soil culture (Tuong *et al*., 2004), direct dry seeding (Tabbal *et al*., 2002) and aerobic rice culture (Kato *et al*., 2009). These water-saving tech-

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nologies are mostly aimed at reducing unproductive losses of water through seepage, percolation, and evaporation, thereby increasing the productivity of total water inputs from rainfall and irrigation. However, very little information is available regarding the minimum volume of water required for enhancing productivity of rice under SRI method in eastern Uttar Pradesh. Further, low use of organic manure by farmers and maximum use of chemical fertilizer leading to the development of nutrient deficiencies are major constraints in realizing higher yield. Nitrogen-management strategies should be aimed at achieving the twin goals of fertilizers economy and sustainability. The negligence to the conservation and use of organic sources for nutrients has not only exhausted soil nutrient reserves but also resulted in an imbalance among the available nutrients leading to problematic soil health (Satyanarayan *et al.,* 2002). Integration of inorganic and organic sources such as green manuring, blue green algae and their efficient management has shown promise in sustaining the productivity and soil health (Karmakar *et al.,* 2011). Alternate wetting and drying and organic manures are important components of SRI. Since location-specific study on irrigation as well as organic nitrogen management in SRI is lacking, a study was undertaken to ascertain the effect of irrigation and nitrogen management on rice under system of rice intensification and its effect on lentil.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2014–15 and 2015–16 at Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25°18' N, 83°03' E, 75.7 m above the mean sea-level) situated in the Northern-Gangetic alluvial plains having characteristics of sub-tropical climate. Soil of the experimental field was sandy-clay loam (typic *Ustochrepts*) with 0.39 and 0.41% organic carbon, 210.1 and 212.0 kg/ha available nitrogen, 24.30 and 26.2 kg/ha available phosphorus and 214.3 and 209.6 kg/ha available potassium during the respective years. The treatments consisted 3 irrigation scheduling in the main-plots (irrigation at 2 DADPW, 5 DADPW and 8 DADPW) and 5 nitrogen-management practices in the sub-plots [Recommended dose of nitrogen (RDN), RDN + *Sesbania aculeata* as co-culture with rice, 75% RDN + *Sesbania aculeata* as co-culture with rice, RDN+BGA and 75% RDN+ BGA] were tested in a split-plot design with 3 replications. Recommended dose of fertilizers was 150, 75 and 75 kg NPK/ha. Nitrogen, phosphorus and potassium were supplied through urea, diammonium phosphate and muriate of potash respectively. Phosphorus and potassium were applied uniformly as basal to all the plots. Half dose of nitrogen was applied as basal and remaining half dose applied in 2-equal splits at tillering and panicle initiation stages respectively as per treatment. Before the transplanting of rice, 50 kg seed/ha of *Sesbania aculeata* was broadcasted manually as per the treatment. Conoweeder as a part of SRI was run manually between rows of rice crop at 20 and 35 days after transplanting irrespective of the treatment to control the weeds as well as to incorporate the green biomass of *Sesbania*. The working principle of conoweeder was uprooting of plants by front wheel and incorporation of uprooted weed into the soil by the rear wheel. The dry algal material was broadcasted at a rate of 12 kg powder/ha as the treatment over the standing water in rice field during both the years. Seedlings of hybrid rice (cv. ‘PHB 71’) were raised as per the principle of SRI in which the rice seedlings were grown separately on raised beds. Single seedling of 12 days old was transplanted at a spacing of 25 cm × 25 cm on July 1 during 2014 and on July 2 during 2015. The plots were inspected every day in the morning between 7 and 8 AM for disappearance of ponded water i.e. 85±2% soil moisture at plough layer (0–15 cm). The soil moisture was measured through Time-Domain Reflectometer. If the ponded water was not visible at the time of observation then from that day counting for the next irrigation was done, considering that day as zero day. The depth of each irrigation was kept at 5 cm with the help of Parshall flume. Rescheduling of irrigation was done if there was rainfall in between. Irrigation application was stopped 15 days before harvest. All the data pertaining to growth, yield attributes and yield were recorded properly. The total rainfall during both the crop seasons of 2014–15 and 2015–16 was 839.8 and 926.8 mm, respectively. The physical and chemical quality characteristics of kernels were determined for head rice recovery, kernel length, kernel breadth, length/breadth (L/B) ratio and linear kernel elongation ratio using an average of 10 randomly selected kernels (Ghosh *et al.,* 1971). Crop response to the treatments was measured in terms of various quantitative and qualitative indices. The leaf-area index (LAI) was measured by leaves of 5 plants taken from each penultimate rows and leaf area was recorded with a leaf-area meter (Systronics 211). The LAI was worked out as: Leaf-area index = Total leaf-area (cm^2)/Land area (cm^2). To calculate different quality parameters such as hulling and milling (%); 100 g sample of unhusked paddy from each plot was subjected to dehusking in a SATAKE dehusker. The hulling percentage was recorded by weight of brown rice divided by weight of rough rice multiplied by hundred. The milling percentage was calculated by weight of milled rice divided by weight of rough rice and multiplied by hundred. The percentage of the head rice recovery was calculated by weight of whole polished rice divided by weight of rough rice and multiplied by hundred. Protein content in grain was worked out by multiplying the nitrogen content in grain with the factor (6.25). Protein yield was determined by multiplying the protein content in grain with their respective yields. Kernel elongation ratio was obtained by division of length of cooked kernel to length of raw kernel. After harvest of hybrid rice, lentil cv. 'HUL 57' (Malaviya Vishwanath) was sown in the second fortnight of November during both the years at a row spacing of 30 cm with a seed rate of 40 kg/ha. Since the objective of this study was to quantify the residual effect of irrigation scheduling and nitrogen management applied to preceding rice on succeeding lentil, only 50% recommended dose of nitrogen and phosphorus (12.5 kg N and 25 kg P_2O_5/ha) was added to succeeding lentil. Yield attributing characters and productivity of preceding rice as well as succeeding lentil were recorded by standard procedure. Grain and straw/stover samples were dried, processed and analysed for their total nitrogen content by micro-Kjeldahl's, phosphorus by Vanadomolybdo phosphoric acid-yellow colour method and potassium by flame-photometer. Nutrient uptake was estimated by multiplying the content with the oven-dry weight of biological yield. The samples were oven dried at 70°C ± 2°C till constant weight was achieved. All the data obtained from hybrid rice and succeeding lentil crop for consecutive two years were statistically analyzed using the F-test.

RESULTS AND DISCUSSION

Growth and yield attributes of rice

Scheduling of irrigation in rice at 2 days after disappearance of ponded water (DADPW) recorded significantly higher leaf-area index (LAI) (5.02), dry matter accumulation (DMA) (67.6g/hill), effective tillers/m^2 (257), panicle length (31.7 cm) and grains/panicle (187) as compared to 8 DADPW but remained at par with 5 DADPW (Table 1). The magnitude of increase in DMA, effective tillers/m^2 and grains/panicle by 2 DADPW over 8 DADPW was 5.6, 16.3 and 6.9%, respectively. The severe water stress in plots irrigated at 8 DADPW led to less LAI, DMA, number of effective tillers, panicle length, panicle weight and test weight of rice. Water stress at the vegetative stage delayed the heading rate with a decrease of effective tillers/hill. The lowest values of yield attributes at 8 DADPW might be attributed to the fact that plants under this treatment could not get sufficient water to fulfill their evapotranspirational demands. Dass and Chandra (2013) and Sandhu and Mahal (2014) observed that filled spikelets/ panicle, and filled spikelets weight/ panicle of rice signicantly higher under irrigation at 1 DADPW over 5 DADPW and 3 DADPW, respectively. Nitrogen management practices also showed significant effect on all the growth and yield attributing characters of hybrid rice. Application of recommended dose of nitrogen (RDN)+blue green algae (BGA) recorded the highest LAI (4.78), DMA (67.6 g/hill), grains/panicle (190), panicle weight (5.64 g) and 1,000-grain weight (24.8 g). However, application of RDN + *Sesbania aculeata* as co-culture remained statistically at par with 75% RDN + *Sesbania aculeata* as co-culture, while 75% RDN + BGA was found superior to RDN alone. Increase in nitrogen release through either *Sesbania* or BGA for longer time facilitated the plants to remain green for longer period. This contributed to the production of more carbohydrates through enhanced absorption, translocation and assimilation of nutrients by the plants required for various physiological processes for increased photosynthetic products in terms of higher panicle weight and grains/panicle (Fageria and Moreira, 2011). These results are in agreement with the findings of Srivastava *et al.* (2014), who observed that application of 100% RDF (150, 75, 75 kg NPK/ha) increased effective tillers/m^2, grains/panicle, test weight, grain yield and straw yield of rice (cv. 'PHB 71') under SRI over the 50% RDF.

Rice yield

Significant increase in grain yield of rice was recorded when scheduling of irrigation was done at 2 DADPW, but it remained at par with 5 DADPW (Table 1). The grain yield of hybrid rice under scheduling of irrigation at 2 DADPW was 44.0% higher (6.67 t/ha) over scheduling of irrigation at 8 DADPW. The reduction in grain yield with curtailment in the amount of irrigation water applied might be due to the fact that due to less availability of water, the physical and chemical conditions of soil might not have been favourable for proper growth and formation of yield attributes, as it was evident from the data on these attributes. Sandhu and Mahal (2014) observed similar result with rice cv. 'PAU 201'. Nitrogen management practices showed significant effect on grain yield as of rice. Application of RDN along with BGA recorded significantly higher grain yield over rest of the nitrogen management treatment. The grain and straw yields of hybrid rice under application of RDN along with BGA were 13.6 and 14.9% higher than RDN alone. This might be due to incorporation of BGA and more availability of nutrients resulting in higher nutrient uptake with consequent increase in yield attributes. The increase in grain and straw yields might be further ascribed to combined application of RDN along with BGA which enhanced the microbial population in soil, root proliferation and nutrients uptake leading to the better dry matter production (Bahadur *at al.*, 2013). Sharma *et al.* (2015) observed that the substitution of 25% NPK through FYM of the recommended dose along with

Table 1. Effect of irrigation and nitrogen management on growth parameters, yields attributes, yield and relative economics of rice as under SRI (pooled data of 2 years)

Treatment	Growth parameters			Yield attributes				Yield (t/ha)		Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit : cost ratio
	LAI at 90 DAT	Dry-matter accumulation (g/hill) 90 DAT	Effective tillers/m²	Panicle length (cm)	Grain/ panicle	Panicle weight (g)	1,000-grain weight (g)	Grain	Straw			
Irrigation scheduling												
Irrigation at 2 DADPW	5.02	67.6	257	31.7	187	5.43	24.7	6.67	8.43	110.2	72.2	1.90
Irrigation at 5 DADPW	4.79	65.6	243	30.9	183	5.15	23.9	6.52	7.96	107.2	71.3	1.99
Irrigation at 8 DADPW	4.60	64.0	221	29.5	175	4.83	23.0	5.85	7.64	97.2	62.1	1.77
SEm±	0.07	0.68	4.81	0.30	2.12	0.11	0.24	0.103	0.121	1.6	1.6	0.045
CD (P=0.05)	0.30	2.67	18.9	1.18	8.36	0.43	0.96	0.403	0.473	6.41	6.42	0.18
Nitrogen management												
RDN (150 kg N/ha)	4.52	64.2	221	29.2	178	4.66	23.0	5.97	7.56	98.8	62.9	1.76
RDN + *S. aculeata* as co-culture	4.63	66.4	241	30.6	182	5.20	23.9	6.34	8.04	105.0	67.8	1.83
75% RDN + *S. aculeata* as co-culture	4.87	65.8	238	30.3	180	5.11	23.7	6.30	7.74	103.6	67.1	1.83
RDN + BGA (12 kg/ha)	4.78	67.6	262	31.7	190	5.64	24.8	6.78	8.69	112.3	75.9	2.08
75% RDN + BGA	5.21	64.8	238	30.5	178	5.08	23.8	6.34	8.02	104.7	68.8	1.92
SEm±	0.10	0.78	5.9	0.27	2.55	0.11	0.26	0.124	0.118	1.8	1.8	0.049
CD (P=0.05)	0.29	2.28	17.2	0.78	7.47	0.34	23.0	0.363	0.346	5.36	5.36	0.14

DADPW, Days after disappearances of ponded water

5 kg Zn/ ha and PSB+BGA were better than NPK treatment alone in respect of grain yield.

Nutrient uptake

Different irrigation scheduling exhibited significant effect on nitrogen uptake by rice and the maximum value was observed with 2 DADPW (Table 2). More phosphorus uptake was recorded in plots irrigated at 2 DADPW over 8 DADPW, but it was statistically at par with irrigation schedule in which irrigation was applied at 5 DADPW. The reason for higher nitrogen and phosphorus uptake with more frequent amount of irrigation water might be due to fast mineralization of nitrogen and solubilization of phosphorus by water resulting, their higher availability to plants and hence an increase in nitrogen and phosphorus uptake. Further, among different irrigation schedules, maximum potassium uptake was found in plots irrigated at 2 DADPW. The increase in potassium uptake by rice with increasing amount of irrigation water might have happened due to addition of potassium through underground water used for irrigation. Hazra and Chandra (2014) and Sandhu and Mahal (2014) reported that soil moisture stress signicantly reduced the uptake of phosphorus and potassium.

Application of RDN + BGA recorded significantly higher N, P and K uptake by rice as compared to rest of the nitrogen management practices. The per cent increase in N, P and K uptake with RDN+BGA was in the order of 25.9, 39.4 and 23.5% respectively over application of RDN alone. BGA is directly involved in increasing concentration of nitrogen through their rapid mineralization due to drying and wetting cycles, synthesis of phytohormones, solubilization of minerals like phosphorus and production of siderophores that chelate iron and make it available to the plant root (Mishra *et al*., 2013). Pooniya and Shivay (2011) reported the highest uptake of nitrogen and zinc by Basmati rice through *Sesbania aculeata* as summer green manure crop. Sharma *et al.* (2015) also observed maximum nutrient (N, P, K, S and Zn) uptake of 75.6, 18.4, 120.1, 27.8 kg/ ha and 231.9 g/ ha, respectively by rice when it was supplied with 75% NPK+5 t FYM/ ha+PSB+BGA+Zn (5 kg Zn /ha).

Soil fertility after rice

Scheduling of irrigation at 5 DADPW recorded significantly higher N, P and K and organic carbon content as compared to 2 DADPW, but remained statistically at par with 8 DADPW with respect to available N, P and K in soil (Table 2). The maximum available nitrogen in soil was recorded with the application of RDN either with *Sesbania aculeata* as co-culture or BGA. In case of available phosphorus it was recorded higher under application of RDN along with BGA. The potassium availability was more under RDN+ *Sesbania aculeata* as co-culture and 75% RDN+ *Sesbania aculeata* as co-culture with rice. Yang *et al.* (2004) observed that the total nitrogen in paddy soil was 37–67% higher with the combined use of organic sources and chemical fertilizers against the sole chemical fertilizers treatment. Increment in available phosphorus content of soil with BGA application may also be ascribed to greater mobilization of native soil phosphorus by reducing the capacity of soil mineral to fix phosphorus and increase its availability through release of organic acids. Sharma *et al.* (2015) recorded that the conjunctive use of organic manure and fertilizers along with biofertilizers and micronutrient (Zn) gave the highest availability of N, P, K, S and Zn at post-harvest soil of rice.

Quality parameters

Scheduling of irrigation to rice at 2 DADPW recorded significant improvement in protein content in grains (7.78%), hulling percentage (74.8), milling percentage (70.1) and head rice recovery (58.5%) except kernel length over scheduling of irrigation at 8 DADPW (Table 3). Quality parameters, viz., kernel length and kernel breadth before and after cooking were analysed and found to be statistically at par due to the different irrigation scheduling. Application of RDN along with BGA showed significantly higher protein content (7.77%), hulling (75.61%), milling (68.6%), head rice recovery (58.2%). Yadav *et al*. (2013) also concluded that the application of 75% RDF along with BGA recorded the highest hulling, milling and head rice recovery percentage.

Yield attributes and yield of succeeding lentil

Number of pods/plant and 1,000-grain weight of succeeding lentil were found to be significantly higher when scheduling of irrigation was carried out at 5 DADPW (Table 4). Residual moisture and nutrient availability after harvest of preceding rice was more with scheduling of irrigation at 5 DADPW as compared to rest of the scheduling, which was evident from the enhanced uniform plant stand. Inspite of the residual moisture availability being the highest at 2 DADPW, comparatively low nutrient availability over 5 DADPW for crop growth resulted in less yield contributing characters of lentil. Residual of RDN+BGA had significant effect on pods/plant and 1,000-grain weight of succeeding lentil. Singh *et al.* (2013) and Jat *et al.* (2015) observed that the residual effect of preceding treatment i.e. the application of 50% RDN + 50% N through FYM + *Azospirillum* to rice recorded the highest number of effective tillers, grains/ear, 1,000-grain weight and grain and straw yields of succeeding wheat (cv. 'HUW 234').

Lentil recorded the highest grain yield when it was grown on the residual moisture at 5 DADPW to rice. The grain and stover yields of succeeding lentil grown with scheduling of irrigation at 5 DADPW was 3.0 and 16.6% higher over scheduling of irrigation at 8 DADPW and 2

Table 2. Effect of irrigation and nitrogen management on uptake of NPK by rice, soil available NPK and organic carbon content after harvest of the crop (pooled data of 2 years)

Treatment	Total nutrient uptake (kg/ha) by hybrid rice			Post harvest available nutrient status (kg/ha) of soil after rice			
	Nitrogen	Phosphorus	Potassium	N	P_2O_5	K_2O	Organic carbon (%)
Irrigation scheduling							
Irrigation at 2 DADPW	140	29.90	157	177	19.30	187	0.42
Irrigation at 5 DADPW	131	28.19	144	208	22.99	242	0.45
Irrigation at 8 DADPW	118	24.37	134	202	23.09	219	0.41
SEm±	2.21	0.56	3.0	5.65	0.74	9.05	0.006
CD (P=0.05)	8.71	2.23	11.7	22.20	2.93	35.5	0.026
Nitrogen management							
RDN (150 kg N/ha)	116	22.89	132	179	19.87	183	0.43
RDN + *S. aculeata* as co-culture	130	27.84	146	210	21.90	237	0.43
75% RDN + *S. aculeata* as co-culture	127	26.76	140	192	21.56	226	0.40
RDN + BGA (12 kg/ha)	146	31.90	163	213	23.02	209	0.42
75% RDN + BGA	129	27.95	143	187	22.67	223	0.45
SEm±	2.30	0.54	2.39	6.95	0.51	10.3	0.008
CD (P=0.05)	6.73	1.58	7.0	20.30	1.49	30.3	0.024
Initial value				210.1	24.3	214.3	0.39

DADPW, Days after disappearances of ponded water

Table 3. Effect of irrigation and nitrogen management on quality parameters of rice under SRI (pooled data of 2 years)

Treatment	Protein content in grain (%)	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length before cooking (cm)	Kernel length after cooking (cm)	Kernel breadth before cooking (mm)	Kernel breadth after cooking (mm)	Length elongation ratio	Length breadth ratio before cooking
Irrigation scheduling										
Irrigation at 2 DADPW	7.78	74.8	70.1	58.5	7.48	13.2	2.11	2.25	1.77	1.08
Irrigation at 5 DADPW	7.52	70.8	66.8	57.3	7.62	13.0	1.89	2.21	1.71	1.21
Irrigation at 8 DADPW	7.34	66.7	63.8	52.0	7.45	12.5	1.83	2.18	1.71	1.22
SEm±	0.07	1.40	1.12	0.88	0.06	0.30	0.06	0.03	0.04	0.04
CD (P=0.05)	0.30	5.50	4.42	3.47	NS	NS	NS	NS	NS	NS
Nitrogen management										
RDN (150 kg N/ha)	7.14	64.9	64.0	54.2	7.22	12.2	1.99	2.24	1.70	1.15
RDN + *S. aculeata* as co-culture	7.60	69.5	64.4	56.9	7.55	12.7	1.93	2.27	1.70	1.23
75% RDN + *S. aculeata* as co-culture	7.55	69.6	62.1	55.5	7.41	13.3	1.89	2.14	1.80	1.18
RDN + BGA (12 kg/ha)	7.77	75.6	68.6	58.2	7.77	13.0	1.97	2.12	1.68	1.09
75% RDN + BGA	7.54	70.3	61.3	54.9	7.64	13.3	1.93	2.29	1.77	1.20
SEm±	0.07	1.50	1.09	0.80	0.19	0.32	0.05	0.05	0.05	0.05
CD (P=0.05)	0.23	4.38	3.20	2.35	NS	NS	NS	NS	NS	NS

DADPW, Days after disappearances of ponded water; NS, non-significant

DADPW, respectively. Further, the highest grain and stover yields of succeeding lentil were recorded with the application of RDN along with BGA to rice and the magnitude of increase was 11.7 and 11.6 per cent, respectively over the application of RDN alone. The residual effect of 100% RDN+BGA to preceding rice on succeeding lentil yield might be due to higher organic carbon content as well as more available NPK in the soil after harvest of rice. Similar findings were observed by Tripathi *et al.* (2009) and Singh *et al.* (2013) under succeeding rice and lentil, respectively.

Nutrient uptake by succeeding lentil

Scheduling of irrigation and nitrogen management practices applied to preceding rice had a significant effect on N, P and K uptake by grain and stover of succeeding lentil (Table 4). This might be due to more available potassium and organic carbon found in the soil as compared to initial value. Further, scheduling of irrigation at 5 DADPW exhibited higher uptake of nitrogen, phosphorus and potassium by grain and stover of lentil but remained at par with 8 DADPW. The nutrient left after harvesting of rice under scheduling of irrigation at 2 DADPW was less as compared to scheduling of irrigation at 5 DADPW and 8 DADPW. Application of RDN+BGA to rice also significantly increased the uptake of NPK by succeeding lentil. This might be due to significantly higher post harvest available NPK content in soil after rice harvest under the treatment. Similar results were reported by Singh *et al.* (2013) under rice-lentil system.

Soil fertility after lentil

Scheduling of irrigation and nitrogen management practices applied to rice remained statistically unaffected with respect to available nitrogen, phosphorus and potassium and organic carbon content in soil after harvest of succeeding lentil.

Relative economics

The gross and net returns were higher at 2 DADPW over 8 DADPW but statistically at par with 5 DADPW (Table 1). This higher gross and net returns could be attributed to higher grain and straw production under this treatment. Among nitrogen management practices higher gross returns, net returns and benefit: cost ratio were recorded with application of RDN along with BGA. Srivastava *et al*. (2014) found that the integration of RDF (150, 75, 75 kg NPK/ha) with vermicompost at 30 kg N/ha gave the maximum net returns by hybrid rice under SRI.

The results of the present field investigation revealed

Table 4. Residual effect of irrigation and nitrogen management practices applied to rice on yield attributes, yield, nutrient uptake by succeeding lentil and soil fertility after harvest of lentil (pooled data of 2 years)

Treatment	Yield attributes of succeeding lentil			Yield (t/ha) of succeeding lentil		Nutrient uptake (kg/ha)			Soil nutrient status (kg/ha) at lentil harvest			
	Pods/ plant	Grains/ pod	1,000- grain weight(g)	Grain	Stover	Nitrogen	Phosphorus	Potassium	N	P_2O_5	K_2O	Organic carbon (%)
Irrigation Scheduling												
Irrigation at 2 DADPW	93.3	1.93	23.6	1.14	1.48	59.8	7.37	40.4	189	19.4	204	0.43
Irrigation at 5 DADPW	102.1	1.93	24.3	1.34	1.93	77.0	9.15	50.7	188	20.9	206	0.46
Irrigation at 8 DADPW	91.8	1.94	23.2	1.27	1.83	74.0	8.31	47.5	198	21.8	185	0.42
SEm±	1.58	0.037	0.19	0.024	0.049	1.43	0.10	1.19	10.2	0.62	6.27	0.009
CD (P=0.05)	6.22	NS	0.78	0.094	0.195	4.19	0.40	3.48	NS	NS	NS	NS
Nitrogen management												
RDN (150 kg N/ha)	87.8	1.97	22.8	1.20	1.72	65.4	7.74	43.6	179	19.7	198	0.44
RDN + *S. aculeata* as co-culture	98.7	1.93	23.8	1.26	1.75	69.8	8.34	46.9	193	20.8	198	0.44
75% RDN + *S. aculeate* as co-culture	93.7	1.97	23.7	1.24	1.67	68.1	8.08	44.8	195	20.8	189	0.43
RDN + BGA (12 kg/ha)	105.8	1.86	24.5	1.34	1.92	80.4	9.28	49.6	196	21.5	196	0.42
75% RDN + BGA	92.8	1.94	23.7	1.22	1.68	67.6	7.94	46.0	195	20.6	210	0.46
SEm±	1.84	0.035	0.20	0.022	0.46	0.80	0.13	0.59	4.54	0.39	10.44	0.008
CD (P=0.05)	5.37	NS	0.60	0.065	0.135	3.16	0.39	2.32	NS	NS	NS	NS

DADPW, Days after disappearances of ponded water; NS, non-significant

that application of 5 cm irrigation at 2 days after disappearance of ponded water and recommended dose of nitrogen (150 kg N/ha) along with blue green algae (12 kg powder/ha) increased the growth, yield attributes, yield and quality of hybrid rice (*cv*. 'PHB 71') and was also found to have best residual effect on yield attributes and yield of lentil.

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