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Effect of irrigation and nitrogen management on yield and economics of SRI-grown hybrid rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted during rainy season (2014–15) at Banaras Hindu University, Varanasi to standardize water saving and economical nitrogen management options for hybrid rice (*Oryza sativa* L.) under SRI. The experiment was laid-out in a three-times replicated split-plot design involving three irrigation scheduling, viz. irrigation at 2 days after disappearance of ponded water (DADPW), 5 DADPW and 8 DADPW assigned to main-plots and five nitrogen management options, viz. 100% recommended dose of nitrogen (RDN, 150 kg N/ha), 100% RDN + *Sesbania aculeata*, 75% RDN + *Sesbania aculeata*, 100% RDN + BGA (12 kg/ha) and 75% RDN + BGA (12 kg/ha) were allotted in sub-plots. Results reveal that scheduling of irrigation at 2 DADPW was recorded significantly higher dry matter accumulation (DMA), leaf area index (LAI), yield attributes and finally enhanced grain yield and net returns by 16.2, 20.3% and 11.7 and 12.6% during 2014 and 2015, respectively over 8 DADPW but statistically at par with scheduling of irrigation at 5 DADPW. Among nitrogen management options, application of 100% RDN (150 kg N/ha) + BGA (12 kg/ha) recorded higher DMA, LAI, yield attributes and finally enhanced grain yield and net returns by 14.4, 22.8% and 12.6 and 18.5%, respectively over application of 100% RDN alone. Hence, irrigation at 2 DADPW and combined application of 100% RDN + BGA (12 kg/ha) can be recommended for obtaining higher yield and profit from hybrid rice under SRI.

Keywords: BGA, Irrigation scheduling, Recommended dose of nitrogen, System of rice intensification, *Sesbania*

Agricultural Policy vision 2020 of Indian Council of Agricultural Research, India has projected that there will be additional need of 112 million tonnes of rice (*Oryza sativa* L.) by 2020 which is 7.2 million tonnes more than the current rice production level. Therefore, there is huge pressure on country to produce 1.7 million tonnes of additional rice every year with the present resource base to ensure national food security (Dass and Chandra 2013). Water is most crucial input for agriculture especially for rice cultivation which consumes nearly 80% of all country's water for agriculture sector (Dass *et al.* 2015). Further, sustainability of the conventional transplanting method; which is most widely adopted method for rice cultivation throughout the country is under threat as it, consumes large amount of water from field preparation to harvest of the crop and also have greater impact on declining ground water table (Tuong and Bouman 2003). Nowadays, it has become more important to go for alternative rice production system that requires less water, produce similar or higher yield as in conventional transplanted method and concurrently able to tackle challenges of water scarcity imposed by traditional method of rice cultivation. For that, system of rice intensification (SRI) is an emerging resource-saving technology which considerably saves resources and sustains productivity and profitability of rice (Zhao *et al*. 2010, Dass and Dhar 2014). Nitrogen is the single most important mineral element which have greater influence on growth, development and finally yield of a crop. Further, hybrid rice is very responsive to higher doses of nitrogen though its use efficiency is nearly 30–40% under lowland rice because major portion of nitrogen was solely supplied through chemical fertilizers and only small amount of this is taken-up by the crop as larger portion lost through leaching and denitrification. Therefore, judicious use of all possible organic and inorganic sources of N could be exploited for achieving higher nitrogen-use efficiency, yield and profitability from hybrid rice under SRI. Hence, current investigation was carried-out to assess the effect of irrigation and nitrogen management options on yield and economics of SRI-grown hybrid rice.

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MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2014 and 2015 at Agricultural Research Farm, Banaras Hindu University, Varanasi (25°18' N, 83°03' E, 75.7 m above the mean sea-level). The soil of experimental field was sandy-clay loam with 0.40% organic carbon, 211.50, 25.25 and 217.70 kg/ha available nitrogen, phosphorus and potassium, respectively. The experiment was carried-out in a split-plot design with three replications. There were 15 treatment combinations consisting of 3-irrigation scheduling: irrigation at 2 days after disappearance of ponded water (DADPW: I_2), 5 DADPW (I_5) and 8 DADPW (I_8) allotted to main plots and 5 nitrogen management options: 100% recommended dose of nitrogen (RDN, 150 kg/ha: N_1), 100% RDN + *Sesbania aculeata* (N_2), 75% RDN + *Sesbania aculeata* (N_3), 100% RDN + blue-green algae (BGA, 12 kg/ha: N_4) and 75% RDN + BGA (N_5) allotted in sub-plots. The average rainfall at the experimental site was 763 and 880.5 mm during 2014 and 2015, respectively. The hybrid rice variety PHB 71 was grown under system of rice intensification and uniformly fertilized with 75 kg/ha P_2O_5 and 75 kg/ha K_2O through di-ammonium phosphate and muriate of potash, whereas N was supplied through urea as per treatments considering recommended dose of N 150 kg/ha. Half of the N and full doses of P_2O_5 and K_2O were applied as basal at the time of puddling and remaining half of the N was top dressed in two equal splits at tillering and panicle initiation stage. Seeds of *Sesbania aculeata* were sown during the transplanting at 50 kg/ha and buried into the soil by cono-weeder at 20-day stage. BGA was inoculated at 12 kg powder/ha. Seedlings were raised as per method suggested for system of rice intensification (SRI) and 12-days old seedlings were transplanted into the main field at spacing of 25 cm × 25 cm. Manually, cono-weeder was run between the rice row, twice at 20 and 35 days after transplanting (DAT) to burry *Sesbania* and BGA in the soil in addition to weed control. Each plot was inspected every day starting from 15 DAT during morning for disappearance of ponded water. Measurement of soil moisture was done using Time-Domain Reflectometer. The ponded water was not visible during observation started when and by considering that day as zero day. Depth of each irrigation was maintained 5±2 cm by Parshall flumes. Application of irrigation water was stopped 15 days before the harvest of the crop. For dry matter accumulation (DMA), randomly plant sample from 1 m running area was collected by cutting near the ground from each plot and sun dried for 2-3 days in field and then oven dried at $70^0C \pm 2^0C$ till constant weight and expressed g/m^2. Leaf area was determined with the help of leaf-area meter (Systronics 211 Leaf-area meter) by samples randomly collected from 50 cm running area from two rows in each plot. A quadrate of 50 cm × 50 cm^2 size was placed at two random spots in each plot and effective tillers were counted and expressed as no./m^2. Randomly five panicles from each plot were taken and from them panicle-weight, panicle-length and grains/panicle and 1000-grain weight were determined. Grain and straw yield were computed by harvesting crop from the net plots leaving border area of 50 cm from each side. Harvested produce was sundried, bundled and brought to thrashing floor and threshed separately. Economics of each treatment were calculated considering the current market price of each input and output during both the years of experimentation. Gross returns were computed based on market price of rice grain and straw prevailing during study years. Net return was obtained by substracting cost of cultivation from the gross return. However, B: C ratio was calculated dividing gross returns by cost of cultivation. Production efficiency (PE) and monetary efficiency (ME) were calculated dividing grain yield and net returns by crop duration, respectively. Grain protein content was calculated by multiplying their respective N content with 5.95. All data were analysed as per the standard procedure for Analysis of Variance (ANOVA) as described by Rana *et al*. (2014). The significance of treatments was tested by 'F' test (Variance ratio). Standard error of mean (SEm±) was computed in all cases. The difference of the treatment mean was tested by using least significant difference (LSD) at 5% level of probability where 'F' test showed significant differences among means.

RESULTS AND DISCUSSION

Growth parameters: Crop growth parameters like DMA and LAI was significantly influenced by irrigation scheduling (Table 1). Scheduling of irrigation at 2 DADPW recorded higher DMA and LAI over 8 DADPW but at par with 5 DADPW. Higher DMA and LAI in scheduling of irrigation at 2 DADPW might be due to the fact that increased frequency of irrigation created favourable moisture regimes which enabled the crop plant to grow lavishly by providing conducive micro-climate and increasing solubility, absorption, translocation and assimilation of nutrients by the plants for various physiological processes enabled synthesis of protoplasm responsible for rapid cell division led to higher crop growth and development consequently, higher DMA and LAI. Present finding is in harmony with the findings of Dass and Chandra (2012). Further, lower DMA and LAI with scheduling of irrigation at 8 DADPW was because of the fact that plants under this treatment could not get sufficient water to fulfill their evapo-transpirational needs results in poor crop growth and development. Among nitrogen management options, application of 100% RDN + BGA (12 kg/ha) was recorded higher DMA and LAI over rest of the nitrogen management options. This was ascribed owing to higher growth and development of the crop, better production and translocation of the photosynthates into different plant parts due to greater nutrient uptake by the crop because of higher nutrients availability near the crop root zone as higher nutrients supplied by inorganic source apart from that BGA provide slow and continuous supply of nutrients after proper decomposition and mineralization.

Yield attributes and yield: Significantly, higher number of effective tillers/m^2, panicle length, grains/panicle, 1000-grain weight and grain and straw yield was recorded with scheduling of irrigation at 2 DADPW over 8 DADPW but statistically at par with 5 DADPW (Table 1). Higher yield attributes and yield with scheduling of irrigation at 2 DADPW was due to the more favourable moisture content in crop root zone results in proper root and shoot growth,

Table 1 Effect of irrigation and nitrogen management on dry matter accumulation, leaf area index, yield attributes and yield of SRI-grown hybrid rice

Treatment	Dry matter accumulation at harvest (g/m^2)		LAI at 60 DAT		Effective tillers/m^2		Panicle length (cm)		Grains/ panicle		1000-grain weight (g)		Grain yield (kg/ha)		Straw yield (kg/ha)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Irrigation scheduling																
I_2	1132	1164	4.97	5.20	254	259	31.4	31.9	187	188	24.1	25.3	6575	6762	8259	8598
I_5	1092	1122	4.89	5.08	239	244	30.6	31.1	183	182	23.3	24.5	6346	6693	7830	8086
I_8	1039	1066	4.37	4.57	219	222	29.6	29.3	175	175	22.3	23.7	5655	6052	7515	7765
SEm±	16.0	16.2	0.10	0.18	5.04	4.61	0.31	0.49	2.04	2.24	0.27	0.22	105.0	100.5	111.2	136.3
CD (P=0.05)	63.8	63.7	0.39	0.46	19.80	18.10	1.24	1.95	8.01	8.82	1.08	0.88	412.4	394.8	436.8	535.5
Nitrogen management options																
N_1	1060	1083	4.33	4.43	220	223	28.8	29.5	179	178	22.5	23.5	5809	6139	7310	7812
N_2	1091	1125	4.80	5.03	239	243	30.6	30.7	181	182	23.3	24.7	6200	6497	7928	8144
N_3	1089	1119	4.61	4.84	236	241	30.4	30.3	180	181	23.0	24.4	6131	6461	7586	7895
N_4	1129	1159	5.43	5.67	258	262	32.4	33.0	190	191	24.1	25.5	6647	6916	8583	8788
N_5	1071	1101	4.54	4.78	236	241	30.5	30.5	178	178	23.1	24.5	6173	6499	7932	8109
SEm±	10.1	10.2	0.10	0.11	6.04	5.80	0.30	0.41	2.68	2.73	0.28	0.26	133.7	119.0	144.1	117.0
CD (P=0.05)	29.4	31.1	0.30	0.34	17.63	16.94	0.88	1.21	7.85	7.99	0.83	0.76	390.3	347.6	420.6	341.7

I_2, Irrigation at 2 DADPW; I_5, Irrigation at 5 DADPW; I_8, Irrigation at 8 DADPW., N_1, 100% RDN; N_2, 100% RDN + *S. aculeata*; N_3, 75% RDN + *S. aculeata*; N_4, 100% RDN + BGA; N_5, 75% RDN + BGA.

Table 2 Effect of irrigation and nitrogen management on economics, monetary efficiency, production efficiency and grain protein content of SRI-grown hybrid rice

Treatment	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio		ME		PE		Grain protein content	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Irrigation scheduling														
I_2	37811	38292	108570	111861	70759	73569	2.87	2.92	532.0	549.0	49.5	50.4	7.5	7.6
I_5	36366	35403	104505	109879	68138	74476	2.87	3.10	512.3	555.8	47.7	50.0	7.3	7.2
I_8	35403	34922	94199	100262	58796	65340	2.66	2.87	442.0	487.6	42.5	45.1	7.1	7.1
SEm±			1638.44	1626.7	1638	1626.7			12.32	12.1	0.79	0.75	0.1	0.1
CD (P=0.05)			6433	6387	6433	6387			48.37	47.66	3.10	2.95	0.2	0.3
Nitrogen management options														
N_1	35981	35660	95946	101577	59965	65917	2.67	2.85	450.8	492.0	43.7	45.8	6.8	6.7
N_2	37265	36944	102654	107245	65389	70301	2.75	2.90	491.6	524.6	46.6	48.4	7.4	7.3
N_3	36778	36457	101004	106249	64226	69792	2.75	2.91	483.0	520.8	46.1	48.2	7.3	7.3
N_4	36548	36227	110224	114397	73676	78170	3.02	3.16	554.0	583.3	50.0	51.6	7.7	7.8
N_5	36061	35740	102293	107203	66232	71462	2.84	3.00	498.0	533.3	46.4	48.5	7.3	7.2
SEm±			1971	1766	1971	1766			14.82	13.1	1.01	0.89	0.1	0.1
CD (P=0.05)			5753	5157	5753	5157			43.26	38.49	2.93	2.59	0.20	0.20

Cost of cultivation=common cost + treatment cost. I_2, Irrigation at 2 DADPW; I_5, Irrigation at 5 DADPW; I_8, Irrigation at 8 DADPW. N_1, 100% RDN; N_2, 100% RDN + *S. aculeata*; N_3, 75% RDN + *S. aculeata*; N_4, 100% RDN + BGA; N_5, 75% RDN + BGA.

nutrient acquisition and higher photosynthetic rate, led to better partitioning of photosynthates from source to sink, all these altogether produce higher yield attributes and crop yield. Similar, results were also reported by Sandhu and Mahal (2014). However, scheduling of irrigation at 8 DADPW recorded lower yield attributes and yield owing to severe water stress results in poor crop growth, lower seed setting, 1000-grain weight and grain yield.

Application of 100% RDN + BGA (12 kg/ha) exhibited marked improvement in yield attributes and produces significantly higher grain and straw yield over the other nitrogen management options. This could be possible due to the combined effect of continuous availability of higher nutrients and growth promoting substances like vitamin B_{12}, ascorbic acid and auxins secreted by BGA and higher dose of chemical fertilizer which enhances crop growth and development, improve expansion of leaf area, accelerate photosynthetic rate and thereby increases supply of carbohydrate to the plants results in higher production of yield attributes, which contributed higher yield. Similar finding was also reported by Srivastava *et al*. (2014). However, 100% RDN + *Sesbania aculeata* and 75% RDN either with BGA or *Sesbania aculeata* being at par with each other and produces higher grain and straw yield over 100% RDN.

Grain protein content: Grain protein content was significantly influenced by irrigation scheduling and nitrogen management options (Table 2). Scheduling of irrigation at 2 DADPW recorded higher grain protein content over 5 DADPW and 8 DADPW. This was attributed due to higher grain yield under this treatment. Among nitrogen management options, application of 100% RDN + BGA (12 kg/ha) recorded significantly higher grain protein content than the other treatments. This could be possible because of higher grain yield under this treatment.

Production efficiency: Higher production efficiency (PE) was recorded with scheduling of irrigation at 2 DADPW followed by 5 DADPW and 8 DADPW (Table 2). Higher PE with scheduling of irrigation at 2 DADPW was due to higher yield under this treatment. However, scheduling of irrigation at 8 DADPW was recorded lower PE due to lower yield within this treatment. Among various nitrogen management options, application of 100% RDN + BGA (12 kg/ha) recorded higher PE than the other treatments due to higher yield under this treatment.

Economics: Scheduling of irrigation at 2 DADPW recorded higher cost of cultivation, gross returns (GRs), net returns (NRs) and B:C ratio over 8 DADP, though it was statistically at par with 5 DADPW (Table 2). Higher cost of cultivation in scheduling of irrigation at 2 DADPW might be due to higher investment on water and its application, whereas higher GRs, NRs and B:C ratio were attributed owing to higher yield than the other the treatments. Among nitrogen management options, application of 100% RDN +BGA (12 kg/ha) was recorded higher cost of cultivation, GRs, NRs and B:C ratio followed by with 75% RDN+BGA (12 kg/ha) than the other treatments. Higher GRs, NRs and B:C ratio with application of 100% RDN +BGA (12 kg/ha) was ascribed to more monetary return owing to higher yield than the other treatments. Similar result also reported by Srivastava *et al*. (2014).

Monetary efficiency: Higher monetary efficiency (ME) was recorded with scheduling of irrigation at 8 DADPW over 5 DADPW and 2 DADPW. This could be possible due to lesser net returns was incurred under this treatment. However, lower ME was found with scheduling of irrigation at 2 DADPW because of higher net returns obtained under this treatment. Among nitrogen management options application of 100% RDN was recorded higher ME than the other treatments. This was ascribed due to lower net returns within this treatment.

Overall, findings of the current study demonstrated that SRI-grown hybrid rice may be irrigated at 2 DADPW and fertilized with combined application of 100% RDN + BGA (12 kg/ha) for obtaining higher resource-use efficiency, yield and profit. However, under condition of scarce water availability, crop may be irrigated at 5 DADPW and fertilized with 100% RDN + BGA (12 kg/ha).

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