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Research Paper

Effect of crop-establishment methods and integrated nitrogen management on productivity of hybrid rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted during the 2 rainy (*kharif*) and winter (*rabi*) seasons (2012–14) on sandy-clay-loam soil at Varanasi, to study the effect of crop-establishment methods and integrated nitrogen management on productivity of hybrid rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system. The experiment was laid out in a split-plot design, comprising crop-establishment methods (normal transplanting and system of rice intensification) and 2 hybrids ('PHB 71' and 'Arize 6444') in combination as main plot and 6 integrated nitrogen-management practices [100% recommended dose of fertilizer (RDF), 125% recommended dose of nitrogen (RDN), 50% RDN + 50% N through farmyard manure (FYM), 50% RDN + 50% N through FYM + *Azospirillum*, 100% N through FYM and No fertilizer)] as subplot treatments, replicated thrice. System of rice intensification (SRI) improved the growth attributes, viz. plant height, number of tillers, dry-matter accumulation, and increased the grain yield by 14.7% over normal transplanting (5.69 t/ha) and recorded significantly higher net monetary returns and output: input ratio over normal transplanting. Rice hybrid, 'Arize 6444' showed significantly higher growth attributes, grain yield, economic return/day and net return with output: input ratio. Integrated N management with 50% RDN + 50% N through FYM + *Azospirillum* resulted in high growth, yield, crop productivity, return/day and net returns. However output: input ratio were recorded higher with 125% RDN followed by 100% RDN. Residual effect of preceding experimental variables particularly normal transplanting, hybrid 'PHB 71' and application of 50% RDN + 50% N through FYM + *Azospirillum* recorded the highest number of effective tillers, grains/ear 1,000-seed weight and grain and straw yield of succeeding wheat.

Key words: Crop establishment, Nitrogen management, Rice hybrids, Residual effect, SRI

System of rice intensification (SRI) is an alternative potential strategic approach to increase rice productivity with less external and cost-effective inputs by altering the environmental conditions that modify microclimatic and soil conditions ultimately reflecting phenotypic expression with the genotype × environment interactions (Krishna and Biradarpati, 2009). Krishna *et al.* (2008) reported an enhanced tillering, early flowering higher yield and better grain quality in SRI practices compared to conventional methods.

Nitrogen application is essential to obtain the higher yield from high yielding nitrogen responsive hybrid rice. But due to increased cost and detrimental effect on soil fertility, supplementing the nutrients through organic sources like farmyard manure (FYM) and other organic manure has become necessary to sustain production of rice and improve soil health. Moreover, the adoption of SRI practices in rice like planting of 8–12 days aged seedlings at wider spacing, using of organic manures and keeping the soil moist without standing water during vegetative growth have resulted in significant yield improvement (Uphoff, 2006). However, there are some constraints for adoption of SRI as per the presently recommended practices like use of organic manures. The release of nutrients from organic manures is not only slow but often organic manures are in scarce supply and doubts have been raised whether organic manures alone can sustain high yield levels on long-term basis or not. Among organic sources like *Azospirillum*, BGA, *Azolla* multiply fast, as well as quickly decompose and proved effective substitute for N fertilizers even up to 25% of the total crop requirement and play a vital role in enhancing growth and development

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of rice after the use of biofertilizer containing *Azospirillum* and promoting rice productivity (Patel, 1998). Residual effect of *Azospirillum* alone clearly revealed marked increase in wheat grain yield during *rabi* season. Use of *Azospirillum* along with no basal application of nitrogen seems more desirable than applying 30 kg N/ha in such condition (Sanoria *et al*., 1982). Hence present investigation was carried out to determine the effect of crop establishment methods and integrated nitrogen management on productivity of hybrid rice and their residual effect on succeeding wheat.

MATERIALS AND METHODS

A field experiment was carried out during the rainy (*kharif*) and winter (*rabi*) seasons of 2012–13 and 2013–14 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) in the Northern-Gangetic alluvial plains having characteristics of sub-tropical climate. The soil of experimental field was sandy-clay loam with 0.34 and 0.35% organic carbon, 205.20 and 213.21 kg/ha available nitrogen, 25.30 and 25.86 kg/ha available phosphorus and 215.60 and 219.80 kg/ha available potassium before the transplanting of rice during 2012 and 2013 respectively. The treatments consisted 2 crop-establishment methods (normal transplanting and system of rice intensification) with 2 hybrids (‘PHB 71’ and ‘Arize 6444’) and 6 integrated nitrogen-management practices [100% recommended dose of fertilizer (RDF), 125% recommended dose of nitrogen (RDN), 50% RDN + 50% N through FYM, 50% RDN + 50% N through FYM + *Azospirillum*, 100% N through FYM and no fertilizer) were tested in a split-plot design, allocating 2 crop-establishment methods and 2 hybrids in main plots and 6 integrated nitrogen management in sub-plots, with 3 replications. Recommended dose of fertilizers, i.e. 150, 75 and 60 kg/ha N, P_2O_5 and K_2O, for rice were applied as per treatments. Nitrogen, phosphorus and potassium were supplied through urea, *diammonium* phosphate and muriate of potash respectively. Phosphorus and potassium were made to all the plots. Half dose of nitrogen was applied as basal and remaining half dose applied in 2 equal splits at tillering and before panicle initiation stages as per treatment. The organic manure (FYM with 0.5% N on dry-weight basis) was applied on equivalent N basis (recommended 150 kg N/ha) (Table 1). Farmyard manure (FYM) was manually incorporated plot wise as per the treatments. Seedlings were treated with biofertilizer ‘*Azospirillum’* by root deep in culture as per treatment. For each hybrid, the rice nursery both for normal transplanting and SRI were grown separately on puddle raised beds. For normal transplanting with 23-day old seedling, nursery bed was raised 14 days before the 10-day-old seedlings to be used for SRI to synchronize the transplanting of rice with spacing 20 cm × 15 cm and 25 cm × 25 cm in puddled soil at a time on 5 July during 2012 and on 4 July during 2013. Weed management was done manually under normal transplanting method. To control weeds in SRI plots, conoweeder was run manually between rows of rice crop twice at 20 and 35 days after transplanting (DAT). Irrigation was scheduled at 5–6 days interval (through Parshall flumes) and the soil was kept only moist (saturation) during vegetative growth followed by 2.5 cm water there onwards in the case of SRI. While in the traditional transplanting 5 cm standing water was maintained from 10 DAT up to 10 days before harvesting. All the data pertaining to growth, yield attributes and yield were suitably recorded. Crop productivity and returns/day were also calculated by grain yield and net returns divided by duration of crop from transplanting to harvest. Economics was computed using the prices of inputs and outputs as per prevailing local market rates. Residual crop wheat (‘HUW 234’) were sown in same layout of rice during both the years with the application of 100% RDF (120, 60 and 60 kg N, P_2O_5 and K_2O/ha) uniformly in each plots. The statistical analysis of the data was done as per procedure of analysis of variance using F-test.

Table 1. Observations pertaining to farmyard manure

Sl. No.	Observations	FYM 2012	FYM 2013
1.	Nutrient content on dry-weight basis (%):		
	(a) Carbon	17.7	17.4
	(b) Nitrogen (N)	0.51	0.50
	(c) Phosphorus (P_2O_5)	0.26	0.25
	(d) Potassium (K_2O)	0.50	0.52
2.	C: N ratio	34.7	34.8

RESULTS AND DISCUSSION

Rice growth and yield attributes

Plant height, number of tillers/hill at harvest, leaf-area index (LAI) at 90 DAT and dry-matter accumulation at harvesting significantly increased owing to SRI planting over normal transplanting (NT) during both the years (Table 2). Younger seedlings of SRI provided sufficient nutrients for vegetative growth by effective utilization of phyllochronic concept, bringing about increased growth and development that lead to enhanced grain and straw yields (Shekhar *et al*., 2009). Amongst rice hybrids, tillers/hill, LAI and dry-matter accumulation/hill significantly increased in ‘Arize 6444’ over ‘PHB 71’ on pooled basis respectively. However, significantly tallest plants were recorded with ‘PHB 71’ in comparison to ‘Arize 6444’.

High efficient photosynthetic performance of super high-yielding rice hybrids to produce more tillers/hill, resulting in to more dry-matter synthesis is largely owing to the increased cytokinin content in their roots contributing to higher grain yield. Root quantity and cytokinin content have been reported to increase in the rice plant at later growth stages (Shu-Qing *et al.,* 2004). These results confirm the findings of Singh *et al.* (2013). Integrated nitrogen management with 50% RDN + 50% N through FYM + *Azospirillum* produced significantly higher plant height, tillers/hill, LAI and dry-matter accumulation than to rest of the treatments, respectively, followed by application of 125% RDN on pooled basis. This might be owing to combined incorporation of inorganic fertilizer with FYM and biofertilizer which supplied nutrients continuously for crop at various growth stages after proper decomposition and mineralization provided favourable effect on vegetative growth with adequately fed with nitrogen. These results confirm with the findings of Sujathamma and Reddy (2004).

Yield

The SRI planting resulted in significantly higher grain and straw yields over NT rice because of to its phyllochronic potential embedded in younger aged seedling (Table 3). Rice hybrid 'Arize 6444' gave significantly higher grain and straw yield and showed greater potential to exploit hybrid vigour over 'PHB 71'. Production of higher number of yield attributes by 'Arize 6444' as compared to 'PHB 71' by owing to efficient utilization and conversion of resources into assimilates increased the yield (Singh *et al.,* 2013). Incorporation of 50% recommended dose of nitrogen (RND) + 50% N through FYM + *Azospirillum* resulted significantly higher grain yield, straw yield than rest of the treatments, mainly owing to beneficial effect of organic sources combined with inorganic fertilizer together with *Azospirillum* inoculation and stimulated photosynthesis activities ultimately led to high yield. *Azospirillum* multiplies fast, as well as quickly decomposes and proved effective substitute for N fertilizers even up to 25% of the total crop requirement and plays a vital role in enhancing rice yield (Patel, 1998). Banayo *et al*. (2012) also reported enhance growth and development of rice after the use of biofertilizer containing *Azospirillum* spp. and are effective biofertilizer providing 30–50% of the crops N requirement.

Crop productivity and returns/day

Crop productivity and returns/day were significantly higher in SRI planting as compared to NT (Table 3). Rice hybrid 'Arize 6444' was found more efficient in production of grain yield than 'PHB 71', which led ultimately to more economic returns/day. Application of 50% RDN + 50% N through FYM + *Azospirillum* significantly resulted

Table 2. Effect of crop-establishment methods, hybrids and integrated nitrogen management on growth attributes of rice (pooled data of 2 years)

Treatment	Plant height (cm) at harvesting	Tillers/hill at harvesting	Leaf-area index at 90 DAT	Dry-matter (g/hill) at harvesting
Crop-establishment methods				
Normal transplanting	118.6	15.2	4.8	62.8
SRI	123.5	18.5	5.3	69.4
SEm±	0.8	0.2	0.1	0.7
CD (P=0.05)	2.6	0.6	0.2	2.0
Hybrids				
'PHB 71'	123.6	15.3	4.9	63.2
'Arize 6444'	118.4	18.4	5.2	69.1
SEm±	0.8	0.2	0.1	0.7
CD (P=0.05)	2.6	0.6	0.2	2.0
Integrated nitrogen management				
100% RDN	124.2	17.5	5.1	71.0
125 % RDN	128.3	19.7	5.3	73.3
50% RDN + 50% N through FYM	119.5	16.7	4.9	69.3
50% RDN + 50% N through FYM + *Azospirillum*	129.1	20.0	5.4	74.5
100% RDN through FYM	113.6	15.3	4.9	62.6
No fertilizer (control)	111.7	11.9	4.8	46.1
SEm±	0.9	0.2	0.1	0.7
CD (P=0.05)	2.8	0.5	0.1	2.0

SRI, System of rice intensification; RDN, recommended dose of nitrogen; DAT, days after transplanting

in higher grain yield and economic returns over rest of the N management treatments, respectively, followed by application of 125% RDN and 100% RDN.

Economics

Among the crop-establishment methods, SRI planting fetched significantly more net returns with output: input

Table 3. Effect of crop-establishment methods, hybrids and integrated nitrogen management on yield, crop productivity, returns/day and economics of rice (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Crop productivity (kg grain/ha/day)	Returns/ day (₹/ha /day)	Net returns (× 10^3 ₹/ha)	Output: input ratio
Crop-establishment method						
Normal transplanting	5.69	7.70	49.1	430.0	49.87	2.27
SRI	6.53	8.71	56.3	570.2	66.13	2.86
SEm±	0.06	0.06	0.5	6.9	-	0.02
CD (P=0.05)	0.18	0.19	1.5	21.2	-	0.06
Hybrid						
'PHB 71'	5.86	7.99	50.5	469.7	54.48	2.47
'Arize 6444'	6.37	8.42	54.9	530.6	61.53	2.66
SEm±	0.06	0.06	0.5	6.9	-	0.02
CD (P=0.05)	0.18	0.19	1.5	21.2	-	0.06
Integrated nitrogen management						
100% RDN	6.49	8.66	55.9	569.3	66.02	2.87
125 % RDN	6.60	8.77	56.9	578.9	67.13	2.88
50% RDN + 50% N through FYM	6.41	8.50	55.2	516.7	59.93	2.50
50% RDN + 50% N through FYM + *Azospirillum*	6.94	9.16	59.9	586.7	68.06	2.70
100% RDN through FYM	5.91	7.92	50.9	397.1	46.06	1.99
No fertilizer (control)	4.33	6.23	37.4	351.9	40.82	2.44
SEm±	0.06	0.07	0.5	7.0	-	0.02
CD (P=0.05)	0.17	0.19	1.5	19.7	-	0.06

SRI, System of rice intensification; RDN, recommended dose of nitrogen; DAT, days after transplanting

Table 4. Residual effects of crop-establishment methods, hybrids and integrated nitrogen management on yield attributes and yield of succeeding wheat (pooled data of 2 years)

Treatment	Effective tillers/m^2	Grains/ ear	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Crop-establishment method					
Normal transplanting	344.8	39.1	41.1	4.56	6.52
SRI	323.6	35.7	39.4	4.27	6.15
SEm±	3.7	0.3	0.2	0.05	0.07
CD (P=0.05)	11.5	1.1	0.5	0.17	0.24
Hybrid					
'PHB 71'	351.0	38.5	40.3	4.58	6.50
'Arize 6444'	317.0	36.2	40.2	4.25	6.17
SEm±	3.7	0.3	0.2	0.05	0.07
CD (P=0.05)	11.5	1.1	NS	0.17	0.24
Integrated nitrogen management					
100% RDN	336.7	34.3	39.6	4.37	6.32
125 % RDN	338.3	38.8	40.6	4.50	6.42
50% RDN + 50% N through FYM	342.5	38.7	40.8	4.52	6.48
50% RDN + 50% N through FYM + *Azospirillum*	352.3	41.8	42.2	4.65	6.59
100% RDN through FYM	336.1	38.3	40.5	4.46	6.32
No fertilizer (control)	299.5	32.4	37.7	4.00	5.89
SEm±	3.5	0.4	0.2	0.06	0.09
CD (P=0.05)	9.8	1.2	0.6	0.18	0.25

SRI, System of rice intensification; RDN, recommended dose of nitrogen; DAT, days after transplanting

ratio over NT on pooled basis respectively (Table 3). Higher grain and straw yields with lower cost of cultivation under SRI than NT resulted in high return. Our results confirm those of Shekhar *et al*. (2009). Hybrid 'Arize 6444' showed significantly more net monetary advantage of over 'PHB 71' with high output: input ratio. Hybrid 'Arize 6444' exhibited more potential to give higher grain and straw yield and recorded higher monetary advantages and output: input ratio than 'PHB 71'. These results support the findings of Singh *et al.* (2013). Application of 50% RDN + 50% N through FYM + *Azospirillum* showed significantly higher monetary advantage over rest of the treatments including the control. It fetched higher net returns over the control. However output: input ratio were higher under application of 125% RDN followed by 100% RDN (2.87), probably owing to more amount of FYM required to supply respective amount of N and thus increased the cost of cultivation, while inorganic sources proved cheaper and recorded higher output: input ratio. Our results confirm those of Gautam *et al*. (2013).

Residual effect on wheat

Residual effect of different experimental variables, viz. Crop-establishment methods, hybrids and integrated nitrogen management showed marked variation on all yield attributes and yield of succeeding wheat (Table 4). Significantly higher number of effective tillers/m^2, grains/ear, 1,000-grain weight, grain yield and straw yield of succeeding wheat were found associated with wheat grown after NT of rice hybrid 'PHB 71' compared to SRI planting and 'Arize 6444'. Relatively lower amount of nutrient absorption under NT and 'PHB 71' produced significant residual effect on increasing yield attributes and yield of succeeding wheat as compared to SRI and 'Arize 6444'. Application of 50% RDN + 50% N through FYM + *Azospirillum* showed higher residual effect and recorded higher value of yield attributes and yield of succeeding wheat during both the years. These results indicated that organic manures supplemented nutrients increased their availability in the soil brought about increase in wheat yield in plots applied with FYM during rice. Our results confirm the findings of Sekhon *et al*. (2011).

Soil-fertility status

Normal transplanting (NT) and rice cultivar 'PHB 71' brought about marked improvement in residual status of N, P and K after harvesting of rice significantly higher over SRI planting and 'Arize 6444' mainly owing to poor uptake of nutrient from the soil. Integrated nitrogen-management practices proved significantly superior to fertilizer alone. Higher value of NPK content in soil was obtained with organic treated source (FYM) than inorganic fertilizer treated. Application of 50% RND + 50% N as FYM + *Azospirillum* left higher amount of residual nutri-

Table 5. Effect of crop-establishment methods, hybrids and integrated nitrogen management on available nutrient status in soil after rice harvest (pooled data of 2 years)

Treatments	Available nitrogen in soil (kg/ha)	Available phosphorus in soil (kg/ha)	Available potassium in soil (kg/ha)
Crop-establishment methods (2)			
Normal transplanting	223.6	26.3	201.8
SRI	212.6	25.6	197.0
SEm±	1.2	0.1	0.7
CD (P=0.05)	3.8	0.4	2.3
Hybrids (2)			
'PHB 71'	220.9	26.3	201.9
'Arize 6444'	215.4	25.5	196.9
SEm±	1.2	0.1	0.7
CD (P=0.05)	3.8	0.4	2.3
Integrated nitrogen management (6)			
100% RDN	211.7	25.3	197.9
125 % RDN	219.1	26.7	200.3
50% RDN + 50% N through FYM	227.2	27.0	200.9
50% RDN + 50% N through FYM + *Azospirillum*	231.7	27.6	202.5
100% RDN through organic source (FYM)	224.5	26.3	201.5
Control (No fertilizer)	195.5	22.5	193.3
SEm±	1.5	0.2	0.9
CD (P=0.05)	4.2	0.5	2.4

SRI, System of rice intensification; RDN, recommended dose of nitrogen; DAT, days after transplanting

ents than to other treatments. Increase in available nutrient with FYM and biofertilizer may be owing to the direct addition of nitrogen through FYM and biofertilizer to the available nitrogen pool of soil. The favourable effect of organic sources in conjunction with chemical fertilizer and biofertilizers in enhancing the availability of nitrogen in soil is well documented. This result confirm with the findings of Paul *et al*. (2013).

It was concluded that 50% of the recommended dose of nitrogen may be substituted by FYM and seedling inoculation with *Azospirillum* performed better than sole inorganic fertilizer to obtain higher yield as well as daily income and economic return from rice cv. 'Arize 6444' under system of rice intensification method. Application of farmyard manure to preceding rice proved advantageous to obtain higher yield of succeeding wheat.

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