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Effect of age of seedling and spacing on yield, economics, soil health and digestibility of rice (*Oryza sativa*) genotypes under system of rice intensification

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ABSTRACT

A field experiment was conducted at the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during 2008 to 2010 to evaluate the influence of system of rice intensification (SRI) under different age of seedling and spacing on productivity of rice genotypes and soil health. Rice genotype PHB 71 was significantly superior to NDR 359 with respect to yield attributes, grain yield, economics, nutrient uptake and soil health. Ten days old seedlings were also significantly better than those of other age of 12 and 14 days old seedlings in respect of yield attributes, grain yield, economics, nutrient uptake and soil health. Similarly wider row spacing of 30 cm × 30 cm significantly favoured higher values of yield attributes, grain yield, economics, nutrient uptake, and soil health due to profuse root growth. Rice hybrid PHB 71 had poor digestibility of rice straw having higher values of crude protein content, crude fiber, oxalic acid and lower values of nitrogen free extract and total ash compared to NDR 359.

Key words: Genotype, Rice straw digestibility, Row spacing, Seedling age, Soil health, SRI, Yield

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population and plays a vital role in food security. It is second most important crop of the world. World rice production nearly doubled from 1960s to 1980s, mainly due to the technological advances coupled with higher yielding crop cultivars referred to 'Green Revolution'. At current rate of population growth (1.5%), the rice requirement by 2025 would be about 125 Mt in the country. Challenges in maintaining the sustainability of rice farming have been increasing with the increased scarcity and competition for water resources, stagnant or declining yield levels, higher fertilizer cost and negative environmental impact due to the increasing use of agrochemicals for rice production. Despite these constraints, rice production must rise over the next generation to meet the world's food needs. Hence, producing more rice (1.7 Mt of additional rice every year) with shrinking resource input is a formidable challenge for ensuring the food, economic, social and water security of the Asian region.

The 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 microclimate and soil conditions ultimately reflecting phenotypic expression with the genotype × environment interactions (Krishna and Biradarpatil 2009). SRI is a set of ideas and insights that emphasizes the use of younger seedling (<15 days) planted singly at wider spacing together with the adoption of intermittent irrigation which together provides better rice growing conditions particularly in the root zone than those grown under traditional practices (Uphoff 2007). By adopting SRI, it is possible to save water (Thiyagarajan *et al.* 2002), protect soil productivity and environment by checking methane gas emission from submerged water cultivation practices (Krishna *et al*. 2008) leading to cost effective rice production (Uphoff 2007).

Seedling age at transplanting is an important factor for uniform rice stands which regulates potential agronomic traits, i e tillering, panicle number and grain yield per unit land area leading to sustained rice production (Ginigaddara and Ranamukhaarachchi 2011). Similarly plant spacing plays a significant role for optimization of rice yield due to efficient utilization of solar radiation as well as nutrients. Closer spacing hampers intercultural operations and as such more competition arises among the plants for nutrients, air and light. As a result, plant becomes weaker and thinner producing lower yield (Salahuddin *et al*. 2009). Keeping this background

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in mind, the present field investigation was carried out to study the effect of SRI on yield, economics and digestibility of rice genotypes and their impact on soil health.

MATERIALS AND METHODS

A field experiment was conducted during rainy (*kharif*) seasons of 2008 to 2010 at the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi situated at 23.2° N latitude, 83.03° E longitude and at an altitude of 128.93 m above mean sea level in north-eastern plains-zone. The soil was Inceptisol, typic Ustochrept. The soil had pH value of 7.46, low in organic carbon (0.41%) and available nitrogen (208.20 kg N/ha) and medium in available phosphorus (18.14 kg P_2O_5/ ha) and potassium (234.46 kg K_2O/ ha).The experiment was laid out in split plot design, comprising genotypes (PHB 71 and NDR 359) and age of seedling [8 Days of sowing (DOS), 10 DOS, 12 DOS and 14 DOS] in combination as main plot and spacing (25 cm × 25 cm and 30 cm × 30 cm) as sub plot treatments replicated thrice. A recommended dose of 120, 60 and 60 kg of N, P_2O_5 and K_2O/ha was applied, respectively. Entire dose of phosphorus and potassium along with half dose of nitrogen was applied as basal (30 kg N through urea and 30 kg N/ha as FYM). The remaining half of the nitrogen was applied in two equal splits at tillering and panicle initiation stages. The field was irrigated to keep it at field capacity without maintaining level of standing water until 45 days after planting to promote tillering. Weeding between rows was done by cono-weeder every two weeks after planting. Biometrical observations on growth, yield attributes and yield were taken. Economics of the treatments and nutrient uptake (N, P and K) were worked out. Rice straw was analyzed to study the different components of its digestibility under SRI following standard procedures. Soil samples were also analyzed for N, P, K status and biological properties (bacteria, fungi and actinomycetes) as well.

RESULTS AND DISCUSSION

Yield and yield attributes

Growth attributes, viz. plant height**,** dry matter production and productive tillers/m^2 of rice differed significantly due to the age of seedling and plant spacing (Table 1) of 2 genotypes. Genotype PHB 71 had significantly taller plants with more productive tillers/m^2 and assimilated higher dry matter due to vigorous plant and root growth leading to higher grain yield. However, age of seedling did not make significant difference in respect of plant height but 10 days old seedlings (DOS) plantation had more productive tillers/m^2 (360.90) and accumulated higher dry matter compared to 12 and 14 DOS except 8 DOS which was comparable and at par to 10 DOS in respect of the said characters. Similarly wider spacing of 30 cm × 30 cm was significantly better than narrow spacing of 25 cm × 25 cm in respect of yield attributes and yield. Infect younger seedling recovered fast enough to transplanting shock for faster growth to achieve higher yield (Sarath and Thilak 2004).

Seedling planted at wider spacing of 30 cm × 30 cm got sufficient space to grow (Shrirame *et al.* 2000) and also utilized resources in a better way (Sarath and Thilak 2004). Therefore, younger seedling planted at wider spacing was congenial for higher yield of both hybrid (PHB 71) and non hybrid (NDR 395) rice genotypes (Rajesh and Thanunathan 2003).

Table 1 Effect of age of seedling and spacing on growth and yield parameters of rice genotypes (Pooled mean over three years)

Treatment	Plant height (cm)	Dry matter production/hill (g)	Productive tillers/ m^2 (No.)	Spikes/hill (No.)	Grains/spike (No.)	Test weight (g)
Genotype						
PHB 71	119.6	76.7	338.8	17.01	213.8	21.18
NDR 359	114.5	75.0	310.5	15.77	249.9	25.25
LSD (P=0.05)	3.24	1.06	24.05	0.432	5.41	1.18
Seedling age (Days)						
8	118.8	75.9	340.8	16.99	211.8	23.36
10	119.0	79.1	360.9	17.45	215.3	23.96
12	117.9	75.1	299.6	15.51	209.4	23.04
14	116.3	73.1	270.5	15.04	198.8	22.91
LSD (P=0.05)	NS*	2.90	26.15	0.61	4.58	0.885
Spacing (cm)						
25 × 25	119.9	73.7	310.5	16.17	203.3	23.40
30 × 30	115.8	77.8	340.6	16.72	210.4	25.10
LSD (P=0.05)	3.48	2.21	21.40	0.50	6.39	0.75

*NS, Not significant

Table 2 Influence of age of seedling and spacing on yield, net return, B:C ratio and NPK uptake by rice genotypes (Pooled mean over three years)

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Net return (₹/ha)	B:C ratio	Nutrient uptake		
					Nitrogen (kg N/ha)	Phosphorus (kg P_2O_5/ha)	Potassium (kg K_2O/ha)
Genotype							
PHB 71	7 219	8 364	32 780	1.13	170.5	59.0	173.2
NDR 359	6 795	7 641	28 781	0.99	199.8	50.7	167.2
LSD (P=0.05)	203	233			15.6	5.5	4.7
Seedling age (Days)							
8	7 295	8 360	33 303	1.15	200.9	62.5	170.8
10	7 334	8 492	33 692	1.16	268.5	67.0	175.7
12	7 028	8 018	31 058	1.07	188.7	54.9	165.6
14	6 647	7 609	27 918	0.96	169.6	50.8	156.2
LSD (P=0.05)	276	313			34.8	5.4	7.2
Spacing (cm)							
25 × 25	6 773	7 760	28 437	0.96	210.5	58.4	163.9
30 × 30	7 455	8 545	35 474	1.26	255.8	65.9	174.8
LSD (P=0.05)	222	254			36.9	5.0	6.4

Economics

Economic analysis indicated that PHB 71 was economical as the values of net returns and B: C ratio were higher than that of NDR 359 (Table 2). It was further observed that high yielding crop cultivars can also give cost effective production under SRI. The net return and B:C ratio were more under 10 days old seedling compared to other age of seedling**.** Planting genotypes with wider spacing of 30 cm × 30 cm was more economical than narrow spacing of 25 cm × 25 cm. Economics is governed by yield of economic produce of the plant and this value was higher for genotype PHB 71, 10 DOS and wider spacing of 30 cm × 30 cm.

Nutrient uptake

The rice genotypes were influenced significantly due to different age of seedling and spacing in respect of uptake of N, P and K (Table 2). Nutrient uptake was significantly higher by genotype PHB 71, 10 DOS and wider spacing of 30 cm × 30 cm and this was probably due to larger root mass production which enabled plants to acquire more nutrients from larger soil volume (Barison and Uphoff 2011).

Rice straw digestibility

The straw of PHB 71 hybrid rice was showed poor in digestibility compared to NDR 359 under SRI due to higher values of per cent crude protein, per cent crude fiber, oxalic acid contents (%) and lower values of nitrogen free extract and total ash contents (%) (Table 3). It is due to genetic characters of hybrid rice. The relatively higher silicon and lignin contents in hybrid rice appears to be another possibility which is directly related to rice straw stiffness lowering down rice straw digestibility (Singh *et al*. 2005 and Shukla *et al.* 2009). However, age of seedling as well as row spicing under SRI did not differ much with respect to digestibility of rice straw.

Table 3 Effect of age of seedling and row spacing on components of digestibility of rice genotypes (Pooled mean over three years)

Treatment	Crude protein (%)	Crude fiber (%)	Nitrogen free extract (%)	Total ash (%)	Oxalic acid (%)
Genotype					
PHB 71	4.96	35.68	37.99	19.84	2.49
NDR 359	3.86	34.97	38.95	20.14	2.40
LSD (P=0.05)	1.15	0.75	0.98	0.36	0.12
Seedling age (Days)					
8	4.52	35.42	37.89	20.01	2.48
10	4.55	35.26	37.47	19.88	2.49
12	4.42	35.50	38.26	20.02	2.42
14	4.13	35.20	38.32	20.03	2.39
LSD (P=0.05)	NS	NS	NS	NS	NS
Spacing (cm)					
25 × 25	4.21	34.90	40.38	20.59	2.58
30 × 30	4.60	35.75	36.56	19.39	2.31
LSD (P=0.05)	NS	NS	NS	NS	NS

Soil nutrient status

The available N, P and K at harvest were affected by age

Table 4 Influence of age of seedling and spacing on soil health after harvest of rice genotype (Pooled mean over three years)

Treatment	Soil chemical parameters			Soil biological parameters		
	Available nutrient					
	Nitrogen (kg N/ha)	Phosphorus (kg P_2O_5/ha)	Potassium (kg K_2O/ha)	Potassium (× 10^3) (cfu)	Fungi (× 10^3) (cfu)	Actinomycetes (× 10^3) (cfu)
Genotype						
PHB 71	188.6	17.03	213.4	66.73	26.03	35.84
NDR 359	184.3	16.52	207.8	65.85	25.50	34.83
LSD (P=0.05)	2.57	NS	4.24			
Seedling age (Days)						
8	186.2	16.47	212.8	80.95	27.00	36.45
10	190.3	17.15	218.4	82.02	31.73	43.22
12	185.8	16.81	208.0	75.44	30.49	37.84
14	183.5	16.38	206.9	69.92	28.43	37.35
LSD (P=0.05)	3.85	NS	7.35			
Spacing (cm)						
25 × 25	182.5	16.72	206.8	82.84	32.55	45.52
30 × 30	189.0	16.39	213.0	83.95	37.06	46.71
LSD (P=0.05)	4.35	NS	3.85			
Initial value	208.2	18.14	234.5	43.90	15.50	32.80

of seedling and spacing of rice genotypes (Table 4). Available N and K were significantly higher in genotype PHB 71, 10 DOS and 30 cm × 30 cm spacing which might be due to profuse root growth of both vertically in deeper zone of the soil and horizontally to cover larger soil volume accelerating nutrient mining (Iranie *et al*. 2009). Biological properties of soil also showed improvement in the soil microbial counts over its initial value under the genotype PHB 71, 10 DOS and wider row spacing 30 cm × 30 cm and was due to aerobic soil conditions favorable to soil aeration under SRI. Further weeding operations performed by cono-weeder facilitated more organic matter into the soil for subsequent decomposition and nutrient recycling besides churning the soil surface leading to biochemically enriched soil rhizosphere (Barison and Uphoff 2011).

Thus it concluded that planting hybrid rice like PHB 71 with young age seedling (10 DOS) and planted at wider spacing of 30 cm × 30 cm under SRI can provide cost effective sustainable rice production on long term basis to meet future projected need of the country.

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