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Research Paper

Effect of seedlings age and plant spacing on growth, yield, nutrient uptake and economics of rice (*Oryza sativa*) genotypes under system of rice intensification

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2008 and 2009 at Varanasi, to evaluate the effect of seedlings age and plant spacing on growth, yield, nutrient uptake and economics of rice (*Oryza sativa L.*) under system of rice intensification (SRI). Sixteen treatments were laid out in a split-plot design, keeping combinations of 2 genotypes ('PHB 71' and 'NDR 359') and 2 spacings (25 cm × 25 cm and 30 cm × 30 cm) in main-plots and 4 seedlings age (8, 10, 12 and 14 days old) in sub-plots with 3 replications. The rice hybrid 'PHB 71' showed significantly higher growth, yield attributes and 12.6% higher yield than 'NDR 359'. This hybrid also gave the highest net monetary returns (₹46,700/ha) and benefit: cost ratio (1.56). Wider spacing i.e. 30 cm × 30 cm gave significantly more tillers/hill (22.7), panicles/hill (21.9) and grains/panicle (168.1) than other spacing. However, plant height (116 cm), leaf-area index (5.0), net monetary returns and yield were significantly higher in closer spacing of 25 cm × 25 cm. The closer spacing resulted in around 12.30% higher grain yield over wider spacing. Amongst the ages of seedlings, 10 days old seedlings resulted in significantly higher growth, yield attributes, net monetary returns and yield than 8 and 14 days old seedlings but remained at par with 12 days old seedlings. The 10 days old seedlings gave 12.8 and 17.6% more grain yield than 8 and 14 days old seedlings, respectively.

Key words: Age of seedlings, Crop production, Economics, Genotype, Growth and yield, System of rice intensification

Low productivity of rice in India is a major concern for food and nutritional security of more than 60% population which is dependent on rice. The increasing scarcity of water for agriculture is becoming a major problem in many countries, particularly the leading rice-producing countries like China and India, where competition for freshwater and growing demands for other sectors are increasing in future (Choudhary *et al*., 2010). In such a situation, the use of water-saving approaches, such as aerobic rice, direct-seeded rice and system of rice intensification (SRI) may prove beneficial while improving rice productivity as well. The system of rice intensification (SRI) is an alternative for conventional rice cultivation that saves the expensive external inputs, improves soil health/quality and protects the environment substantially (Satyanarayana *et al*., 2007).

The SRI practices include transplanting of single and young seedlings preferably 8-12 days old in a widely spaced square pattern, weed management through manual or mechanical means and water application as intermittent irrigation resulting in 40–50% water saving (Hussain *et al.,* 2012), and produce yield increases in the range 10–42% (Ghritlahre and Sarial, 2011; Thakur *et al.,* 2010). Some instances of yield reductions under SRI have also been reported (McDonald *et al.,* 2006, 2008). Considering, the advantages, controversies and inadequate scientific insight associated with SRI, the present investigation was undertaken to optimize age of seedlings and spacing for SRI to sustainable rice production for eastern region of Utter Pradesh.

MATERIALS AND METHODS

The present investigation was conducted during the rainy (*kharif*) seasons of 2008 and 2009 at the Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh (25^0 18' N, 83^0 31' E and altitude of 75.7 m amsl) and receiving average annual rainfall of 1,100 mm in the northern Indo-gangetic alluvial plains. The soil was sandy clay loam (Ustochrepts), with pH 7.23

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and electrical conductivity (EC) 0.42 dS/m, low in organic carbon (0.42%), available N (197 kg/ha), and medium in available (0.5 M sodium bicarbonate extracted) phosphorus (23.80 kg/ha) and potassium (209.7 kg/ha, 1 N ammonium acetate extracted). The treatments were laid out in a split-plot design, keeping combinations of genotypes (‘PHB 71’ and ‘NDR 359’) and spacings (25 cm × 25 cm and 30 cm × 30 cm) in main-plots and age of seedlings (8, 10, 12 and 14 days old) in sub-plots with 3 replications. A well-drained fertile soil having good irrigation facility near to nursery plot was selected for raring nursery. For each variety, the rice nursery was grown separately on puddled raised beds of 5 m × 1.0 m with 50 cm wide irrigation-cum-drainage channel prepared all around the beds. On these nursery beds, 1:1 soil: decomposed FYM mixture was spread to 3–4 cm thickness besides adding recommended dose of nutrients, viz. 1.0: 0.5: 0.5: kg/100 m^2 NPK in the form of urea, single superphosphate and muriate of potash, respectively. Using a seed rate of 6 kg/ha and seeds were soaked in water for 24 hours and incubated in moist gunny bags. For better aeration as well as avoiding the flooding of nursery beds a rose can was used for sprinkling water on beds. The sowing of both the varieties was done on 30 May and transplanting was done in staggered fashion depending on the requisite age of seedlings.

The experimental field was prepared with the help of tractor-drawn implements (disc plough, harrow, puddler and leveller). Water was drained out of the field at transplanting. Field was demarcated into plots providing irrigation and drainage channels according to layout plan. The experimental field was kept moist through light and frequent irrigations throughout the vegetative growth stages and excess water was allowed to drain out whenever intensive rains occurred. During flowering to milking stage, water was maintained at 3–4 cm depth. Weeds were kept under check through conoweedings at 15, 25 and 35 days after transplanting (DAT) and no herbicides were used for this propose. The crop was fertilized using 10 tonnes FYM/ha besides recommended dose of nutrients, viz. 100 : 60 : 50 kg/ha NPK in the form of urea, SSP and MOP, respectively. Half dose of nitrogen and full dose of P and K were applied basal and remaining half N was applied as top-dressing in 2 equal splits-at active tillering (30 DAT) and panicle-initiation stages (55 DAT). All the data pertaining to growth, yield attributes and yield were suitably recorded. Nutrient uptake was estimated by multiplying the grain and straw yields with concentration (%) of nutrients in grains/straw. The cost of cultivation and net returns were calculated by taking into account the prevailing cost of inputs and MSP of grain and straw price as per local market. The statistical analysis of the data was done as per procedure of analysis of variance using F-test (Cochran and Cox, 1957).

RESULTS AND DISCUSSION

Growth and yield attributes

Rice hybrid ‘PHB 71’ recorded significantly higher plant height, leaf area index (LAI), tillers/hill, panicles/hill and grains/panicle during both the years compared to ‘NDR 359’ (Table 1) mainly because hybrid genotypes

Table 1. Growth and yield attributes of rice as influenced by genotype, spacing and age of seedlings (mean data of 2 years)

Treatment	Plant height (cm) at harvest	LAI at 60 DAT	Tillers/hill at harvest	Panicles/ hill	Grains/ panicle	1,000-grain weight (g)
Genotype						
‘PHB 71’	116.5	5.36	22.7	21.9	168.1	21.26
‘NDR 359’	113.7	4.35	20.7	19.2	152.7	25.81
SEm±	0.4	0.03	0.3	0.2	0.7	0.09
CD (P=0.05)	1.2	0.10	1.1	0.8	2.3	0.30
Spacing						
25 cm × 25 cm	116.3	4.96	20.8	19.7	157.7	23.43
30 cm × 30 cm	113.8	4.75	22.6	21.4	163.1	23.63
SEm±	0.4	0.03	0.3	0.2	0.7	0.09
CD (P=0.05)	1.2	0.10	1.05	0.8	2.3	NS
Age of seedlings (days)						
8	114.8	4.90	21.2	20.4	156.5	23.35
10	117.7	5.30	22.9	22.1	172.2	23.81
12	114.9	4.99	22.8	21.6	161.9	23.69
14	113.0	4.24	19.8	18.1	151.1	23.27
SEm±	0.5	0.04	0.2	0.3	0.5	0.11
CD (P=0.05)	1.6	0.12	0.7	0.8	1.6	0.34

LAI, Leaf-area index; DAT, Days after transplanting possess heterosis resulting in vigorous root system, greater source size, higher number of tillers, grains/ panicle and leaf area than the inbred variety (Dey *et al.,* 2006; Choudhary *et al.,* 2010). The 1,000-grain weight, being a variety specific trait, was significantly higher in 'NDR 359' than that in 'PHB 71'.

The closer spacing (25 cm × 25 cm) recorded significantly higher plant height and leaf-area index (Table 1) than wider spacing (30 cm × 30 cm). This might be due to the more competition for interception and utilization of solar light under higher number of tillers/hill in closer spacing than wider spacing. The findings are in conformity with those of Kumar *et al.* (2006). Tillers/hill, panicles/hill and grains/panicle were significantly higher with wider spacing of 30 cm × 30 cm compared to closer spacing (25 cm × 25 cm) due to advantage of space and less competition for nutrition under wider spacing. An increase of the tune of 8.6% in panicles/hill and 3.4% in grains/panicle under wider spacing (30 cm × 30 cm) compared to closer spacing of 25 cm × 25 cm. Kumar *et al.* (2006) and Thakur *et al.* (2010) also reported similar results.

Ten days old seedlings produced significantly higher plant height, LAI, tillers/ hill, panicles/ hill, grains/ panicle and 1,000-grain weight (Table 1) than the other seedlings ages. However, it was on a par with 12 days old seedlings in tillers/hill, panicles/hill and 1,000-grain weight. The transplanting of younger seedlings along with soil, keeping the roots intact, resulted in early adaptation of the young seedlings to soil and climatic conditions thereby recording better growth and yield attributes in agreement with the findings of Uphoff (2002) and Wang Shao Hua (2003). Eight days old seedlings probably proved too tender to adopt and were therefore inferior to 10 days old seedlings.

Grain yield, straw yield and harvest index

The hybrid 'PHB 71' was recorded significantly higher grain yield (12.6%) and harvest index (8.0%) over 'NDR 359' (Table 2). However, in the straw yield did not affect significant during both the years. It is well known that biological yield of a cereal crops is the product of total yield of plant tops and is an indication of the yield of the photosynthetic capacity of a crop. Therefore, substantial variation in growth and yield attributes of different rice varieties caused a significant variation in their grain yield (Yoshida, 1981). Better growth parameters and yield attributes of hybrid helped in recording significantly higher grain yield (12.6%) and harvest index over 'NDR 359'. Many other studies (Biju *et al.,* 2006; Satanarayana *et al.,* 2007; Thakur *et al.,* 2010) have revealed yield advantages of 10–15% in hybrids over high yielding varieties and have cited increased cytokinin content in roots of hybrids leading to delayed leaf senescence and longer crop duration as another reason for high productivity. The higher harvest index in hybrid 'PHB 71' is indicative of high efficiency of partitioning of photosynthates into grain than other plant parts compared to 'NDR 359'. In the present investigation, days to 50% flowering and maturity were more by a week

Table 2. Effect of genotypes, spacings and age of seedlings on yield, harvest index and economics of rice (mean data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index(%)	Cost of cultivation (×10³ ₹/ha)	Net returns (×10³ ₹/ha)*	Benefit: cost ratio
Genotype						
'PHB 71'	7.33	8.14	47.37	29.9	46.7	1.56
'NDR 359'	6.51	8.34	43.86	29.9	40.2	1.39
SEm±	0.10	0.12	0.57			0.03
CD (P=0.05)	0.34	NS	1.98			0.10
Spacing						
25 cm × 25 cm	7.32	8.52	46.21	29.7	47.2	1.59
30 cm × 30 cm	6.52	7.96	45.02	29.1	39.7	1.37
SEm±	0.10	0.12	0.57			0.03
CD (P=0.05)	0.34	0.41	NS			0.10
Age of seedlings (days)						
8	6.64	8.08	45.19	29.6	40.5	1.36
10	7.49	8.60	46.59	29.4	49.2	1.67
12	7.17	8.45	45.90	29.4	46.0	1.56
14	6.37	7.84	44.78	29.1	38.2	1.31
SEm±	0.07	0.14	0.56			0.02
CD (P=0.05)	0.19	0.41	NS			0.07

*Based on prices of grain = ₹9,500/t and straw = ₹880/t in 'PHB 71' than the 'NDR 359' which was main reason for significant higher grain yield.

Closer spacing resulted significantly higher grain and straw yields than wider spacing (Table 2). The percentage increase in the grain yield of rice owing to closer spacing (25 cm × 25 cm) was 12.3% over wider spacing (30 cm × 30 cm). However, due to spacing harvest index did not attain a level of significance. At the closer spacing of 25 cm × 25 cm, straw yield increased 7.0% over wider spacing of 30 cm × 30 cm. The optimum plant population coupled with better yield parameters, delay in leaf senescence resulted more photosynthesis in later phase of crop growth and reproductive phase and plants maintain high CO_2 assimilation rate might be possible cause of higher grain yield with closer spacing than wider spacing. Our findings confirm the results of Yoshida (1981) and Singh *et al.* (2012).

The 10 days old seedlings gave 17.6% and 12.8% higher grain yield than 14 and 8 days old seedlings, respectively. Ten days old seedlings also recorded significantly higher straw yield compared to 14 and 8 days old seedlings. Higher grain and straw yield by transplanting of younger seedlings (10 days old) was owing to better growth and yield attributes recorded with young seedlings than older seedlings. These results corroborate the findings of Shekhar *et al.* (2009) and Satyanarayana *et al.* (2007).

Nutrient uptake

The hybrid 'PHB 71' recorded significantly higher N, P and K uptake by grain, straw and so also the total uptake than 'NDR 359' (Table 3). Since nutrient uptake is the outcome of the nutrient concentration and the crop output, the higher grain and straw yields of hybrid 'PHB 71' resulted in its higher values of NPK uptake. An increase of 8.5–9.8% in total nutrient uptake with 25 cm × 25 cm spacing compared to 30 cm × 30 cm spacing commensurate with similar increases in grain yield recorded under 25 cm × 25 cm plant spacing. Similarly, significantly higher nutrient uptake (NPK) values by grain, straw and total uptake were recorded by 10 days old seedlings than 8 and 14 days old seedlings. These results are in close conformity with the findings of Hussain *et al.* (2012).

Economics

The hybrid 'PHB 71' resulted in ₹6.5 × 10^3/ha additional net returns and significantly higher benefit: cost ratio (1.56) over inbred cultivar 'NDR 359'. Similarly, closer spacing (25 cm × 25 cm) gave ₹7.5 ×10^3/ha higher net returns and significantly higher benefit: cost ratio (1.59) than wider spacing (30 cm × 30 cm). Among the ages of seedlings, transplanting of 10 days old seedlings recorded the highest net return (₹49.2 ×10^3/ha) and benefit: cost ratio (1.67) were recorded with 10 days old seedlings followed by 12, 8 and 14 days old seedlings. The present findings of results are conformity with the findings of Shekhar *et al.* (2009) and Singh *et al.* (2012).

Thus, on the basis of results it is concluded that use of 10 days old seedlings of hybrid rice 'PHB 71' at spacing of 25 cm × 25 cm is most suitable to increase productivity and profitability of transplanted rice under Eastern Utter Pradesh conditions.

Table 3. Effect of genotype, spacing and age of seedlings on nutrient uptake of rice (mean data of 2 years)

Treatment	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Genotype									
'PHB 71'	93.0	31.5	124.5	22.4	13.5	36.0	33.0	121.9	154.9
'NDR 359'	81.2	29.2	110.5	19.9	12.2	32.2	29.3	113.5	142.8
SEm±	1.4	0.4	1.2	0.4	0.3	0.4	0.5	1.6	1.4
CD (P=0.05)	4.9	1.4	4.0	1.4	0.9	1.3	1.8	5.5	4.7
Spacing									
25 cm × 25 cm	90.9	31.4	122.3	22.0	13.7	35.7	33.1	121.9	155.1
30 cm × 30 cm	83.4	29.3	112.7	20.3	12.1	32.5	29.2	113.4	142.6
SEm±	1.4	0.4	1.2	0.4	0.3	0.4	0.5	1.6	1.4
CD (P=0.05)	4.9	1.5	4.0	1.4	0.9	1.3	1.8	5.5	4.7
Age of seedlings (days)									
8	82.8	29.3	112.1	20.3	12.6	32.9	29.9	115.5	145.5
10	94.1	32.2	126.3	22.5	13.3	35.9	33.6	122.8	156.3
12	91.7	31.3	122.9	22.1	13.3	35.4	32.2	120.4	152.6
14	79.9	28.7	108.7	19.8	12.2	32.1	28.9	112.0	140.9
SEm±	1.3	0.5	1.4	0.4	0.3	0.4	0.4	1.4	1.4
CD (P=0.05)	3.8	1.3	4.1	1.1	0.7	1.2	1.3	3.9	4.1

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