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Assessment of productivity, profitability and quality of rice (*Oryza sativa*) under System of Rice Intensification in eastern Uttar Pradesh

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ABSTRACT

A field experiment was conducted to find out optimum age of seedlings and plant density of rice (*Oryza sativa* L.) genotypes under system of rice intensification (SRI) on sandy-clay-loam (Ustochrepts) soil at Agriculture Research Farm of Institute of Agricultural Sciences, Banaras Hindu University during *kharif* (rainy) seasons of 2008 and 2009. The experiment was laid out in split-plot design with two genotypes and two spacing consign to main plots and four ages of seedlings were allocated as sub-plot treatments have replicated thrice. Transplanted of rice hybrid PHB 71 with 25 cm × 25 cm showed significantly higher growth, yield attributes, yield (12.6%), harvest index (8%), production efficiency (60.32 kg/ha/day), net monetary returns (₹ 47 239) and benefit: cost ratio (1.56) than NDR 359. Quality parameters, viz. hulling, milling, head rice recovery and protein content were significantly higher in PHB 71. The age of seedlings significantly affected in growth, yield, quality parameters, net monetary returns and benefit: cost ratio. Transplanted of 10 days old seedlings increased 12.7, 4.4 and 17.5% more grain yield as compared to 8, 12 and 14 days old seedlings, respectively. Maximum mean monetary net returns of ₹ 49 227, benefit: cost ratio (1.67) and per day returns (414 ₹/ha/day) were obtained with 10 days old seedlings. Quality parameters, viz. hulling, milling and head rice recovery were improved significantly with young seedlings of 10 days.

Key words: Genotype, Net return, Production efficiency, Productivity, Quality, Seedling age

Traditionally rice (*Oryza sativa* L.) is grown by flooding, resulted losses of water is very high through seepage, deep percolation and evaporation resulted ground water depleted, increasing GHGs emission due to continuous flooding and increasing cost of cultivation. In such water crisis scenario, the use of water-saving approaches, like aerobic rice, direct-seeded rice and system of rice intensification (SRI) may help to increasing the rice productivity with less use of water. The system of rice intensification (SRI) appears to be a viable alternative for conventional rice cultivation that saves the expensive external inputs (seed, water and agro-chemicals), improves soil health/quality and protects the environment substantially (Satyanarayana *et al*. 2007).

It is estimated that SRI increase the yield about 10-42% and lead to higher ripening ratio with saving of 40-50% water (Hussain *et al.* 2012 and Thakur *et al.* 2010) in different rice growing areas. Varieties differed in their genetic potential to exploit achievable yield in different growing system are not promising for SRI. Therefore, it is necessary to select and identify phenotypically stable genotypes that perform consistently and give better response under SRI (Ghritlahre and Sarial 2011). Claim of very high yield under SRI have been dismissed by several researchers (McDonald *et al.* 2008 and Sheehy *et al*. 2005). Therefore, present field experiment was planned to study the productivity, profitability and quality of rice as influenced by different genotypes, spacings and age of seedlings under system of rice intensification.

MATERIALS AND METHODS

The experiment was conducted in 2008 and 2009 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, situated at 25° 18’ N latitude, 83° 03’ E longitudes and at an altitude of 75.7 m above mean sea level (amsl) in the Northern-Gangetic alluvial plains having semi-arid to sub-humid type of climate. The cumulative rainfall received during the period of study was 1042.8 mm and 527.4 mm during 2008 and 2009, respectively. The soil of experimental site was Inceptisols, sandy clay-loam (Ustochrepts) in texture class (49.47% sand, 28.86% silt and 21.67% clay) with low in organic carbon (0.42 and 0.42%) and nitrogen (198.08 and 196.0 kg/ha) but medium in phosphorus (23.35 and 24.26 kg/ha,

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0.5 M sodium bicarbonate extracted) and potassium (219.2 and 221.1 kg/ha, 1 N ammonium acetate extracted) during 2008 and 2009, respectively. However, experimental plots having optimum range of pH (7.23) and EC (0.42 dS/m) that congenial for better crop growth during investigation. The treatment were laid out in split plot design, comprised two genotypes (PHB 71 and NDR 359) with two spacings (25 cm × 25 cm and 30 cm × 30 cm) as assigned to main plots. Each main plots were further divided into four sub-plot to accommodate four ages of seedlings (8 days, 10 days, 12 days and 14 days) with replicated thrice. A well-drained fertile soil having good irrigation facility near to nursery plots was selected for raised nursery. For each variety using 5 kg/ha seed, rice nursery was grown separately on puddle 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 was spread to 3-4 cm thickness besides adding NPK @ 1.0, 0.5 and 0.5 kg/100 m^2 areas in the form of urea, single super phosphate and muriate of potash were applied at the time of final nursery bed preparation, respectively. The single seedling was transplanted in staggered fashion according to treatments, seedling was taken out along with soils to minimizing transplanting shocks. Experimental 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 when hair line cracks were appearing and excess water was allowed to drain out whenever intensive rains occurred. During flowering to milky stage, 3-4 cm standing water was continuously maintained. Weeds were kept under check through conoweedings at 15, 25 and 35 days after transplanting (DAT) and herbicides were not used for this purpose. The crop was fertilized using 10 tonnes of FYM/ha and half dose of total (100 kg N/ha) nitrogen along with full dose of phosphorus (60 kg P_2O_5/ha) and potassium (50 kg K_2O/ha) were applied just before transplanting in the form of urea (46% N), SSP (16% P_2O_5) and MOP (60% K_2O), respectively. Remaining half dose of nitrogen was top-dressed in two equal splits-at active tillering (30 DAT) and panicle initiation stages (55 DAT). Growth, yield attributes, yield and quality were observed by standard procedures. Economics were also calculated based on prevailing cost of inputs and minimum support price (MSP) of grain and local price of straw. All the data were statistically analyzed using the analysis of the variance (ANOVA) technique of (Cochran and Cox 1957). The critical differences at 0.05% level of probability were calculated to assess the significance between treatments if significant.

RESULTS AND DISCUSSION

Growth and yield attributes

Growth (plant height, LAI and dry matter accumulation) and yield attributes (effective tillers/hill and grains/panicle) of hybrid cultivar PHB 71 was significantly increasing during both the years of experimentation over inbred cultivar NDR 359 (Table 1). This might be mainly due to hybrid genotypes possessing heterosis resulting in vigorous root system, greater source and sink size and contributing to higher photosynthesis efficiency and increasing cytokinin content in their roots, increasing plant height, dry matter accumulation, tillers/hill, grains/panicle and leaf area compared to inbred varieties (Singh *et al.* 2013 and Choudhary *et al.* 2010). The thousand grain weight, being a variety specific trait was significantly higher in NDR 359

Table 1 Growth and yield attributes of rice as influenced by genotype, spacing and age of seedlings

Treatment	Plant height (cm) 90 DAT		LAI at 90 DAT		DMA (g/hill) at 90 DAT		Effective tillers/ hill		Grains/ panicle		Test weight (g)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Genotype												
PHB 71	115.01	112.41	3.44	3.53	66.79	58.81	23.17	20.61	171.93	164.24	21.28	21.27
NDR 359	111.54	108.77	3.24	3.23	62.23	57.05	19.50	18.83	154.73	150.73	25.76	25.86
SEm ±	0.42	0.52	0.05	0.08	0.66	0.49	0.24	0.38	0.73	0.81	0.07	0.09
CD (P=0.05)	1.46	1.78	0.18	0.29	2.27	1.69	0.82	1.31	2.51	2.81	0.25	0.31
Spacing (cm)												
25×25	114.08	111.50	3.43	3.56	62.91	56.99	20.62	18.74	160.05	155.29	23.40	23.50
30×30	112.47	109.69	3.25	3.20	66.10	58.87	22.05	20.70	166.61	159.68	23.63	23.63
SEm ±	0.42	0.52	0.05	0.08	0.66	0.49	0.24	0.38	0.73	0.81	0.07	0.09
CD (P=0.05)	1.46	1.78	0.18	0.29	2.27	1.69	0.82	1.31	2.51	2.81	0.25	0.31
Age of seedlings (days)												
8	113.68	110.70	3.36	3.49	63.75	58.30	21.16	19.56	158.42	154.52	23.35	23.40
10	115.25	112.69	3.59	3.55	68.51	61.07	22.73	21.46	175.47	168.87	23.85	23.78
12	112.68	110.58	3.24	3.36	66.67	59.23	22.49	20.61	165.91	157.83	23.64	23.74
14	111.48	108.41	3.18	3.11	59.10	53.12	18.98	17.25	153.53	148.72	23.22	23.32
SEm ±	0.478	0.538	0.06	0.08	0.751	0.557	0.26	0.43	0.78	0.61	0.10	0.10
CD (P=0.05)	1.394	1.571	0.17	0.24	2.191	1.625	0.74	1.26	2.27	1.78	0.30	0.30

DAT, days after transplanting; DMA, dry matter accumulation as compared to PHB 71.

Under wider spacing (30 cm×30 cm) significantly improved dry matter accumulation, leaf area index, effective tillers/hill, grains/panicle and test weight (Table 1) compared to closer spacing (25 cm × 25 cm). However, per hill performance of growth and yield attributes were significantly improved under wider spacing due to advantage of space and less competition for resources (light, moisture and nutrients) but under wider spacing (30 cm × 30 cm) only 11 hills/m^2 was accommodated as compared to 16 hills/m^2 at closer spacing (25 cm × 25 cm) resulting decreased final yield on net area basis in wider spaced transplanting. Similar results are also reported by Thakur *et al.* (2010). However, plant height was significantly increasing under closer spacing (25 cm × 25 cm) might be due to the more competition for interception and utilization of solar light under closer spacing increasing plant height as compared to wider spacing (30 cm × 30 cm). The findings are in conformity with those of Kumar *et al.* (2006).

Plant height, dry matter accumulation, LAI, effective tillers/hill, grains/panicle and 1000-grain weight (Table 1) markedly increased due to transplanting of 10 days old seedlings (Table 1) as compared to other seedlings ages. Younger seedlings of 10 days old utilized phyllochronic potential resulting more growth attributes and further diverted energy towards reproductive phases resulting in increased yield attributes that may lead to finally enhanced grain yield (Singh *et al.* 2013, Wang Shao Hua 2003 and Uphoff 2002,). Eight days old seedlings probably proved too tender to adopt therefore, inferior to 10 days old seedlings.

Yield, harvest index and production efficiency

Rice hybrid PHB 71 produced significantly higher grain yield, harvest index and production efficiency as compared to inbred cultivar NDR 359. Rice hybrid PHB 71 produced 12.5% higher grain yield over NDR 359 (Table 1, mean data of two years). However, increment was recorded more during first year mainly due to congenial rainfall as compared to second year of experiment. Production efficiency was significantly higher in hybrid PHB 71 proved that hybrid's vigorous growth habit markedly increased 9.6% more production efficiency as compared to NDR 359 during each year of experimentation. Straw yield was remained unaffected by cultivars. Hybrid cultivars possesses higher physiological efficiency due to its vigorous root growth, greater sink size, high LAI during grain filling, have 10-15% yield advantage in hybrids over high yielding varieties and have cited increased cytokinin content in roots of hybrids consequently delayed leaf senescence and longer crop duration are other reason of higher productivity (Thakur *et al.* 2010 and Satyanarayana *et al.* 2007). The higher harvest index was mainly due to higher grain yield of hybrid PHB 71 and enables to variation in partitioning of photosynthetic in grain is possible cause of a significant variation in harvest index.

Closer spacing produced significantly higher grain and straw yield than wider spacing during both the years. The percentage increase in the grain yield of rice due to closer spacing (25 cm × 25 cm) were 9.17 and 15.5% over wider spacing (30 cm × 30 cm) during 2008 and 2009, respectively (Table 2). However, harvest index remained unaffected by spacings. At the closer spacing of 25 cm×25 cm, straw yield increased to the tune of 8.38 and 5.2% over wider spacing of 30 cm × 30 cm in 2008 and 2009, respectively. Similar trend was also recorded in production efficiency which was increased by 13.5 and 14% during 2008 and 2009, respectively as compared to wider spacing. The optimum plant population, better yield parameters, delay in leaf senescence resulted more photosynthesis and plants maintain high CO_2 assimilation rate in reproductive phase which might be possible cause of higher grain, straw yield and production efficiency with closer spacing than wider spacing. These findings are in conformity with findings of Yoshida (1981) and Singh *et al.* (2012).

The transplanting younger seedling (10 days old) produced significantly higher grain yield to the tune of 12.7, 4.4 and 17.5% over 8, 12 and 14 days old seedlings, respectively (Table 2). The straw yield also found similar trend like grain yield. However, harvest index was not influenced by ages of seedlings. Transplanting of 10 days old seedlings proved significant improvement in growth and yield attributes due to profuse root growth and tillering which increased assimilates synthesis and diverted more assimilates from source to sink ultimately increased grain yield. Similar results were also reported by Singh *et al.* (2013), Sekhar *et al.* (2009) and Jain and Upadhyay (2008). Transplanting of younger seedlings (10 days old) utilized phyllochronic potential to produce significantly higher production efficiency (62.88 kg/ha/days) which was 12.14, 5.98 and 20.12% higher as compared to 8, 12 and 14 days old seedling, respectively (Table 2, mean data of two years). The present results are close to the findings of Satyanarayana *et al.* (2007).

Quality parameters

The quality parameters, viz. hulling (%), milling (%) and head rice recovery were significantly higher in hybrid cultivar PHB 71 than inbred cultivar NDR 359 (Table 3). Zhang *et al.* (2008) and Rani (2003) also reported that the varieties with higher protein content suffered less breakage and increasing strength to the grains resulting higher milling % and head rice recovery. However, protein content was unaffected due to different ages of seedlings. Satyanarayana *et al.* (2007) and Wang Sho Hua *et al.* (2003) proved that under SRI system increasing root activity, soluble sugar, non-protein N, proline and malondiadehyde (MDA) content resulted in significantly increasing quality parameters and due to higher chlorophyll content, resulting higher photosynthetic rate and photosynthates content, slow senescence and high rate of transport of assimilates from source to sink during grain filling period resulting improved quality parameters.

Table 2 Yield, harvest index, economics and production efficiency of rice as influenced by genotype, spacing and age of seedlings

Treatment	Grain yield (kg/ha)			Straw yield (kg/ha)			Harvest index			Production efficiency (kg/ha/day)		
	2008	2009	Pooled	2008	2009	Pooled	2008	2009	Pooled	2008	2009	Pooled
Genotype												
PHB 71	7 534	7 119	7 326	8 277	8 006	8 141	47.72	47.32	47.52	60.79	60.30	60.32
NDR 359	6 604	6 421	6 513	8 377	8 307	8 342	44.06	43.72	43.89	55.38	55.00	55.00
SEm ±	85	87	54	190	124	117	0.71	0.67	0.53	0.77	0.78	0.81
CD (P=0.05)	295	301	188	NS	NS	NS	2.46	2.31	1.83	2.66	2.70	2.80
Spacing (cm)												
25×25	7 378	7 260	7 319	8 660	8 388	8 524	46.01	46.39	46.20	61.10	61.45	61.44
30×30	6 760	6 280	6 520	7 994	7 926	7 960	45.78	44.65	45.22	55.07	53.84	53.88
SEm ±	85	87	54	190	124	117	0.71	0.67	0.53	0.77	0.78	0.81
CD (P=0.05)	295	301	188	656	430	405	NS	NS	NS	2.66	2.70	2.80
Age of seedlings (days)												
8	6 708	6 578	6 643	8 178	7 977	8 078	45.04	45.03	45.03	55.77	56.07	56.07
10	7 645	7 333	7 489	8 754	8 450	8 602	46.67	46.14	46.40	63.22	62.86	62.88
12	7 412	6 936	7 174	8 448	8 457	8 452	46.68	45.44	46.06	60.51	59.31	59.33
14	6 512	6 233	6 373	7 928	7 743	7 835	45.18	45.48	45.33	52.84	52.36	52.35
SEm ±	116	106	85	183	189	139	0.75	0.39	0.40	0.87	0.53	0.66
CD (P=0.05)	338	308	249	535	551	407	NS	NS	NS	2.53	1.55	1.93

Table 3 Quality and economics of rice as influenced by genotype, spacing and age of seedlings (Pooled data for two years)

Treatment	Hulling (%)	Milling (%)	Head rice recovery (%)	Protein content (%)	Cost of cultivation (₹/ha)	Net return (₹/ha)	Per day return (₹/ha/day)	B:C ratio
Genotype								
PHB 71	77.82	67.35	56.41	7.34	29 894	46 731	385	1.56
NDR 359	75.20	65.38	52.49	7.08	28 894	40 228	340	1.39
SEm ±	0.35	0.190	0.130	0.01				0.03
CD (P=0.05)	1.22	0.66	0.45	0.04				0.10
Spacing (cm)								
25×25	76.24	66.32	54.50	7.20	29 706	47 239	397	1.59
30×30	76.79	66.41	54.39	7.22	29 081	39 719	328	1.37
SEm ±	0.35	0.19	0.13	0.01				0.03
CD (P=0.05)	NS	NS	NS	NS				0.10
Age of seedlings (days)								
8	76.51	65.83	54.61	7.22	29 644	40 483	342	1.36
10	78.24	67.62	55.64	7.19	29 394	49 227	414	1.67
12	76.70	66.57	54.11	7.24	29 394	46 034	381	1.56
14	74.61	65.43	53.43	7.19	29 144	38 172	314	1.31
SEm ±	0.35	0.22	0.16	0.02				0.03
CD (P=0.05)	1.03	0.65	0.45	NS				0.07

Economics

It is evident from the data that economics of the rice significantly influenced by cultivars, spacings and ages of seedlings (Table 3). Rice hybrid PHB 71 showed that mean net return of ₹ 46 731/ha, per day returns of ₹ 385 and benefit cost ratio of 1.56 and gave an additional net profit of ₹ 6 503/ha over inbred cultivar NDR 359. In spite of higher cost of hybrid seed of PHB 71, produced higher mean net monetary returns as compared to inbred cultivars. Similarly, closer spacing (25 cm × 25 cm) gave substantially higher mean net return of ₹ 47 239/ha, per day returns of ₹ 397 and B:C ratio of 1.59 compared to wider spacing (30 cm × 30 cm). The additional net profit of ₹ 7 520/ha was recorded with closer spacing over wider one. Among the ages of seedlings, the cost of cultivation was decreased with increasing age of seedlings and maximum cost of cultivation was recorded with 8 days old seedling followed by 10, 12 and 14 days old seedlings. The mean net return

(₹ 49 227/ha), per day returns (₹ 414) and B:C ratio (1.67) were recorded with 10 days old seedlings followed by 12, 8 and 14 days old seedlings. This might be due to higher grain and straw yield under 10 days old seedlings (Shekhar *et al.* 2009 and Singh *et al.* 2012) compared to other ages of seedlings.

Thus, on the basis of results presented and summarized in preceding texts it is concluded that transplanting of hybrid rice (PHB 71) with a 10 days old seedlings and 25 cm × 25 cm spacing can be helpful to growers for higher productivity, profitability and produced quality rice under SRI in the eastern region of Uttar Pradesh.

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