Indian Journal of Agronomy **61** (3): 315–320 (September 2016)

Research Paper

Productivity and profitability of rice (*Oryza sativa*) hybrids as influenced by date of transplanting and age of seedling under system of rice intensification

AKHILESH VISHWAKARMA[1] J.K. SINGH[2], RAJESH KUMAR SINGH[3] AND A.L. JAT[4]

Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005

Received : July 2015; Revised accepted : July 2016

ABSTRACT

The field experiment was conducted during the rainy (*kharif*) seasons of 2012 and 2013 on sandy-clay loam soil at Varanasi, Uttar Pradesh, to evaluate suitable date of transplanting (27 June, 7 July and 17 July) and age of seedling (10, 14 and 18-days-old) of rice (*Oryza sativa* L.) hybrids ('PHB 71' and 'Pusa RH 10') under system of rice intensification. Transplanting of rice on 27 June showed significantly higher growth parameters, viz. plant height, tillers/hill, leaf-area index (LAI) and dry-matter accumulation, and also superior in phenology, effective tillers/m^2, grains/panicle and grain weight as compared to 7 July and 17 July planting. Further, grain yield, net returns, benefit: cost ratio and nutrient uptake were significantly increased by 27 June transplanting over rest of the dates of transplanting. Of the rice cultivars, 'PHB 71' exhibited significantly higher growth parameters, phenology, yield attributes, yield, net returns, benefit: cost ratio and nutrient uptake over 'Pusa RH 10'. The 10-day-old seedlings registered 12.9% and 6.4% higher grain yield than seedlings of 14 days and 18 days by significant improvement in growth parameters, and nutrient uptake. Rice 'PHB 71' transplanted on 27 June with 10-day-old seedlings exhibited 33.9% higher grain yield over the transplanting on 17 July of 18-day-old seedlings. Moreover, aromatic hybrid rice 'Pusa RH 10' planted on 27 June with 10-day-old seedlings improved grain yield by 38.3% as compared to it planted on 17 July with 18-day-old seedlings.

Key words : Date of transplanting, Rice hybrids, Seedling age, System of rice intensification

To meet the food requirement of the burgeoning population, particularly in the developing countries like India, increased production and productivity of rice are essential. The production target of rice with the background of declining resources such as land, water, labour and the costly inputs is a challenging task. Area under rice is expected to be reduced about 40 million ha in the next 15 to 20 years due to water shortage and rapid urbanization (Bhatt, 2015). System of rice intensification (SRI) is an alternative to improve the water productivity and rice yield. Usually, timely transplanting and use of seedlings of appropriate age for transplanting are important non-cash inputs for realizing the higher productivity in rice (Pattar *et al*., 2001), and early transplanting of rice seedlings assumes special significance in obtaining higher yields in SRI cultivation. Rice seedlings lose much of their growth potential if they are transplanted more than 15 days after they emerge in the nursery (Manjunatha *et al*., 2010). Among the various cultural practices, date of transplanting, number of seedling and age of seedling are most important for yield maximization. Performance of a genotype entirely depends on the time of planting. Delay in planting generally results in yield reduction which cannot be compensated by any other means, transplanting of the photoperiod insensitive cultivars after 15 June can caused significant reduction in grain yield (Mahajan *et al*., 2009). Hybrids have relatively higher degree of thermo-sensitivity during flowering and grain-filling stages as compared to high-yielding varieties. India is the first country after China to exploit the hybrid rice technology on a commercial scale. Hybrid rice technology has contributed significantly towards food security, environment protection, and employment opportunities in China for the past 34 years, more than 50% area covered by hybrid rice in China. Since the mid-1990s, this technology has also been developed and introduced to farmers in India, Vietnam, the Philippines, Bangladesh, and the United States, either independently or in close collaboration with IRRI (Singh *et al.,* 2013a). Ap-

Based on a part of Ph.D. thesis of the first author submitted to BHU, Varanasi, during 2015 (unpublished)

[1]**Corresponding author Email:** akhileshagro@gmail.com
[1]Ph.D. Scholar; [2]Associate Professor; [3]Assistant Professor; [4]Ex-Research Scholar, Department of Agronomy

propriate agronomic management is a pre-requisite to exploit the full potential of a hybrid. Transplanting aged seedling (more than 15 days) of rice hybrid lose much of their potential. Keeping these points in view, an investigation was undertaken to study the productivity and profitability of rice hybrids as influenced by date of transplanting and age of seedling under SRI.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2012 and 2013 at Agricultural Research Farm, Banaras Hindu University, Varanasi (25°18' N, 88°03' E, 128.93 m above the mean sea level), Uttar Pradesh. The soil was sandy clay loam (typic *Ustochrepts*) with *p*H 7.39, moderately fertile being low in organic carbon (0.39%) and available nitrogen (205.2 kg/ha), high in available phosphorus (25.3 kg/ha) and medium in potassium (215.6 kg/ha). The amount of total rainfall received during the period of investigation was 691.5 and 825.0 mm in the first and second year, respectively. The experiment was laid out in a split-split plot design assigning three date of transplanting (27 June, 7 and 17 July) in main plot, 2 rice hybrids (‘PHB 71’ and ‘Pusa RH 10’) in subplot and three age of seedling (10, 14 and 18-day old) in sub-sub plot were replicated thrice. Half dose of the total nitrogen (150 kg N/ha) through urea (37.5 kg N/ha) and vermicompost (37.5 kg N/ha) along with the full dose of phosphorus (75 kg P_2O_5/ha) through diammonium phosphate and potassium (75 kg K_2O/ha) through muriate of potash, were applied just before transplanting on puddled surface and incorporated into the top 15 cm soil. The remaining nitrogen (75 kg/ha) was applied through urea as top-dressed in 2 equal instalments-at active tillering and 5–7 days before panicle initiation. A common dose of zinc sulphate (21% Zn) was applied to all plots as basal dose of 25 kg/ha during the first year and it was not applied during the second year. The seed rate used 5 kg/100 m^2 nursery area for 1 ha area of main field. Raised nursery beds having a width of 1 m and length of 10 m provided with 40 cm channels all around were prepared well before sowing of seed. The nursery beds were prepared with a massive mixture of soil and vermicompost (2 : 1). Prior to sowing, seeds were treated with streptocycline and carbendazim (6 g streptocycline with 20 litres water and 1 g carbendazim dissolved in 1 litre water were used for seed treatment). Sprouted seeds were spread uniformly on to moist soil such a manner that each seed could be isolated to one another. The seed was covered on seed-beds with rice straw at least 2 days after sowing to protect seeds from birds and keep moist the soil. After covering the seed, watering was done twice a day. Single seedling along with soil was transplanted by using index finger and thumb and gently planting at the intersection of marking 25 cm × 25 cm in puddled soil. Soil was kept moist but not flooded during the vegetative growth phase till panicle initiation. Excess rain water was drained out as and when required. Irrigation was given only on appearing of hairline cracks. Two irrigations were applied during the crop period depending on the requirements. As cono-weeding being a part of SRI was used 2 times during 15–20 and 30–35 days after transplanting (DAT) to manage the weeds. Days to 50% flowering was recorded when 50% plants were found by manual counting of plant row-by-row at flowering stage. Further, days to 50% physiological maturity observed when 50% leaves were drying/ senescencing and grains of 50% panicles were found to be dry after removing husk by nail in representative plants of each row. The crop was harvested according to maturity as per treatments. All the data pertaining to growth, yield and economics were suitably recorded. The prevailing sale price of ‘PHB 71’, ‘Pusa RH 10’ and straw was ₹12, 14 and 2/kg, respectively. Grain and straw samples were dried, processed and analysed for their total N content by micro-Kjeldahl’s, P by vanadomolybdo phosphoric acid-yellow colour method and K was estimated by flame-photometer. Nutrient uptake was estimated by multiplying the content with the oven-dry weight of biological yield. The samples were oven-dried at 70°C ± 2°C till constant weight achieved. The data recorded were analysed on pooled basis as per analysis of variance technique for split-split plot design. For leaf-area index (LAI), 5 representative plants were selected in penultimate rows, leaf area of all the leaves was calculated with the help of leaf-area meter (Systronics 211 Leaf area meter). The LAI was calculated as leaf area/land area.

RESULTS AND DISCUSSION

Growth and yield attributes

The date of transplanting significantly affected plant height, tillers/hill, LAI, dry-matter accumulation/hill, days to 50% flowering, days to 50% physiological maturity, effective tillers/m^2, grains/panicle and grain weight (Table 1). Rice transplanted on 27 June produced significantly taller plant with higher tillers/hill, LAI, dry-matter accumulation and delayed days to 50% flowering and physiological maturity over 7 and 17 July planting under SRI. It might be owing to more favourable temperature and relative humidity for 27 June-planted crop during its different phenophases compared to rest of the planting dates (Verma *et al*., 2008). Transplanting of rice on 27 June significantly exhibited 14.8, 15.8 and 6.9% more effective tillers/m^2, grains/ panicle and grain weight over 17 July transplanting. It might be owing to longer growing period of the crop for better development of parts to allocate greater accumulation of photosynthates in early planted which may results in the better development of growth and yield attributes (Singh *et al*., 2004). Kumar and Mahajan (2007) also observed that low temperature at anthesis and grain filling period reduced grain-filling, which ultimately resulted less grains/panicle. Further, rice cultivar 'PHB 71' exhibited significantly higher plant height, tillers/hill, LAI, dry-matter accumulation with delayed flowering and physiological maturity and effective tillers/m^2, grains/panicle and test weight over 'Pusa RH-10'. The differences in parameters between the cultivars were mainly due to their genetic build up (Singh *et al.,* 2013b). Amongst age of seedling, tender age seedling (10-day) produced significantly higher growth parameters with delayed flowering and physiological maturity over both the aged seedling, i.e.14-and 18-day. This was might be due to transplanting of seedlings at younger stage provides sufficient nutrients for vegetative growth by effective utilization of phyllochronic concept and saved energy diverting during nursery for tillering as well as for reproductive phase which ultimately leads to increased plant growth parameters (Shukla *et al*., 2014). The transplanting of early aged seedlings (10-day old) produced significantly more effective tillers/ m^2 (4.7 and 10%), grains/panicle (4.9 and 8.9%) and grain weight (7 and 7%) over 14-and 18-day-old seedlings. Mobasser *et al*. (2007) also noticed that when seedlings allowed staying for a longer period of time in the nursery beds, primary tiller buds on the lower nodes of the main culm become degenerated leading to reduced tiller production and resulted in poor yield.

Grain and straw yields and harvest index

Earlier planting on 27 June significantly enhanced grain yield, straw yield and harvest index (43.2%) over date of transplanting on 7 and 17 July and the magnitude of increase was 9.7 and 19.9% more in grain yield than 7 and 17 July planting, respectively (Table 2). Mukesh *et al.* (2013) also found that the 25 June transplanting resulted in more grain yield, straw yield and harvest index of basmati rice. Instead of date of transplanting, 'PHB 71' showed greater potential to exploit hybrid vigour to produce higher grain yield, straw yield and harvest index and showed marked superiority to 'Pusa RH 10'. Vigorous growth of 'PHB 71' proved increment of 25.7% higher grain yield over 'Pusa RH 10'. Production potential and physiological efficiency of hybrids are responsible to differentiate from others in their growth habits and input utilization for obtaining higher yield under SRI (Singh *et al.,* 2013b). Further, 'PHB 71' being hybrid have recorded increased cytokinins in roots leading to delayed leaf senescence and larger crop duration as another reason for high productivity (Thakur *et al.*, 2010). Transplanting of

Table 1. Effect of date of transplanting and age of seedling on growth parameters, phenology and yield attributes of rice hybrids under system of rice intensification (pooled data of 2 years)

Treatment	Plant height (cm)	Tillers/hill	LAI at 90 DAT	Dry-matter accumulation (g/hill)	Phenology: Days to 50% flowering	Phenology: Days to 50% physiological maturity	Effective tillers/m^2	Grains/ panicle	1000-grain weight (g)
Date of transplanting									
27 June	124.1	17.1	4.5	68.5	95	112	248	176	23.1
7 July	115.9	15.0	4.1	66.0	92	111	231	165	22.2
17 July	108.0	13.7	3.9	62.2	88	108	216	152	21.6
SEm±	1.97	0.45	0.14	0.57	0.1	0.2	3.1	2.8	0.2
CD (P=0.05)	7.74	1.77	0.58	2.26	0.3	0.7	12.1	10.9	0.8
Hybrids									
'PHB 71'	131.3	16.0	4.4	66.8	95	115	236	188	22.7
'Pusa RH 10'	100.7	12. 6	4.0	64.4	88	105	227	141	21.9
SEm±	1.45	0.15	0.04	0.42	0.1	0.1	2.2	1.8	0.2
CD (P=0.05)	5.03	0.52	0.15	1.47	0.4	0.4	7.5	6.0	0.5
Age of seedling									
10-day	120.4	16.8	4.5	68.0	94	115	243	172	23.0
14-day	116.2	15.2	4.2	65.4	91	110	232	164	22.3
18-day	111.3	13.9	3.9	6.3	89	106	221	158	21.5
SEm±	1.01	0.26	0.05	0.54	0.1	0.2	2.4	1.8	0.2
CD (P=0.05)	2.95	0.77	0.14	1.59	0.3	0.4	7.0	5.1	0.5

LAI, Leaf-area index; DAT, days after transplanting younger seedling (10-day old) showed marked improvement in yield and gave significantly higher grain yield, straw yield and harvest index over both more aged seedling. Younger aged seedling utilized phyllochronic potential to produce higher yield over rest of the aged seedling (Shukla *et al*., 2014). Moreover, grain yield of rice was significantly interacted among date of transplanting, hybrids and age of seedling (Table 3). Transplanting of 10-day-old seedling of 'PHB 71' on 27 June gave significantly maximum grain yield of rice and this treatment combination was found statistically at par with 14-day-old seedling of 'PHB 71' transplanted on 27 June.

Nutrient uptake

Transplanting on 27 June proved significantly more effective in respect of nitrogen, phosphorus and potassium uptake by grain and straw over transplanted on 7 July and 17 July (Table 4). Increase in the uptake may be ascribed to higher both in grain and straw yields and their NPK contents than the July transplanting. It may be owing to enhanced growth leading to increased rate of grain filling, highest grain weight with more number of grains/ panicle as well as grain and straw yields in comparison to July plantings (Choudhary *et al*., 2011). Hybrid 'PHB 71' recorded significantly greater efficiency in extracting higher amount of nitrogen, phosphorus and potassium and proved markedly superiority to 'Pusa RH 10' during both the years. This might be due to 'PHB 71' has higher affinity in absorbing more N and also producing more biological yield than 'Pusa RH 10'. These results corroborate the findings of Ram *et al*. (2014) under genotype 'PHB 71' as compared to 'NDR 359'. Younger seedling (10-day old) showed significantly higher nitrogen, phosphorus and potassium uptake by grain and straw and proved its superiority to the other aged seedling (14-and 18-day). It might be due to higher concentration of NKP contents in grain as

Table 2. Effect of dates of transplanting and age of seedling on yield and economics of rice hybrids under system of rice intensification (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Cost of cultivation (× 10^3 ₹/ha)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Date of transplanting							
27June	6.67	8.71	43.2	42.7	103.1	60.4	1.42
7 July	6.08	8.14	42.6	42.7	94.4	51.7	1.21
17 July	5.56	7.56	42.2	42.7	86.6	43.9	1.03
SEm±	0.12	0.13	0.8	-	1.61	1.61	0.04
CD (P=0.05)	0.49	0.52	NS	-	6.34	6.34	0.15
Hybrids							
'PHB 71'	7.00	8.95	43.9	42.6	101.9	59.2	1.39
'Pusa RH 10'	5.20	7.33	41.5	42.7	87.5	44.8	1.05
SEm±	0.07	0.09	0.4	-	1.03	1.03	0.02
CD (P=0.05)	0.25	0.31	1.4	-	3.56	3.55	0.08
Age of seedling							
10-day	6.48	8.42	43.4	42.5	100.1	57.6	1.35
14-day	6.09	8.13	42.7	42.7	94.5	51.8	1.21
18-day	5.74	7.87	41.9	42.8	89.5	46.7	1.09
SEm±	0.07	0.09	0.4	-	0.89	0.89	0.02
CD (P=0.05)	0.20	0.26	1.1	-	2.60	2.60	0.06

Table 3. Interaction effect of date of transplanting, rice hybrids and age of seedling on grain yield (t/ha) under system of rice intensification

Treatment	'PHB 71'			'Pusa RH 10'			Mean
	10-day	14-day	18-day	10-day	14-day	18-day	
27 June	8.11	7.67	7.23	6.13	5.65	5.22	6.67
7 July	7.33	6.93	6.52	5.55	5.15	4.97	6.08
17 July	6.70	6.45	6.06	5.05	4.69	4.43	5.56
Mean	7.38	7.01	6.60	5.57	5.16	4.87	6.10
D×V×A		SEm±			CD (P=0.05)		
		0.17			0.50		

D, Date of transplanting; V, Variety; A, Age of seedling

Table 4. Effect of date of transplanting and age of seedlings on nutrient uptake by grain straw of rice hybrids under system of rice intensification (pooled data of 2 years)

Treatment	Nutrient uptake (kg/ha)					
	Nitrogen (N)		Phosphorus (P)		Potassium (K)	
	Grain	Straw	Grain	Straw	Grain	Straw
Date of transplanting						
27 June	83.1	53.4	16.2	13.8	22.8	141.5
7 July	74.5	49.2	14.4	12.3	20.6	128.5
17 July	67.2	45.4	13.1	10.8	18.4	116.7
SEm±	1.93	0.86	0.33	0.24	0.39	3.07
CD (P=0.05)	7.57	3.39	1.29	0.95	1.51	12.06
Hybrids						
'PHB 71'	86.7	54.3	16.9	13.7	23.7	143.0
'Pusa RH 10'	63.1	44.4	12.3	10.9	17.5	114.8
SEm±	0.94	0.55	0.16	0.12	0.25	1.44
CD (P=0.05)	3.26	1.92	0.55	0.43	0.88	4.98
Age of seedling						
10-day	81.2	51.3	15.6	13.7	22.1	136.4
14-day	74.7	49.3	14.5	12.2	20.6	128.6
18-day	68.9	47.4	13.5	10.9	19.2	121.7
SEm±	0.95	0.54	0.18	0.14	0.24	1.50
CD (P=0.05)	2.76	1.58	0.52	0.42	0.69	4.38

well as in straw and more biological yield than rest of the aged seedling. Noteworthy, more removal of K by straw mainly associated with luxury consumption of this nutrient during crop cycles than grains. The present findings confirm the results of Singh *et al.* (2013b).

Economics

Gross returns, net returns and benefit: cost ratio of rice under SRI differed significantly with date of transplanting, hybrids and age of seedling (Table 2). The significantly higher gross returns, net returns and benefit: cost ratio were realized with earlier planting on 27 June compared to their later date of transplanting. Between hybrids, 'PHB 71' showed significant improvement in case of economic returns in terms of gross returns, net returns and benefit: cost ratio over 'Pusa RH 10'. Tender aged seedling has distinct advantage of higher yield with lower input cost and this led to obtained higher gross returns, net returns and benefit: cost ratio over the other aged (14-and 18-day) seedling during experiments. Shukla *et al.* (2014) also observed that 10-day-old seedling gave higher economic returns over rest of the aged seedling.

It can be concluded that 10-day-old seedling of rice hybrid 'PHB 71' transplanted on 27 June is most suitable to increase productivity and profitability under system of rice intensification of eastern Uttar Pradesh conditions.

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