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Influence of spacing and weed management on rice (*Oryza sativa*) varieties under system of rice intensification

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ABSTRACT

Field experiments were conducted in a sandy clay loam soil during *kharif* 2005 and 2006 at New Delhi to evaluate the performance of aromatic rice (*Oryza sativa* L.) varieties under varying weed management options and planting geometry in system of rice intensification (SRI). Rice 'Pusa Sugandh 5' proved better as compared to the other two varieties, i.e. 'Pusa Basmati 1' and 'Pusa Sugandh 3', especially in terms of growth, yield attributes and grain yield. On an average, 'Pusa Sugandh 5' produced 18.9% and 22.5% more grain yield over 'Pusa Basmati 1' and 'Pusa Sugandh 3', respectively. 'Pusa Sugandh 5' also gave the highest economic returns. Spacing 25 × 25 cm resulted in higher grain and straw yields and better economic returns than 30 × 30 cm. Averaged over two years, the increase in grain yield with 25 × 25 cm over 30 × 30 cm was to the tune of 19.5%. Maintaining fields weed free gave higher plant growth, yield attributes, grain yield and economics as compared to either anilophos @ 0.4 kg/ha or the weedy check. Anilophos @ 0.4 kg/ha was far advantageous than the weedy check.

Key words : Spacing, System of rice intensification (SRI), Varieties, Weed management

In India, rice is the most important and extensively grown food crop, occupying 44.0 million hectares of land. Among the rice growing countries, India has the largest area under rice in the world. The per hectare yield of rice (3.37 t/ha) in India, though increasing marginally, but is still well below the world's average yield of 4.31 t/ha. (FAOSTAT Database 2010). To safeguard and sustain the food security in India, it is quite important to increase the productivity of rice under limited resources, especially water. Rice consumes about 3000-5000 litres of water to produce 1 kg grain, depending on the different rice cultivation methods (Geethalakshmi *et al.*, 2011). Thus the water requirement in rice cultivation is enormous. At present, the water crisis is threatening the sustainability of the irrigated rice system and food security in many parts of the world (Satyanarayana *et al*. 2007). Varietal improvement, including genetic engineering has not resulted in concrete solution for improved yield and nutrition. There is a challenge to develop novel technologies and production systems that allow rice production to be maintained or increased in the face of declining water availability. Growing rice by system of rice intensification (SRI) is a novel approach of rice cultivation which saves water and other inputs (Satyanarayana *et al.* 2007). Higher grain yields of rice have been reported when rice is grown by SRI method as compared to the conventional rice culture (Hugar *et al*. 2009, Thakur *et al.* 2010, Zhao *et al.* 2010).

There are three basic concepts constituting SRI (Uphoff 2002, 2003,). Transplanting the seedlings while still young <14 days i.e., prior to the start of the 4th phyllochron of growth (Kumar and Shivay 2004). Wide spacing between plants is maintained with preferably just one plant per hill and set them out in a square pattern of 25 × 25 cm or even wider if soil fertility is good. Another important aspect in SRI is to keep the soil both moist and aerated at least during the vegetative growth period, so that roots have access to both oxygen and water. The wider spacing and aerobic conditions under SRI–grown rice results in increased weed infestation. Weed population could be reduced by standardizing the cultural practices, especially row spacing, in rice cultivation. Besides row spacing, certain herbicides could be used to keep the weed population to the minimum. Not only this, certain rice varieties may be more efficient in reducing the weed growth than the others. There is also possibility that a particular

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variety may be more fit than the other varieties in SRI method. In this context, need to identify the high yielding varieties is being increasingly felt to adopt the SRI method of rice cultivation, particularly in north India. Therefore, keeping the above facts in view, a field experiment was conducted to evaluate the comparative performance of rice varieties under different weed management practices and spacing, grown as per the SRI methods.

MATERIALS AND METHODS

Field experiment was conducted during *kharif* 2005 and 2006 at the research farm of Indian Agricultural Research Institute, New Delhi, which is situated at a latitude of 28°40´N and longitude of 77°12´E, altitude of 228.6 metres above the mean sea level. The soil was sandy clay loam in texture with moderate water holding capacity, low in organic carbon (0.46%), low in total nitrogen (0.049%), low in available (0.5 M sodium bicarbonate extracted) phosphorus (9.3 kg P/ha) and medium in available (1N ammonium acetate extracted) potassium (195 kg K/ha) content as per the methods described by Prasad *et al.* (2006). pH at the start of the experiment was 7.1. The experiment was laid out in a randomized block design with three replications. The treatments comprised of the all possible combinations of 3 varieties ('Pusa Basmati 1', 'Pusa Sugandh 5' and 'Pusa Sugandh 3'), 2 spacings (25 × 25 cm, 30 × 30 cm) and 3 weed management options (weedy check, anilophos @ 0.4 kg/ha and weed free). For each variety, the rice nursery was grown separately on puddled raised beds of 10 m × 1.5 m with a half metre wide irrigation cum drainage channel all around the beds. Varieties 'Pusa Basmati 1', 'Pusa Sugandh 5' and 'Pusa Sugandh 3' mature (seed to seed) in 135–140, 120–125 and 120–130 days, respectively.

The experimental field was prepared by harrowing, discing and leveling by a tractor drawn implement. The field was puddled twice using disc harrow and puddler and then leveled properly. 14 days' old seedlings were transplanted, as per treatment, singly (one seedling per hill) in muddy field. The experimental field was kept moist throughout the vegetative growth by applying light and frequent irrigations. During flowering to milk stage about 2-3 cm standing water was maintained continuously. The irrigation of the experimental field was stopped 15 days before the harvesting of the crop. Anilophos @ 0.4 kg/ha, a selective herbicide, as pre-emergence was applied 3-4 days after transplanting (DAT), as per allocation of treatment combination. Two weedings were done by hand rotary weeder at 25 DAT and 60 DAT, along with occasional manual weeding, in weed free treatment. Nitrogen @ 120 kg/ha was applied in three equal splits through urea. 1/2 N was applied 7 days after transplanting (DAT), the other 1/4 nitrogen was top dressed at maximum tillering stage and remaining 1/4 N was top dressed at panicle initiation stage of the crop. Basal dose of 26.2 kg P, 33.3 kg K/ha and 25 kg Zinc sulphate was applied uniformly. After removing the border rows, the net plots were harvested, tied, tagged and left in the field to dry for 2–3 days. Threshing was done manually after recording the weight of the total produce of an individual plot. After proper cleaning and winnowing, the grain weight of each plot at 14% moisture was recorded. All the data pertaining to growth, yield attributes and yield were recorded. The data related to each parameter of the experiment were statistically analyzed as per procedure of analysis of variance using F-test (Cochran and Cox 1957).

RESULTS AND DISCUSSION

Growth attributes

Varieties 'Pusa Sugandh 5' and 'Pusa Sugandh 3' recorded statistically similar plant height, but both recorded significantly taller plants than 'Pusa Basmati 1' at harvest in both the years of experimentation. Significantly taller plants were recorded at 30 × 30 cm than at 25 × 25 cm spacing during year 2005. The plant height in weed free and anilophos @ 0.4 kg/ha treatments was at par, but significantly more than weedy check. Rice varieties did not differ significantly in respect of leaf area index (LAI) at 30 DAT, (Fig. 1). At 60 DAT, 'Pusa Sugandh 3' recorded highest LAI, which was significantly higher than 'Pusa Sugandh 5' in year 2005 in both the years. At both the stages, 30 × 30 cm plant spacing gave significantly higher LAI than 25 × 25 cm, because wider plant spacing produced more leaves with greater size. At 60 DAT, the highest value of LAI was observed in weed free treatments, being at par with anilophos @ 0.4 kg/ha, both recording significantly superior to weedy check.

The variation in LAI is an important physiological parameter that eventually determines crop yield because it influences the light interception by the crop canopy (Fageria *et al*. 2006). The LAI of rice increases as crop growth advances and reaches a maximum at about heading or flowering (Yoshida 1981). The increase in LAI is caused by an increase in tiller number or leaves on each tiller and in size of successive leaves. The increasing LAI increases dry matter production, but net canopy photosynthesis did not show increase indefinitely because of increased mutual shading of leaves. Overall, genetic makeup, plant densities and fertilization are the major factors influencing the leaf area of plants grown under field conditions (Fageria *et al*. 2006).

'Pusa Sugandh 5' produced significantly more tillers/hill than 'Pusa Sugandh 3' and 'Pusa Basmati 1' at harvest (Fig. 2). Wider spacing (30 × 30 cm) produced signifi-

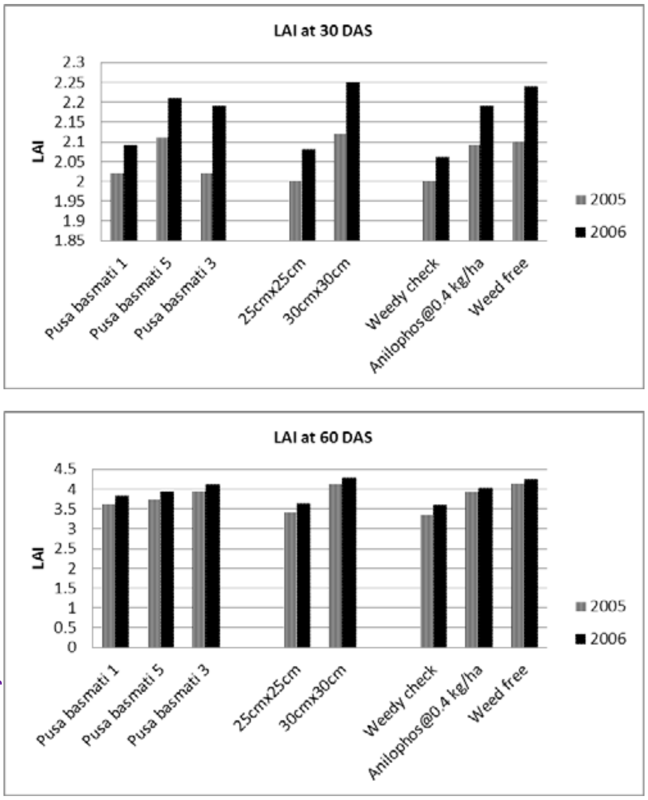

Fig. 1. Leaf area index (LAI) of rice as influenced by variety, spacing and weed control measure

cantly more tillers/hill than the narrower spacing (25 × 25 cm). Weed free treatment produced significantly more tillers/hill than anilophos @ 0.4 kg/ha, which in turn pro-

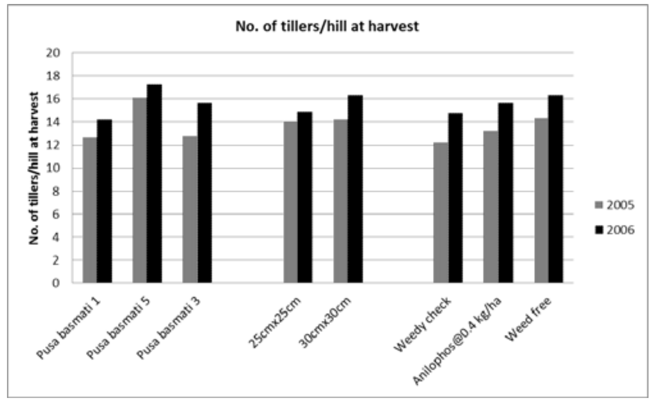

Fig. 2. Number of tillers/hill of rice at harvest as influenced by variety, spacing and weed control measure

duced more tillers than the weedy check in the first year. In the second year, the weed free treatment and application of anilophos @ 0.4 kg/ha were at par but significantly superior to weedy check.

Yield attributes

'Pusa Sugandh 5' recorded the highest number of panicles/m^2, significantly higher than 'Pusa Sugandh 3' and 'Pusa Basmati 1' (Table 1). Significantly more panicles/m^2 was recorded with 25 × 25 cm as compared to 30 × 30 cm. Highest number of panicles/m^2 recorded in weed free treatment, being at par to anilophos @ 0.4 kg/ha, but both were superior than weedy check. 'Pusa Sugandh 5' being at par with 'Pusa Sugandh 3' produced significantly heavier panicles than 'Pusa Basmati 1'. Spac-

Table 1. Plant height and yield attributes of rice as influenced by variety, spacing and weed control measure

Treatment	Plant height (cm) at harvest		Panicles/ m^2		Panicle weight (g)		Grains/ panicle		1,000-grain weight (g)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Variety										
'Pusa Basmati 1'	103.9	97.2	240.0	270.0	2.75	2.88	106.1	106.1	21.3	21.5
'Pusa Sugandh 5'	108.7	109.3	362.0	390.0	3.75	3.38	129.5	127.6	24.5	22.3
'Pusa Sugandh 3'	110.2	109.7	232.0	262.5	3.50	3.25	117.8	107.4	24.1	23.3
SEm±	1.3	0.1	7.25	8.00	0.17	0.04	4.7	4.7	0.37	0.28
CD (P=0.05)	5.2	0.4	28.5	32.0	0.56	0.15	18.5	18.5	1.46	1.09
Spacing										
25 × 25 cm	105.6	104.8	290.0	325.0	3.38	3.15	120.1	115.7	23.2	22.7
30 × 30 cm	109.1	105.9	265.0	292.0	3.38	3.12	115.5	111.5	23.3	22.0
SEm±	0.7	0.1	6.25	6.50	0.49	0.05	2.6	1.4	0.38	0.12
CD (P=0.05)	2.3	NS	21.2	23.0	NS	NS	NS	NS	NS	0.41
Weed control measure										
Weedy check	102.3	103.5	252.5	285.0	3.37	2.87	112.3	105.1	22.5	21.4
Anilophos@0.4 kg/ha	110.7	106.2	282.5	312.5	3.25	3.25	115.9	115.3	23.5	22.5
Weed free	109.5	106.4	297.5	327.5	3.38	3.37	125.4	120.8	23.8	23.1
SEm±	2.0	0.1	9.70	8.31	0.11	0.06	3.4	2.9	0.42	0.26
CD (P=0.05)	5.9	0.3	28.2	24.2	NS	0.17	9.7	8.3	NS	0.76

Table 2. Grain yield, straw yield, harvest index and economics of rice as influenced by variety, spacing and weed control measure

Treatment	Yield						Economics					
	Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)		Gross income (× 10³₹/ha)		Net income (×10³₹/ha)		Benefit: Cost ratio	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Variety												
'Pusa Basmati 1'	3.16	3.27	4.48	5.04	41.4	39.3	24.9	26.0	10.5	11.0	0.73	0.72
'Pusa Sugandh 5'	3.85	4.08	5.72	6.17	40.2	39.8	30.6	32.4	16.2	17.4	1.12	1.16
'Pusa Sugandh 3'	3.02	3.12	5.00	5.22	37.6	37.4	24.1	24.9	9.7	9.9	0.67	0.66
SEm±	0.03	0.01	0.11	0.10	0.52	0.25	-	-	-	-	-	-
CD (P=0.05)	0.13	0.04	0.43	0.39	2.04	0.97	-	-	-	-	-	-
Spacing												
25 × 25 cm	3.71	3.86	5.45	5.95	40.5	39.3	29.5	30.7	15.1	15.7	1.04	1.02
30 × 30 cm	2.99	3.12	4.68	5.01	39.0	38.4	23.9	24.9	9.4	9.8	0.66	0.65
SEm±	0.03	0.006	0.10	0.10	0.45	0.24	-	-	-	-	-	-
CD (P=0.05)	0.10	0.02	0.36	0.35	1.50	0.80	-	-	-	-	-	-
Weed control measure												
Weedy check	2.39	2.49	3.93	4.08	37.8	37.9	19.3	19.8	4.9	4.8	0.34	0.32
Anilophos @ 0.4 kg/ha	3.61	3.74	5.18	5.72	41.0	39.5	28.7	29.8	14.3	14.8	0.99	0.98
Weed free	4.05	4.24	6.08	6.63	40.0	39.0	32.2	33.8	17.7	18.7	1.23	1.25
SEm±	0.08	0.007	0.12	0.09	0.62	0.54	-	-	-	-	-	-
CD (P=0.05)	0.24	0.03	0.37	0.27	1.80	1.57	-	-	-	-	-	-

ing did not affect the panicle weight significantly. Weed free treatment had the highest panicle weight, and was at par with anilophos @ 0.4 kg/ha, but both produced significantly heavier panicles than the weedy check in 2006. In 2006, the highest number of filled grains/panicle observed in 'Pusa Sugandh 5', which was significantly higher than 'Pusa Basmati 1' and 'Pusa Sugandh 3'. Spacing did not affect the number of filled grains/panicle significantly. In year 2005, the highest number of grains/panicle observed with weed free treatment, which was significantly higher than anilophos @ 0.4 kg/ha and weedy check.

'Pusa Sugandh 5' had the highest 1,000-grain weight, which was at par with 'Pusa Sugandh 3', both recording significantly higher 1000-grain weight than 'Pusa Basmati 1' in 2005. In 2006, 'Pusa Sugandh 3' recorded the highest 1,000-grain weight, being at par to 'Pusa Sugandh 5' and significantly higher than 'Pusa Basmati 1'. Plant spacing 25 × 25 cm had significantly higher 1,000-grain weight than 30 × 30 cm in year 2006 of the study. The highest 1,000-grain weight was recorded in weed free treatment, being at par to anilophos @ 0.4 kg/ha and both recording significantly higher 1,000-grain weight than the weedy check in year 2006.

Grain yield, straw yield and harvest index

The data on grain yield, straw yield and harvest index are given in table 2. The highest grain yield was obtained in 'Pusa Sugandh 5', which was significantly higher than both 'Pusa Basmati 1' and 'Pusa Sugandh 3'. 'Pusa Basmati 1' also produced significantly higher grain yield over 'Pusa Sugandh 3'. On an average, 'Pusa Sugandh 5' produced 18.9 and 22.5% higher grain yield over 'Pusa Basmati 1' and 'Pusa Sugandh 3', respectively. Similarly, 'Pusa Basmati 1' produced 4.3% more grain yield over 'Pusa Sugandh 3'. Overall, 'Pusa Sugandh 5' outyielded the other two varieties substantially. The main reason for higher yields with 'Pusa Sugandh 5' than 'Pusa Basmati 1' and 'Pusa Sugandh 3' could be the significant difference in major yield attributes. Their genetic constitution may have caused a significant variation in grain yield of different varieties. Similarly, Singh *et al.* (2005) concluded from a field study that 'Pusa Basmati 1' and 'IET-13548' gave significantly higher grain yield compared to the mean grain yield of 'Taraori Basmati'. Dongarwar *et al.* (2005) also reported a significant variation in grain yield of scented rice varieties.

A spacing of 25 × 25 cm produced substantially and significantly higher grain yield than 30 × 30 cm spacing. Averaged over two years, the increase in grain yield with 25 × 25 cm over 30 × 30 cm was to the tune of 19.5%. The highest grain yield was obtained in weed free treatment, which was significantly higher than anilophos @ 0.4 kg/ha and weedy check during both the years. Averaged over the two years, weed free treatment recorded 41.2% and 11.3% more grain yield over the weedy check and anilophos @ 0.4 kg/ha treatment, respectively. The increase in grain yields with anilophos @ 0.4 kg/ha over the weedy check was to the tune of 33.7%.

During both the years, 'Pusa Sugandh 5' produced highest straw yield, which was significantly greater than 'Pusa Basmati 1' and 'Pusa Sugandh 3'. Significantly more straw was obtained with 25 × 25 cm spacing than 30 × 30 cm during both the years. The highest quantity of straw was produced in weed free treatment, which was significantly greater than both anilophos @ 0.4 kg/ha and the weedy check in both the years. Rice varieties had a significant effect on harvest index (Table 2). 'Pusa Basmati 1' and 'Pusa Sugandh 5' were at par and significantly superior to 'Pusa Sugandh 3'. A spacing of 25 × 25 cm recorded significantly higher harvest index (mean 39.9% than 30 × 30 cm) (mean 38.7%). The highest value of harvest index recorded with anilophos @ 0.4 kg/ha, which was at par with the weed free treatment, and both recording significantly higher harvest index than the weedy check.

Economics

Gross and net income and B:C ratio of 3 rice varieties were in the following decreasing order: 'Pusa Sugandh 5'> 'Pusa Basmati 1'> 'Pusa Sugandh 3', 'Pusa Sugandh 5' giving the higher values (Table 2). Narrower plant spacing (25 × 25 cm) gave substantially higher gross and net income and B:C ratio than the wider (30 × 30 cm) one. The weed free treatment gave the highest net income and B:C ratio, followed by anilophos @ 0.4 kg/ha, which in turn gave higher values than the weedy check.

It is concluded that rice 'Pusa Sugandh 5' gave higher yields and economic returns than the other 'Pusa Basmati 1' and 'Pusa Sugandh 3', when grown by the SRI method spacing of 25 × 25 cm was better than 30 × 30 cm. Weed free treatment gave higher yields and returns than anilophos treated and weedy check.

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