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Study on yield potentiality and spatial requirement of rice varieties (*Oryza sativa* L.) in system of rice intensification (SRI) under red and laterite zone of West Bengal, India

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Abstract: Field experiment was conducted at Rice Research Station, Bankura during kharif season 2009 and 2010 to study the yield potentiality and spatial requirement of rice varieties in system of rice intensification (SRI) under red and laterite zone of West Bengal. The experiment was laid out in a randomized complete block design (RCBD) in a three replications with two rice varieties (Swarna and Lalat). Performances of swarna and lalat varieties in SRI as compared to conventional method of rice cultivation (CMRC) were investigated. Swarna (MTU 7029) has yielded maximum grain yield (6.07, 5.66 and 5.86 t ha-1 during 2009, 2010 and in pooled, respectively) from the treatment T7 (25 × 25 cm spacing) under SRI. Lowest grain yield (3.55, 3.23 and 3.38 t ha-1 during 2009, 2010 and in pooled, respectively) was recorded from treatment T9 (Lalat at 20 × 15 cm spacing) under CMRC. SRI technology has potential in increasing more grain yield, it saves seed requirement and irrigation water and chemical fertilizer considering than conventional method of cultivation. Rice cultivation is more sustainable and profitable for the farmers in SRI under the red and laterite zone of West Bengal.

Keywords: Grain yield, Plant-hill spacing, Rice cultivation, Rice intensification, Sustainable system

INTRODUCTION

The System of Rice Intensification (SRI) is a new methodology for increasing the yield of rice. It was developed in 1983 by the father Henri de Laulanie in Madagascar. SRI is a combination of several practices that include slight changes in nursery management, time of transplanting and management of water, nutrients and weeds. Though fundamental practices remain more or less same, SRI emphasizes certain changes in agronomic practices from conventional method of rice cultivation (Satyanarayana, 2004).

SRI methodology involves a set of practices in nursery, soil, water, plant and nutrient management. The convergence of changes in the way that plants, soil and water are best managed and produced is what is known as the as the System of Rice Intensification. Sinha and Talati (2007) reported that SRI increased rice grain yield as compared to conventional method of rice cultivation by 32% in West Bengal, India. Sato and Uphoff (2007) reported that 78% increase in average rice yield under SRI with reduction of 40% in water use, 50% in fertilizer and 20% in cost of production as compared to conventional method of rice cultivation in Indonesia. Jana *et al*. (2015) reported that grain yield was significantly higher in SRI than conventional method of rice cultivation. Mc Donald *et al.* (2006) analysed data from 40 sites from different countries including China, Nepal, Madagascar, Thailand, India, Sri Lanka, Bangladesh, Philippines and Indonesia and reported that 24 of 35 sites demonstrated inferior rice yields with SRI than with best management practices of rice cultivation. Farmers and researchers have reported that yield increases through SRI of 1.5 to 2.54 t ha^{-1} in Tamil Nadu and Andhra Pradesh (Satyanarayana, 2004; Thiyagarajan *et al*., 2005). Sinha and Talati (2005) also reported in the IWMI TATA study a saving in water, an increase in straw yield by 50%, labour productivity increased by 43%, with net return increase by 67% in Purulia, West Bengal, India. SRI creates favourable micro-climates conditions for plant growth (DRR, 2011). Better root growth and proliferation in SRI and also opportunity to extract water and nutrients both from larger soil profile area, which in turn improved synthesis as reported by Barla and Kumar (2011). Therefore, the present study was undertaken to study the yield potentiality and spatial requirement of rice varieties (*Oryza sativa* L.) in system of rice intensification (SRI) under red and laterite zone of West Bengal, India.

MATERIALS AND METHODS

Filed experiment was conducted comparing SRI and

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Table 1. Treatments details.

Treat-ments	Variety	Spacing	System of Cultivation
T_1	Lalat	20 cm × 15 cm	SRI
T_2	Lalat	20 cm × 20 cm	SRI
T_3	Lalat	25 cm × 25 cm	SRI
T_4	Lalat	30 cm × 30 cm	SRI
T_5	Swarna	20 cm × 15 cm	SRI
T_6	Swarna	20 cm × 20 cm	SRI
T_7	Swarna	25 cm × 25 cm	SRI
T_8	Swarna	30 cm × 30 cm	SRI
T_9	Lalat	20 cm × 15 cm	CMRC
T_{10}	Swarna	20 cm × 15 cm	CMRC

SRI: System of rice intensification; CMRC: Conventional method of rice cultivation

conventional method of rice cultivation (CMRC) on varietal performance and plant-hill spacing during *kharif* season 2009 and 2010 at Rice Research Station, Bankura, West Bengal, India located under red and laterite zone (western region of West Bengal). The experimental site represents low rainfall area (drought prone) of the state, with average annual rainfall of 1200-1400 mm. The mean monthly temperature varied between 9.84^{0}C in the January (coldest month) and 38.68^{0}C in April (hottest month) and mean relative humidity 65% in November and 89% in July. The experimental soil was sandy loam with acidic in nature (pH: 4.9) and 0.12 ds m^{-1} EC, 0.56% organic carbon, 36 kg ha^{-1} available P_2O_5, 193 kg ha^{-1} available K.

The experiment was laid out in a randomized complete block design (RCBD), replicated thrice and compared three factors in ten treatment combination (Table 1). The three factors were: rice varieties (two), plant-hill spacing (four) and crop establishment methods (two). Transplanting of younger rice seedlings (12 days old) was done in SRI and transplanting older seedling (28 and 33 days old for lalat and swarna, respectively) in CMRC. The average length of seedling at transplanting in SRI was about 10-12 cm (at about 2 leaf stage) and of seedling in CMRC was about 30-35 cm (at 4-5 leaf stage). The two rice varieties were Lalat and Swarna (MTU-7029). The plot size was 4m × 3m. Regarding fertilizer management N, P_2O_5, K_2O @ 60, 30, 30 kg ha^{-1} were applied [75% by inorganic source and 25% through organic source (vermicompost)]. Application of 1/4th (25%) of the recommended dose of N and total P and 75% K as basal were done. Second dose of N (50%) at the time of 2nd weeding (20 DAT) was applied. Final dose of 25% N along with remaining 25% K at panicle initiation stage were applied. Applied F.Y.M @ 5 t ha^{-1} and incorporation of *Glyricidia* (leaf and twigs) as green manure @ 5 t ha^{-1} at 20 DBP (days before planting) was done.

Plant height (from ground level to the tip of the flag leaf) was taken at ripening stage based on randomly selected ten plants. The 5 m^2 area in the middle of each plot was harvested for recording grain yield. Ten rice hills outside the harvested area were selected and harvested separately for recording yield parameters, viz., number of tillers hill^{-1}, 1000-grain weight, length of panicle (cm) and panicle weight etc.

RESULTS AND DISCUSSION

Plant height: It was affected by the crop establishment methods (SRI and CMC). Transplanting of younger seedlings (12 days old) produced significantly taller plants than the transplanting of older seedlings (28-33 days old). Highest plant height (122.20, 115.72 and 118.9 cm during 2009, 2010 and in pooled, respectively) was recorded from treatment T_3 (25 × 25cm plant-hill spacing) under SRI (Table 2) and lowest plant height (115.42, 107.57 and 108.8 cm during 2009, 2010 and in pooled, respectively) was obtained from T_9 treatment (20 × 15cm plant-hill spacing) under conventional method of rice cultivation in case of lalat. Swarna has recorded maximum plant height (114.27, 106.37 and 110.2 cm 2009, 2010 and in pooled, respectively) at 25 × 25cm plant-hill spacing from treatment T_7 under SRI and lowest plant height (107.23, 99.35 and 103.2 cm 2009, 2010 and in pooled, respectively) was recorded from treatment T_{10}

Table 2. Plant height and number of tillers hill^{-1} of rice varieties as influenced by SRI and CMRC.

Treatments	Plant height (cm) at harvest			No. of tillers hill^{-1}		
	2009	2010	Pooled	2009	2010	Pooled (No. of hills m^{-2})
T_1	117.5	110.8	114.1	7.64	6.87	7.23 (33)
T_2	119.6	113.5	116.5	10.75	10.24	10.35 (25)
T_3	122.2	115.7	118.9	17.56	16.75	16.82 (16)
T_4	116.8	110.8	113.8	23.35	22.27	22.74 (11)
T_5	113.2	103.6	108.2	9.42	8.69	9.05 (33)
T_6	112.4	104.4	108.4	13.78	12.60	13.10 (25)
T_7	114.2	106.3	110.2	22.62	21.18	21.26 (16)
T_8	110.8	103.9	106.3	28.94	26.54	27.14 (11)
T_9	115.4	107.5	108.8	6.78	6.57	6.67 (33)
T_{10}	107.2	99.3	103.2	8.77	8.33	8.42 (33)
S.Em (±)	2.30	2.71	2.52	1.80	1.51	1.78
C.D. (0.05)	6.83	8.07	7.58	5.35	4.48	5.32

SRI: System of rice intensification (T_1 to T_8) CMRC: Conventional method of rice cultivation (T_9 and T_{10})

Table 3. Number of matured panicles m^{-2}, 1000-grain weight and panicle length of rice varieties as influenced by SRI and CMRC.

Treatments	No. of matured panicles m^{-2}			1000-grain weight (g)			Panicle length (cm)		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
T_1	234.3	215.3	224.2	21.83	20.23	21.03	24.19	23.51	23.82
T_2	256.7	248.2	252.4	22.25	22.50	22.21	26.16	24.68	25.35
T_3	272.9	256.1	264.3	22.34	23.27	22.62	26.83	25.45	26.14
T_4	240.8	237.3	239.0	22.84	23.50	23.17	26.10	24.22	25.16
T_5	295.8	277.6	285.4	19.53	20.17	19.74	24.70	23.92	24.31
T_6	330.5	315.8	322.1	20.25	20.33	21.25	25.72	24.05	24.12
T_7	355.9	331.6	343.5	20.87	20.85	20.86	26.63	25.12	25.84
T_8	300.3	285.5	292.6	21.58	22.33	21.82	25.23	23.64	24.43
T_9	212.1	205.4	207.7	21.56	19.60	20.58	23.92	20.23	21.92
T_{10}	271.4	263.2	267.1	19.42	19.97	19.59	22.54	19.74	21.12
S.Em (±)	9.87	5.45	6.63	1.27	1.22	1.26	0.84	2.01	1.25
C.D. (0.05)	29.31	16.83	19.68	NS	NS	NS	2.50	5.96	3.72

SRI: System of rice intensification (T_1 to T_8) CMRC: Conventional method of rice cultivation (T_9 and T_{10})

(20 × 15cm plant-hill spacing) under CMRC. This might be due to development of better root system (length and growth) by younger seedlings under SRI which in turn produced vigorous and taller plants. It was also reported by Uphoff in the year of 2002. Vijayakumar *et al.* (2006) reported that rice plants were taller under SRI as compared to CMRC.

Number of tillers hill^{-1}: It was significantly affected during both the years and in pooled data is presented in table 2. The maximum no. of tillers hill^{-1} were recorded from treatment T_4 (lalat at 30 × 30cm spacing) and T_8 (swarna at 30 × 30cm spacing) under SRI. The minimum no. of tillers hill^{-1} were obtained from treatment T_9 (lalat at 20 × 15cm spacing) and T_{10} (swarna at 20 × 15cm spacing) under traditional method of cultivation. The number of tillers hill^{-1} were higher at 30 × 30cm spacing (wider) under SRI than at 20 × 15cm spacing (narrow) under conventional method of cultivation by about 3.3 times. It might be due to production of relatively more tillers at wider spacing as compared to narrow spacing, because of advantage of space, nutrition and sunlight at wider spacing. Wider spacing was adopted in SRI, which provides ample light and soil space – this situation encourages luxuries root growth and more number of tillers per hill supporting synergistically (DRR, 2011).

Number of mature panicles m^{-2}: It was statistically significant. In case of lalat, highest no. of matured panicles m^{-2} (272.9, 256.1 and 264.3 during both years and in pooled data, respectively) were recorded from treatment T_3 (25 × 25cm spacing) and it was statistically at par with treatment T_2 (20 × 20cm spacing) under SRI (Table 3). Lowest number of matured panicles m^{-2} (212.1, 205.4 and 207.7 during 2009, 2010 and in pooled, respectively) were obtained from treatment T_9 (20 × 15cm spacing) under CMC and was at par with treatment T_1 (20 x 15cm spacing) and T_4 (30 × 30cm spacing) under SRI and it was significantly lower than other treatments. In case of swarna, maximum no. of matured panicles m^{-2} (355.9, 331.6 and 343.5 during 2009, 2010 and in pooled data, respectively) were recorded from treatment T_7 (25 × 25cm spacing) and it was significantly higher than other treatments and statistically at par with treatment T_6 (20 × 20cm spacing) under SRI. Lowest no. of matured panicles m^{-2} (271.4, 263.2 and 267.1 during 2009, 2010 and in pooled, respectively) were obtained from treatment T_{10} (20 × 15cm spacing) under CMRC and it was statistically at par with treatment T_5 (20 × 15cm spacing) and T_8 (30 × 30cm spacing) under SRI. Number of tillers hill^{-1}was more at 30 × 30cm spacing due to wider spacing, but number of hills m^{-2} was decrease. 11 hills m^{-2} were accommodated at 30 × 30cm spacing as compared to 33 hills m^{-2} at 20 × 15cm spacing. Sharma and Masand (2008) observed that lowest number of mature panicles m^{-2} was obtained from conventional method of rice cultivation (CMRC) and highest number of matured panicles m^{-2} was recorded from SRI (25 x 25cm spacing).

1000-grain weight: It was not significantly affected by the SRI and CMRC. It is more or less genetically controlled character. However, the value of 1000-grain weight was higher at 30 × 30cm spacing under SRI than at 20 x 15cm spacing under CMRC.

Length of panicle: Experimental results also revealed that the length of panicle was statistically significant and affected by the methods of establishment (SRI and CMRC). In case of lalat the highest length of panicle (26.83, 25.45 and 26.14cm during 2009, 2010 and in pooled, respectively) was obtained from treatment T_3 (25 × 25cm spacing) under SRI and it was statistically at par with treatment T_2 and T_4 and significantly higher than treatment T_9 and T_1. In case of swarna, maximum length of panicle (26.63, 25.12 and 25.84cm during 2009, 2010 and in pooled, respectively) was recorded from treatment T_7 (25 × 25cm spacing) under SRI and lowest panicle length was obtained from treatment T_{10} (20 × 15cm spacing) under CMRC. It was statistically at par with treatment T_5 and significantly lower than other treatment (Table 3).

Table 4. Panicle weight and grain yield of rice varieties as influenced by SRI and CMRC.

Treatments	Panicle weight (g)			Grain yield (t ha^{-1})		
	2009	2010	Pooled	2009	2010	Pooled
T_1	2.15	1.98	2.06	3.84	3.48	3.65
T_2	2.69	2.61	2.62	4.43	4.22	4.32
T_3	3.15	3.06	3.10	4.98	4.42	4.69
T_4	2.89	2.84	2.84	4.11	3.80	3.92
T_5	2.46	2.36	2.41	4.73	4.20	4.46
T_6	2.97	2.82	2.86	5.58	5.16	5.36
T_7	3.37	3.28	3.31	6.07	5.66	5.86
T_8	3.08	2.95	3.01	4.97	4.47	4.69
T_9	1.97	1.84	1.90	3.55	3.23	3.38
T_{10}	2.22	2.15	2.17	4.32	4.18	4.25
S.Em (±)	0.21	0.11	0.20	0.24	0.18	0.22
C.D. (0.05)	0.63	0.33	0.59	0.73	0.55	0.66

SRI: System of rice intensification (T_1 to T_8) CMRC: Conventional method of rice cultivation (T_9 and T_{10})

Panicle weight: It was also significantly affected. The highest panicle weight was recorded at 25 × 25cm spacing under SRI and lowest at 20 × 15cm spacing under conventional method of cultivation in case of lalat and swarna varieties both (Table 4). The highest value of panicle weight (3.37, 3.28 and 3.31gm in case of swarna and 3.15, 3.06 and 3.10gm in case of lalat during both years and in pooled data, respectively) were recorded at 25 × 25cm spacing under SRI. Lowest value of panicle weight (2.22, 2.15 and 2.17gm in case of swarna and 1.97, 1.84 and 1.90gm in case of lalat during 2009, 2010 and in pooled data, respectively) were obtained at 20 ×15cm spacing under conventional method of rice cultivation (Table 4). Moreover, the panicle length and panicle weight of rice crop were more with SRI than CMRC. Similar findings were observed by Sharma and Masand (2008).

Grain yield: During *kharif* season 2009, 2010 and in pooled data (Table 4) revealed that the grain yield was significantly affected by crop establishment methods (SRI and CMRC). Lalat variety yielded highest grain yield (4.98, 4.42 and 4.69 t ha^{-1} during 2009, 2010 and in pooled, respectively) and it was obtained from T_3 (25 × 25cm spacing) under SRI and it was statistically at par with treatment T_2 (20 × 20cm spacing) and significantly higher than other treatments. Where as, the lowest grain yield (3.55, 3.23 and 3.38 t ha^{-1} during 2009, 2010 and in pooled, respectively) was recorded from treatment T_9 (20 × 15cm spacing) under traditional method of rice cultivation. It was statistically at pat with treatment T_1 (20 × 15cm spacing) and T_4 (30 × 30cm spacing) under SRI. Swarna yielded maximum grain yield (6.07, 5.66 and 5.86 t ha^{-1} during 2009, 2010 and in pooled, respectively) from treatment T_7 (25 × 25cm spacing) under SRI and it was statistically at par with T_6 treatment (20 × 20cm spacing) under SRI. Where as, the lowest grain yield (4.32, 4.18 and 4.25 t ha^{-1} during 2009, 2010 and in pooled, respectively) was recorded from treatment T_{10} (20 × 15cm spacing) under CMRC and it was statistically at par with treatment T_5 (20 × 15cm spacing) and T_8 (30 × 30cm spacing) under SRI. This might be due to improved synthesis and translocation of metabolites to various reproductive structures of rice plant and better distribution of it's into grain would always results in higher grain yield of rice under SRI. This was agreed with Barla and Kumar (2011) as they reported that significantly more grain yield of rice was recorded under SRI than conventional method of rice cultivation.

Increased grain yield under SRI is mainly due to the synergistic effects of modification in the cultivation practices such as use of young and single seedling per hill, frequent loosening of the top soil to stimulate aerobic soil conditions. Transplanting of very young seedling usually 10-12 days old, preserves it's potential for tillering and rooting, which was reduced if transplanted after the occurrence of fourth phyllochron. This might be due to combination of plant, soil, nutrient and water management practices followed in SRI increased the root growth along with increase in productive tillers, panicle length, panicle weight, grain filling and higher grain weight that ultimately resulted in higher grain yield. Use of conoweeder might improve aeration and health status of the soil due to incorporation of weed biomass in soil under SRI. Crop growth has been emphasized by different proponents of SRI as reported by Uphoff (2002) and resulting in increased crop vigour and yield attributes.

Conclusion

Swarna variety (MTU 7029) has yielded more grain yield than Lalat variety at 25 × 25cm spacing under system of rice intensification (SRI) as compared to conventional method of cultivation in red and laterite zone of West Bengal. Less time was required for transplanting rice seedlings under SRI. It lowered the man-day requirement for transplanting rice seedlings under SRI as compared to CMC. Transplanting of one seedling $hill^{-1}$ in SRI significantly lower seed requirement as compared to conventional method of rice cultivation (3 seedlings hill^{-1}). Higher grain yield was recorded from SRI as compared to CMRC. Thus, SRI technology has potential in increasing more grain yield. It saves seed requirement and irrigation water and chemical fertilizer than the traditional method of cultivation. Rice cultivation is more sustainable and profitable for the farmers under SRI in the red and laterite zone of West Bengal, India.

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