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Research Paper

Influence of establishment methods, irrigation water levels and weed-management practices on growth and yield of rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) and winter (*rabi*) seasons of of 2012–13 and 2013–14 at the Indian Institute of Rice Research (IIRR), Hyderabad, Telangana, in clay loam soils, to evaluate the influence of different establishment techniques, irrigation water levels and weed-management practices on productivity, growth and yield of rice (*Oryza sativa* L.). System of rice intensification (SRI) was significantly superior to conventional and mechanized transplanting for grain yield (6.10 and 6.47 t/ha), yield attributes like panicles/m^2 (376 and 405), panicle weight (4.6 and 4.9 g), 1,000-grains weight (17 and 18 g) and growth parameters like leaf area (2,743.6 and 2,820.5 cm^2/hill) and effective tillers/m^2 (470 and 482) during *kharif* and *rabi* respectively, in both the years. Alternate wetting and drying (AWD) and cono-weeding recorded significantly higher growth and yield parameters over the other irrigation and weed-management practices, respectively, due to profuse root growth and aerated condition.

Key words : Alternate wetting and drying (AWD), Growth and yield attributes, Rice, Saturation, SRI, Yield

In India, rice occupies an area of 44 m ha with an average production of 90 m tonnes, with productivity of 2.0 tonnes/ha. Demand for rice is growing every year and it is estimated that in 2025 AD, the requirement would be 140 m tonnes. According to the projections made by the Population Foundation of India, India's population will be 1,546 million by the end of 2030. It is estimated that the demand for rice will be 121.2 m tonnes. In order to achieve this target, the productivity of rice has to be brought to the level of 3.3 tonnes/ha from present level of 2.2 tonnes/ha (Anjani *et al.,* 2014). Rice cultivation requires large quantity of water and for producing 1 kg rice, about 3,000–5,000 litres of water is required depending on the different rice cultivation methods such as transplanted rice, direct-sown rice (wet seeded), alternate wetting and drying (AWD) method, system of rice intensification (SRI) and aerobic rice. Due to increasing water scarcity, a shifting trend towards less-water demanding crops against rice is noticed in most parts of the India and this warrants alternate methods of rice cultivation that aims at minimal use of water and high crop productivity. There are evidences that cultivation of rice through system of rice intensification (SRI) can increase rice yields by 2 to 3 fold compared to current yield levels (Shantappa *et al*., 2014).

Increasing water scarcity is becoming real threat to rice cultivation. Hence water-saving technology which also maintains soil health and sustainability as well as economically beneficial, needs to be developed (Subramaniam *et al*., 2013). Any approach that would lessen the amount of water use without compromising the rice yield would certainly be a welcome strategy. Introduction of SRI is an alternative practice to solve water crisis, and as a methodology for increasing the productivity of irrigated rice. Hence, a field experiment was conducted to study effect of different establishment methods, irrigation water levels and weed-management practices on growth and yield parameters of rice.

MATERIALS AND METHODS

A field experiment was carried out during the rainy

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(*kharif*) and winter (*rabi*) seasons of 2012–13 and 2013–14 at wetland farm of ICAR-Indian Institute of Rice Research (Formerly Directorate of Rice Research), Hyderabad, under irrigated conditions, on clay loam soil. The soil had *p*H 8.1, available P (25.4 kg/ha) and available K (139.5 kg/ha). The experiment was laid out in a split-split plot design with 3 replications. The main plots consisted of 3 establishment methods, *viz.* system of rice intensification (SRI), normal transplanting (NTP) and mechanized transplanting; sub plots comprised of 3 water levels, *viz.* flooding (maintaining continuous submergence at a depth of 5 cm standing water), saturation and alternate wetting and drying (AWD); sub-subplot consisted of 2 weed-management practices like cono-weeding at 10, 20, 30 and 40 days after transplanting (DAT) and chemical weed control. Pre-emergent application of butachlor (50% EC) @ 1 kg a.i./ha, followed by early post-emergent application of bispyribac sodium (10% EC) @ 0.025 kg a.i./ha at 25–30 DAT. Irrigation treatments were isolated with buffer channels, so that water movement can be effectively controlled and managed. Seedlings were raised in nursery in accordance with establishment methods. Seeds were soaked for 24 hr and incubated in moist gunny bags for 2 days. Pre-germinated seeds were broadcast uniformly on nursery beds. Soil : farmyard manure mixture (1:1) was spread in a thin layer. The beds were irrigated daily and thoroughly before lifting the seedlings. For mechanized transplanting method, seedbed was prepared on plastic sheet having a thick layer of sieved soil. Sprouted seeds were spread on it and covered with hay, drenched with water. Seedlings of 14 to 17 days and 18 to 22 days were used during *kharif* and *rabi* respectively. Mats were mounted on riding-type 6 rows Korean transplanter for transplanting uniformly 2–3 seedlings/hill with spacing of 30 cm × 10 cm. To overcome the inconvenience of mechanized transplanting in small plots, main plots were transplanted followed by layout of sub plots and imposed treatments.

The main field was prepared based on the establishment techniques. The FYM was incorporated 2 weeks before transplanting. Seedlings of 12, 18 and 25 days were used, respectively, for SRI, mechanized transplanting and normal transplanting. Marked ropes were used for square planting in the SRI method with 25 cm × 25 cm spacing. Similarly, 20 cm × 10 cm for NTP and mechanized transplanting (6 rows Korean transplanter) was done with 30 cm of row-to-row spacing in lines. Recommended dose of fertilizer was applied, i.e. 120, 40 and 60 kg/ha N, P_2O_5 and K_2O in all methods. Half the recommended dose of N and full dose of P and K were applied basal and remaining N was applied in 2 equal splits–at 30 and 60 DAT.

The length and maximum width of each leaf on the middle tiller was measured and leaf area of each leaf was computed as fallows;

$$\text{Leaf area} = K \times L \times W$$

where K = constant factor (0.67 to 0.80), L = length of leaf (cm) and W = width of leaf (cm)

RESULTS AND DISCUSSION

Growth parameters

During both rainy (*kharif*) and winter (*rabi*) seasons, except plant height all the growth parameters were significantly higher in SRI method. NTP showed taller plants during both *kharif* and *rabi*, whereas SRI method recorded significantly higher leaf area during both the seasons at maturity compared to NTP and mechanized transplanting. Optimum plant population and geometry under SRI led to availability of more resources to the plants that resulted in higher leaf area and more number of tillers. This might be owing to adequate availability of nutrients through wider spacing which also produced higher number of effective tillers with higher leaf area, less plant density and early establishment in the SRI method. Minimum number of tillers/m^2 was recorded under normal transplanting in both the seasons which might be due to intra-competition between plants and due to transplanting shock, as a consequence of which growth components were reduced under NTP compared to SRI methods (Satyanarayana and Babu, 2004).

There is need to conserve irrigation water, as it is one of the major drivers of change from traditional transplanting technique with prolonged periods of submergence to SRI with AWD water management. Intermittent application of water through AWD resulted in higher grain yield, being 21.3 and 9.6% higher during *rabi* over continuous submergence and saturation respectively. Increased yield in AWD was attributed by higher 1,000-seed weight and filled grains/panicle (127). Similarly, AWD resulted in significantly higher growth parameters like plant height, leaf area and tillers which paved the way for formation of required yield-contributing parameters over continuous submergence and saturation during *rabi* (Table 1). However, during *kharif* the growth and yield attributes of rice were not influenced due to unconditional rainfall. Increased growth and yield might be due to AWD practice which has provided sufficient nutrients for vegetative and reproductive growth due to aeration and better root growth. These results confirm the findings of Chandrapala *et al.* (2010). However, there may be yield decline when the irrigation interval increased from 5 to 8 days (Zhang *et al.*, 2009).

Four times conoweeded @ 10, 20, 30 and 40 DAT plots showed significantly higher grain yield of 17.1 and 13.6% compared to chemical control practice during both the *kharif* and *rabi* respectively. The higher yield was owing to higher values of yield-attributing characters, *viz.* higher number of panicles/m^2, 1,000-seed weight and filled grains/panicle, over the chemical control (Table 1). Sangeetha *et al*. (2015) also reported increase in growth and yield-attributing characters in cono-weeded plots compared to chemical control of weeds. The higher yield and yield parameters might be due to weed-free condition in cono-weeded plots. The cono-weeding process led to churning and decomposition of weed biomass that mineralized the nutrients and made them available to the plants (Barison and Uphoff, 2011). Cono-weeding also created aeration around rhizosphere of rice plants, which may act as oxidizer catalyst to enhance the micro-organism activity and rapid disintegration of weed biomass and led to increased availability of nutrients to the crop. Our findings confirm those of Mohapatra *et al.* (2012) and Hanumanthappa *et al.* (2012). As a result, these conditions enabled the crop to make maximum utilization of inputs for the crop growth, thereby improvement in yield attributes with low spikelet sterility and higher grain yield (Babar and Velayutham, 2012). Higher growth and yield components were recorded in treatment combinations involving SRI, intermittent application of water and cono-weeding which was followed by treatment combinations of SRI and saturation soil moisture compared to the other treatment combinations.

Yield and yield parameters

Yield is the complex character and it depends on many morphological and bio-chemical events that occur within plant during the crop growth and development. Optimization of the physical inputs through appropriate bio-hydro-chemical technologies along with better crop-establishment techniques, proper water and weed-management practices can results better yields. Among the methods followed, SRI recorded significantly higher grain yield over NTP and mechanized transplanting during *kharif* and *rabi* respectively (Table 2). The increased grain yield in SRI method was 53.8 and 45.7%, followed by mechanized transplanting with 32.2 and 11.55% over NTP during *kharif* and *rabi* seasons respectively. The higher grain yield was owing to outcome of higher values of yield-attributing characters. The SRI method recorded appreciably higher number of panicles/m^2, panicle weight and and filled grains over NTP and mechanized transplanting, respectively, during *kharif*. Similar trend was observed during *rabi* with relatively higher growth and yield parameters. The large root volume, profuse and strong tillers

Table 1. Influence of transplanting methods, irrigation water levels and weed-management practices on growth and yield parameters of rice (pooled data of 2 years)

Treatment	Plant height (cm)		Leaf area (cm^2/hill)		Tillers/m^2		Panicles/m^2		Panicle weight (g)		1,000-grain weight (g)	
	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season
Transplanting method (M)												
SRI	87.9	88.5	2,743.6	2,820.5	469.6	481.5	376.0	404.5	4.61	4.88	17.1	17.8
NTP	92.4	93.3	1,144.1	1,155.3	333.2	351.8	299.4	329.3	4.03	4.25	15.9	16.7
Mechanized transplanting	90.1	91.7	1,242.3	1,355.3	354.9	368.5	342.65	368.1	4.29	4.55	16.6	17.2
SEm±	0.42	0.75	64.48	74.64	12.00	13.05	5.71	5.41	0.06	0.03	0.21	0.18
CD (P=0.05)	1.63	2.9	256.83	293.05	47.13	51.24	22.43	21.2	0.26	0.18	0.84	0.68
Irrigation method (I)												
Flooding	88.9	89.8	1,563.5	1,650.9	362.8	377.3	314.7	341.0	4.22	4.32	15.8	16.6
Saturation	88.5	88.1	1,710.1	1,742.1	385.2	397.2	341.5	369.7	4.27	4.47	16.5	17.2
Alternate wetting and drying (AWD)	92.9	95.6	1,856.6	1,938.1	409.7	427.5	361.8	391.2	4.45	4.87	17.2	18.0
SEm±	1.68	1.52	21.99	24.03	9.22	8.77	11.79	11.74	0.05	0.01	0.30	0.29
CD (P=0.05)	NS	4.67	NS	74.03	NS	27.04	NS	36.1	NS	0.31	NS	0.89
Weed-management practice (W)												
Chemical control*	88.11	89.19	1,614.1	1,686.9	364.8	378.2	323.1	350.3	4.14	4.38	16.0	16.7
Cono-weeding (at 10, 20, 30 and 40 DAT)	92.15	93.09	1,805.9	1,867.1	407.1	423.1	355.5	384.4	4.49	4.74	17.0	17.8
SEm±	1.23	1.71	27.28	32.68	10.8	8.73	8.91	8.97	0.01	0.07	0.33	0.34
CD (P=0.05)	3.86	5.07	81.04	97.09	31.98	25.95	26.47	26.67	NS	NS	0.97	0.99

SRI, System of rice intensification; NTP, Normal Transplanting; DAT, Days after transplanting; NS, Non-significant

*Pre-emergent application of butachlor 50% EC @ 1 kg a.i./ha, followed by early post-emergent application of bispyribac sodium 10% EC @ 0.025 kg a.i./ha at 25–30 DAT with big panicles and well-filled spikelets with higher grain weight contributed to higher yield parameters in SRI method of establishment. The results confirm the findings of Satyanarayana and Babu (2004). The other possible reasons could be wider spacing, avoiding root injury and transplanting shock and planting of seedling before third phyllochron leading to quicker tiller initiation (Barison and Uphoff, 2011).

Weed management

During both the years, establishment techniques did not much influenced significantly the total number of weed count. whereas irrigation and weed-management practices differed significantly in respect of fertilizer total number of weed count. Significantly lower weed density was recorded under continuous submergence with 17.3 and 24.1, 11.4 and 16.8, 7.8 and 13.3% compared to saturation and AWD at 20, 40 and 60 DAT, respectively, during *kharif* pooled experimentation. The lower weed population in continuous submergence was perhaps due to creation of anaerobic conditions that led to formation of hydrogen peroxides. These peroxides have lethal effect on germination of weed seeds. Higher weed population in AWD plots might be due to the optimum conditions for weed seed germination (Haefele *et al.,* 2004).

Cono-weeding proved 41.9, 32.4 and 27.3% more effective in controlling weeds at 20, 40 and 60 DAT respectively, over pre- and post-emergent weedicide-sprayed plots (Table 2). Continuous tilling of soils with cono-weeder between inter- and intra-row spaces and incorporation of weed biomass into the soil proved advantageous (Kumar *et al*., 2012). Interaction effects of establishment methods, irrigation water levels and weed-management practices failed to pose significant impact on weed growth.

Water usage

Crop-establishment methods and weed-management practices did not influence significantly on the total water used unlike irrigation water levels during both the years (Table 2). The total quantity of irrigation water used was 1,433 and 1,259 mm/ha in continuous submergence, 960 and 802 mm/ha in saturation and 1,151 and 996 mm/ha in AWD during *kharif* and *rabi* respectively. Water saving of 33.0 and 19.6% during *kharif*, 36.3 and 31.2% during *rabi* in saturation and AWD, respectively, were recorded over continuous submergence. The maximum irrigation water

Table 2. Effect of transplanting methods, irrigation water levels and weed-management practices on yield and yield parameters of rice (pooled data of 2 years)

Treatment	Yield (t/ha)		Total weed population/m²						Water use-efficiency (%)		Benefit: cost ratio	
			20 DAT		40 DAT		60 DAT					
	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season
Transplanting method (M)												
SRI	6.1	6.5	3.24	4.03	8.06	9.81	13.50	14.94	55.2	68.3	3.12	3.37
NTP	4.0	4.4	6.72	7.31	12.72	13.64	20.17	21.33	35.0	45.9	2.14	2.48
Mechanized transplanting	4.6	5.0	5.88	6.36	10.92	12.72	18.33	18.19	41.8	51.0	2.64	2.99
SEm±	0.04	0.05	0.24	0.08	0.12	0.29	0.24	0.25	1.0	2.0	0.04	0.04
CD (P=0.05)	0.16	0.19	0.94	0.31	0.49	1.17	0.93	0.97	4.0	7.0	0.16	0.17
Irrigation method (I)												
Flooding	4.6	4.8	4.49	4.14	9.52	9.28	16.06	14.89	34.0	38.2	2.46	2.64
Saturation	4.9	5.3	5.43	6.39	10.75	12.44	17.42	18.44	52.0	67.0	2.64	2.94
Alternate wetting and drying (AWD)	5.1	5.8	5.91	7.17	11.44	14.44	18.53	21.11	46.13	59.6	2.79	3.26
SEm±	0.14	0.17	0.32	0.28	0.31	0.19	0.18	0.29	1.5	2.0	0.08	0.10
CD (P=0.05)	NS	0.53	0.98	0.87	0.96	0.59	0.57	0.92	4.6	7.12	0.26	0.32
Weed management practice (W)												
Chemical control*	4.5	5.0	6.68	7.35	12.61	14.54	20.07	20.37	40.2	51.4	2.53	2.86
Cono-weeding (at 10, 20, 30 and 40 DAT)	5.3	5.7	3.88	4.44	8.52	9.57	14.59	15.93	48.5	59.6	2.74	3.03
SEm±	0.11	0.10	0.06	0.19	0.23	0.18	0.20	0.28	1.0	1.6	0.07	0.08
CD (P=0.05)	0.33	0.30	0.21	0.55	0.69	0.53	0.59	0.84	NS	NS	0.22	NS

SRI, System of rice intensification; NTP, Normal Transplanting; DAT, Days after transplanting; NS, Non-significant

*Pre-emergent application of butachlor 50% EC @ 1 kg a.i./ha, followed by early post-emergent application of bispyribac sodium 10% EC @ 0.025 kg a.i./ha at 25–30 DA saving was observed under saturation method, followed by AWD due to the restriction of seepage and deep percolation losses by maintaining water level up to saturation attributing to lesser water use under saturation. Application of irrigation water, after formation of hairline cracks showed considerable water saving besides providing a better root-growing environment and microbial environment in AWD. Shantappa *et al*. (2014) reported more quantity of water saved (34%) in AWD than continuous submergence without reduction in yield. This could be because of significant reduction in seepage and percolation losses in rice field.

Economics

Economic viability is a function of gains and losses of production practices. The adoption of any technology in modern agriculture can only be feasible and acceptable to the farmers if it is economically viable. The SRI recorded 93.2 and 42.7% higher net income during *kharif* and 70.6 and 35.3% higher during *rabi* than NTP and mechanized transplanting respectively. It also recorded higher benefit : cost ratio of 45.8 and 18.18% higher during *kharif* and 35.8 and 12.7% higher during *rabi* season over NTP and mechanized transplanting. Among irrigation water levels and weed-management practices, AWD and cono-weeding recorded higher benefit: cost ratio over the other treatments. These are in line with findings of Singh *et al.* (2013).

The results of the study showed superiority of SRI in terms of growth and yield parameters, seed and water saving in rice over normal transplanting. Further, multi-location long-term research is useful to quantify each component of SRI, for enhancing resource conservation economically.

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