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Productivity of rice as influenced by irrigation regimes and nitrogen management practices under SRI

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ABSTRACT

A field experiment was conducted on a clay loam soil at Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad, Telangana during the kharif seasons of 2013 and 2014 to studay the effect of irrigation regimes and nitrogen management on rice under SRI. The Varadhan (DRR Dhan 36) variety was used in field experiment. The results revealed that the system of rice intensification proved significantly superior in terms of growth and yield parameters such as plant height, number of tillers, leaf area index, number panicles^{-1}, filled grains panicle^{-1}, test weight, grain yield and straw yield as compared to mechanized system of rice intensification. Irrigation maintained at saturation level produced significantly higher growth, yield parameters and yield which were comparable with irrigation at 3 DADPW. Application of nitrogen based on leaf colour chart registered significantly higher growth, yield parameters and yield which were at par with soil test crop response based nitrogen management practice but both these treatments were significantly superior over the RDN - 75 % inorganic and 25 % organic and RDN - 100 % through inorganic management practices.

Key words: Mechanized system of rice intensification, leaf colour chart, Productiviy, regression

INTRODUCTION

Traditional planting has been the most important and common method of crop establishment practice under irrigated lowland rice ecosystems in tropical Asia. In irrigated lowland rice which not only consumes more water but also causes wastage of water resulting in degradation of land. In recent years to tackle this problem, many methods of cultivation have been developed and one among them is System of Rice Intensification (SRI). SRI is a holistic agro ecological crop management technique seeking alternatives to the conventional high-input agriculture through effective integration of crop, soil, water and nutrient management. The mechanical transplanting of rice has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity. Overexploitation of ground water during recent decades has caused serious problems in South Asia (Perveen *et al*, 2012) which is affecting rice growing areas. Further, they observed that groundwater tables have dropped on an average by about 1 m y^{-1} in southern India, where flooded rice is the dominant cropping system. Therefore, rice could face a threat due to water shortages and hence, there is need to develop and adopt water saving methods in rice cultivation so that production and productivity levels are elevated despite the looming water crisis. Among nutrients, Nitrogen is the most important limiting element in rice growth (Jayanthi *et al.*, 2007a). Limitation of nitrogen in any growth phase of the plant growth causes reduction in yield. Improved understanding of the availability of nitrogen from the native organic nitrogen sources and the fate of added nitrogen fertilizer should aid in developing innovative nitrogen management practices and an increase in the efficiency of fertilizer. Keeping these points in view the field experiment was conducted to study effect of irrigation regimes and nitrogen management on productivity of rice under SRI.

Materials and Methods

A field experiment was conducted on a clay loam soil at Indian Institute of Rice Research (IIRR) formerly Directorate of Rice Research (DRR), Rajendranagar, Hyderabad, Telangana during the *kharif* seasons of 2013 and 2014. The variety was used Varadhan (DRR Dhan 36) is a derivative of indica / japonica cross with mid early duration that matures in 120-125 days. The treatments consisted of two planting methods (Mechanized system of rice intensification (MSRI) and system of rice

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intensification (SRI) as main plot treatments, three irrigation regimes (saturation, 5 cm irrigation at three and five days after disappearance of ponded water) as sub plot treatments and four nitrogen management practices (RDN - 100 % through inorganic, RDN - 75 % inorganic and 25 % organic, Leaf Colour Chart (LCC) based nitrogen application and Soil Test Crop Response (STCR) based nitrogen application with target yield of 6.5 t ha^{-1}) as sub-sub plot treatments summing up to 24 treatment combinations laid out in split-split plot design with three replications. Yangio - China paddy transplanter [Self-propelled rice transplanter] was used in the present field experiment. Irrigation water was applied through plastic pipe from the source and a water meter was used for measuring irrigation water.The recommended dose of phosphorus (60 kg P_2O_5 ha^{-1}) as single superphosphate, potassium (40 kg K_2O ha^{-1}) as muriate of potash and $ZnSO_4$ (20 kg ha^{-1}) were applied to all the treatments uniformly as basal. Recommended dose of nitrogen (120 kg ha^{-1}) and RDN - 75 % inorganic and 25 % organic treatment (20 kg ha^{-1}) was applied during both the seasons. Leaf colour chart (LCC) measures the green colour intensity of rice leaves. Five-panel LCC was used in present study and manufactured by Nitrogen Parameters, Chennai, India as per specifications of Directorate of Rice Research. Whenever the LCC values were found to be below the fixed critical level of three, recommended quantity of nitrogen was applied @ 25 kg $ha^{-1}$and the basal dose of nitrogen was applied @ 30 kg ha^{-1}. LCC based nitrogen management practice treatment was applied in 4 splits and remaining treatments 3 splits were applied (130 kg ha^{-1} in both the seasons). STCR based nitrogen application formula **FN=42 T - 0.55 SN** Where, FN= Fertilizer nitrogen (kg ha^{-1}), T= Targeted yield (t ha^{-1}), SN= Soil available nitrogen (kg ha^{-1}) during 2013 @ 145 kg $ha^{-1}$and 2014 @ 150 kg ha^{-1}.

The leaf area index (LAI), Leaf area duration (LAD), Crop growth rate (CGR), Relative growth rate (RGR) were calculated.The data obtained on the growth and yield parameters were analysed statistically by the method of analysis of variance (Gomez and Gomez, 1984). Statistical significance was tested by F value at 0.05 level of probability and critical difference was worked out whereever the effect was significant.

Results and Discussion

Growth parameters

The plant height was recorded significantly higher in system of rice intensification (7.3 %) as compared to mechanized SRI method (Table 1). Taller plants by transplanting of younger and single seedling by keeping the roots straight (ensuring that the roots do not assume 'J' shape) and wider spacing in both row to row and plant to plant might have encouraged vigorous root system and the plants get sufficient space above the ground to grow and the increased light transmission in the canopy thus leading to greater plant height in SRI (Singh *et al.*, 2013 and Mohanty *et al.*, 2014). The average number of tillers m^{-2} was not significantly influenced by planting methods at all the crop growth stages because of narrow spacing in MSRI and wider spacing at SRI as it led to similar number of tillers m^{-2}. But number of tillers $hill^{-1}$ recorded was significantly higher in SRI (12.6, 20.5, 18.9 and 16.8) over MSRI (7.6, 12.5, 11.5 and 10.4) at 30, 60, 90 DAT and at harvest of pooled means, respectively. SRI practice gets the benefit of the early phyllochron stages (less than four leaves) having higher potential to quick recovery and to produce more tillers $hill^{-1}$. Leaf area index during both the years was not significantly different at 30 DAT. At 60 and 90 DAT, system of rice intensification registered significantly higher leaf area index over MSRI in pooled means. The mean percentage increases of LAI in SRI at 60 and 90 DAT was 10.10 % and 17.24 % in pooled means, respectively over MSRI (Table 2). The dry matter production was not significantly different between planting methods at 30 DAT. At 60, 90 DAT and at harvest, significantly higher dry matter production was reported in SRI (603.7, 1200 and 1279 g m^{-2}, respectively) as compared to MSRI (572.9, 1129 and 1189 g m^{-2}). The higher dry matter production in SRI planting method was attributed to taller plants, LAI and profuse and strong tillers with higher crop growth rate. The results obtained in this investigation are in conformity to the findings of Sridevi and Chellamuthu (2012) and Rajendran *et al.* (2013).

Table 1: Plant height and number of tillers of rice at different crop growth stages as influenced by planting methods, irrigation regimes and nitrogen management practices (pooled data of two years)

Treatments	Plant height (cm)				No. tillers (m^{-2})			
	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest
Planting methods (M)								
M_1 – MSRI	43.8	82.2	100.2	101.3	202.3	327.8	303.0	268.7
M_2 – SRI	47.3	88.4	107.9	109.3	202.0	331.7	310.4	280.4
S.Em±	0.03	0.42	0.78	0.50	1.0	3.4	4.1	6.7
C.D. (P=0.05)	0.16	2.54	4.74	3.03	NS	NS	NS	NS
Irrigation regimes (I)								
I_1 – Saturation	46.3	89.0	107.9	109.0	206.4	343.0	320.5	292.2
I_2 – 3 DADPW	45.8	87.0	105.5	106.4	202.9	339.2	313.9	282.2
I_3 – 5 DADPW	44.6	79.8	98.7	100.5	197.2	307.1	285.6	249.3
S.Em.±	0.48	0.63	0.59	0.47	2.8	3.7	6.6	8.9
C.D. (P=0.05)	NS	2.05	1.91	1.53	NS	12.2	21.5	29.2
Nitrogen management practices (N)								
N_1 – 100 % RDN (inorganic)	43.1	81.8	98.3	99.9	191.6	309.3	289.6	258.1
N_2 – 75% inorganic + 25% organic	44.9	84.0	104.1	104.6	198.3	323.7	300.8	271.7
N_3 – LCC based nitrogen	47.3	89.2	108.4	110.0	211.9	348.1	322.8	290.2
N_4 – STCR targeted yield 6.5 t ha^{-1}	47.0	86.1	105.4	106.6	206.8	338.1	313.5	278.2
S.Em.±	0.47	0.62	0.81	0.93	3.3	4.7	3.8	3.9
C.D. (P=0.05)	1.33	1.75	2.31	2.64	9.4	13.5	10.9	11.2
Interactions	NS	NS	NS	NS	NS	NS	NS	NS

SRI - System of Rice Intensification; MSRI - Mechanized System of Rice Intensification
DADPW - Days after disappearance of ponded water; LCC- Leaf Colour Chart; STCR – Soil Test Crop Response

Irrigation maintained at saturation level registered taller plants (89, 108 and 109 cm of poled means at 60, 90 and harvest, respectively). There was no significant difference between saturation and 3 days after disappearance of ponded water (DADPW), but both the treatments were statistically superior over 5 DADPW at 60, 90 DAT and at harvest. It could be due to rapid growth by maintenance of adequate water supply to crop which maintained good metabolic processes that perform better nutrient mobilization, which resulted in increased activity of meristematic cells and cell elongation of internodes thus contributing to higher growth rate of stem which inturn promoting the increased plant height of rice (Rahaman and Sinha, 2013). At 60, 90 DAT and at harvest significantly higher number (343, 321 and 292, respectively) of tillers m^{-2} was recorded with saturation of pooled means which was comparable with irrigation at 3 DADPW. The lowest number of tillers m^{-2} was observed in irrigation at 5 DADPW (307, 286 and 249) at 60, 90 DAT and at harvest of pooled means. Irrigation maintained at saturation level recorded higher LAI at 60 and 90 DAT during both the years of study. Significantly lower LAI was found with irrigation at 5 DADPW at 60 (3.36) and 90 DAT (3.05) of pooled means. The mean per cent decrease in LAI was observed in irrigation at 5 DADPW *i.e.*16.31 and 13.78 % at 60 DAT and 16.74 and 13.30 % at 90 DAT as compared to saturation and 3 DADPW of pooled means, respectively. The dry matter production was found to be non significant among irrigation regimes at 30 DAT during both the years of study. At 60, 90 DAT and at harvest, irrigation maintained at saturation level recorded significantly higher dry matter production (6102, 1209 and 1300 g m^{-2}, respectively) and it was comparable with irrigation at 3 DADPW (599.6, 1184 and 1260 g m^{-2}, respectively) but both the treatments were statistically superior over irrigation at 5 DADPW (555.1, 1099 and 1142 g m^{-2}, respectively) in pooled means.

Among nitrogen management practices, application of nitrogen based on leaf colour chart (LCC) recorded significantly higher plant height at all the growth stages of crop, which was on par with soil test crop response (STCR) based nitrogen application. LCC based nitrogen application significantly increased the tiller number m^{-2} over other nitrogen management practices, except the STCR based nitrogen application. The mean percentage increase of tillers m^{-2} at harvest with LCC, STCR based N application and RDN (75 % inorganic and 25 % organic) was 12.41, 7.79 and 5.25 % as compared to RDN through inorganic source of pooled means, respectively. LCC based nitrogen application recorded significantly higher LAI which was at par with STCR based nitrogen application and RDN (75 % inorganic and 25 % organic) but significantly superior over RDN through inorganic source. LCC based nitrogen application registered significantly higher dry matter production in all the growth stages (167.3, 611.4, 1229 and 1323 g m^{-2}) which were at par with STCR (163.3, 5953, 1181 and 1257 g m^{-2}) based nitrogen application management practice but both these treatments were significantly greater than RDN (75 % inorganic and 25 % organic) and RDN (154.8, 563.0, 1100 and 1152 g m^{-2}) through inorganic source at 30, 60, 90 and at harvest of pooled means. This might be due to favorable vegetative growth and development as they received adequate and sufficient nitrogen at proper amount and in critical stages. As the results of which the plant height, number of tillers, leaf area index and crop growth rate contributed to higher dry matter production through increased photosynthetic activity of leaves (Ghosh *et al.*, 2014 and Yoseftabar, 2013).

Table 2: Leaf area index and dry matter production of rice at different crop growth stages as influenced by planting methods, irrigation regimes and nitrogen management practices (pooled data of two years)

Treatments	Plant height (cm)			No. tillers (m^{-2})			
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	Harvest
Planting methods (M)							
M_1 – MSRI	1.51	3.57	3.14	159.3	572.9	1129	1189
M_2 – SRI	1.53	3.93	3.68	163.3	603.7	1200	1279
S.Em±	0.02	0.05	0.09	0.9	3.8	6	10
C.D. (P=0.05)	NS	0.31	0.52	NS	22.9	36	59
Irrigation regimes (I)							
I_1 – Saturation	1.56	4.01	3.67	163.6	610.2	1209	1300
I_2 – 3 DADPW	1.53	3.89	3.52	162.2	599.6	1184	1260
I_3 – 5 DADPW	1.47	3.36	3.05	158.2	555.1	1099	1142
S.Em.±	0.04	0.08	0.08	1.0	8.3	9	12
C.D. (P=0.05)	NS	0.26	0.25	NS	27.0	30	40
Nitrogen management practices (N)							
N_1 – 100 % RDN (inorganic)	1.39	3.39	3.06	154.8	563.0	1100	1152
N_2 – 75% inorganic + 25% organic	1.47	3.71	3.40	159.9	583.5	1147	1205
N_3 – LCC based nitrogen	1.65	4.03	3.69	167.3	611.4	1229	1323
N_4 – STCR targeted yield 6.5 t ha^{-1}	1.58	3.88	3.51	163.3	595.3	1181	1257
S.Em.±	0.04	0.07	0.06	2.1	7.2	13	14
C.D. (P=0.05)	0.11	0.19	0.18	6.0	20.5	37	39
Interactions	NS	NS	NS	NS	NS	NS	NS

SRI - System of Rice Intensification; MSRI - Mechanized System of Rice Intensification
DADPW - Days after disappearance of ponded water; LCC- Leaf Colour Chart; STCR – Soil Test Crop Response

Yield parameters

Number of panicles m^{-2} did not differ significantly between MSRI and SRI. This might be due to higher number of seedlings hill^{-1} and lesser spacing between plant to plant in MSRI, which helps to produce more number of tillers m^{-2}. Both MSRI and SRI had performed equally better in respect to number of panicles m^{-2}. The numerically higher number of filled grains panicle^{-1} and higher test weight were more in system of rice intensification 122.08 and 22.19 g in pooled means, respectively as compared to mechanized system of rice intensification. System of rice intensification recorded with 4.90 % band 4.75 % higher grain and straw yield, respectively as compared to mechanized SRI. The SRI planting method provides better aeration, wider spacing and less competition, which enabled the plants to grow vigorously. The increased seed yield under SRI could be attributed to the higher root growth which enabled them to access nutrients from much greater volume of soil. It helped to capture all the essential nutrient elements important for plant growth and there by leading to higher tillering and dry matter production as has been reported earlier (Thiyagarajan *et al.*, 2002 and Rajendran *et al.*, 2013).

Table 3: Yield attributes and yield of rice as influenced by planting methods, irrigation regimes and nitrogen management practices (pooled data of two years)

Treatments	Number of panicles m^{-2}	Filled grains $panicle^{-1}$	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Planting methods (M)					
M_1 – MSRI	247.4	117.07	22.14	5804	6854
M_2 – SRI	260.1	122.08	22.19	6089	7180
S.Em±	6.7	2.77	0.05	38	31
C.D. (P=0.05)	NS	16.88	NS	230	190
Irrigation regimes (I)					
I_1 – Saturation	270.2	126.55	22.34	6219	7241
I_2 – 3 DADPW	260.2	122.39	22.23	6127	7221
I_3 – 5 DADPW	230.8	109.79	21.92	5494	6588
S.Em.±	8.6	1.87	0.08	60	29
C.D. (P=0.05)	28.2	6.11	0.25	196	96
Nitrogen management practices (N)					
N_1 – 100 % RDN (inorganic)	240.1	111.02	22.00	5670	6753
N_2 – 75% inorganic + 25% organic	251.5	117.71	22.20	5940	6983
N_3 – LCC based nitrogen	265.4	128.57	22.26	6150	7146
N_4 – STCR targeted yield 6.5 t ha^{-1}	258.0	121.00	22.19	6026	7185
S.Em.±	3.9	1.33	0.09	66	41
C.D. (P=0.05)	11.0	3.78	NS	188	115
Interactions	NS	NS	NS	NS	NS

SRI - System of Rice Intensification; MSRI - Mechanized System of Rice Intensification
DADPW - Days after disappearance of ponded water; LCC- Leaf Colour Chart; STCR – Soil Test Crop Response

The lowest number of panicles m^{-2} was observed with irrigation at 5 DADPW (14.60 and 11.32 %) which was lower than the saturation treatment and irrigation at 3 DADPW, respectively of pooled means. Deficit irrigation during crop growth affected partitioning of dry matter at grain filling stage and thus there was significant reduction in number of filled grains $panicle^{-1}$ and test weight at 5 DADPW (109.79 and 21.92 g) as compared to saturation (126.55 and 22.34 g, respectively) and 3 DADPW (122.39 and 22.24 g). The potential grain weight is mostly dependent on genotype, but it may be limited to some extent by post anthesis assimilate supply which inturn is governed by water availability. Therefore, test weight or grain weight is determined by the rate of grain growth and the duration of grain fill, both of which are markedly affected by water stress (Kumar *et al.*, 2014) as is evident from test weight of irrigation at 5 DADPW. Irrigation maintained at saturation level throughout crop growth period registered significantly higher grain (6219 kg ha^{-1}) and straw yield (7241 kg ha^{-1}). However, the grain and straw yield recorded with irrigation at 3 DADPW were found to be statistically at par with saturation treatment but both of these treatments were produced significantly superior grain yield as compared to irrigation at 5 DADPW (Table 3). This might be due to favorable vegetative growth and development as they received adequate and sufficient moisture at proper amount and critical stages during entire period of growth. Thus maintained favorable soil water balance under saturation and irrigation at 3 DADPW treatments helped the crop plants to put forth improved performance over irrigation at 5 DADPW, since water plays a vital role in the carbohydrate metabolism, protein synthesis, cell division, cell enlargement and partitioning of photosynthates to sink for improved development of growth traits. Results were substantiated with Kumar *et al.* (2014). The lowest grain and straw yield were observed with irrigation at 5 DADPW during both the years of study.

Table 4: Empirical estimates for the regression of growth and yield components on grain yield of rice (pooled data of two years)

Relationship	Regression constant, coefficients and test statistics				
	a (intercept)	b (regression coefficient)	SEb	R^2	F value for testing R^2
Yield - Plant height (cm)	192.48	54.66	184.20	0.803	89.49
yield - No. tillers m^{-2}	1296.86	16.94	104.94	0.936	321.51
yield - LAI	3145.91	820.37	158.99	0.853	127.66
Yield - Total dry matter (g m^{-2})	1608.60	3.52	154.40	0.861	136.69
Yield - No. panicles m^{-2}	1147.81	18.91	94.30	0.948	403.38
Yield - Filled grains	1445.18	37.65	137.99	0.889	176.66
Yield - Test weight (g)	-24554.59	1376.32	226.52	0.702	51.72
yield - Straw yield (kg ha^{-1})	-317.98	0.89	169.93	0.832	109.01

Application of nitrogen based on leaf colour chart (LCC) registered higher number panicles m^{-2} (265.4) over other nitrogen management practices in pooled means. The per cent increase in number of panicles noticed in LCC based N management (10.5 %), STCR (7.4 %) and in RDN (75 % inorganic and 25 % organic) management practice (4.7 %) was appreciable over RDN through inorganic practice. The leaf colour chart based nitrogen application (128.57 and 22.26 g) recorded significantly higher number of filled grains panicle^{-1} and higher test weight which were at par with STCR based nitrogen application and RDN (75 % inorganic and 25 % organic) management practices in pooled means. This might be due to split application of nitrogen supplied to crop as and when needed and higher N application contributing to better N uptake and leading to greater dry matter production and its translocation to sink. The lowest number of filled grains panicle^{-1} and test weight were recorded at RDN though inorganic source (111.02 and 22.00 g in pooled means, respectviely). Application of nitrogen based on leaf colour chart (8.47 and 5.82 %) and STCR (6.28 and 6.40 %) higher grain and straw yield, respectively as compared to RDN through inorganic source (Taable 4). This could be due to the fact that leaf nitrogen status of rice is closely related to photosynthetic rate and biomass production and it is a sensitive indicator of changes in crop nitrogen demand within a growing season of rice. Application of fertilizer based on soil test availability of nutrients at critical physiological phases would have supported for better assimilation of photosynthates towards grain. Increase in grain yield can also be attributed to favourable effect in accelerating the growth and yield parameters (Stalin *et al.*, 1999).

Regression of growth traits, yield components on grain yield of rice

The empirical results of all the linear best fits established between grain yield (as dependent variable) of rice versus growth traits and yield components as independent variables. All the independent variables showed a significant positive and linear relationship with grain yield (Table 4) suggesting an increment in grain yield with increases in given growth trait and yield components. The explained total variation as indicated by coefficient of determination (R^2) in grain yield by various plant height (R^2 = 0.802), number of tillers (R^2 = 0.932), LAI (R^2 = 0.853), dry matter production (R^2 =0.861), number of panicles (R^2 = 0.948), filled grains (R^2 = 0.889), test weight (R^2 = 0.701) and straw yield (R^2 = 0.832). This suggests that the grain yield of rice can be adequately predicated using the tested independent variables *viz*., growth and yield components.

From the results, it may be concluded that system of rice intensification was superior in terms of growth parameters; yield attributes and yield over mechanized system of rice intensification. Irrigation maintained at saturation level produced significantly higher growth, yield attributes and yield which were comparable with irrigation at 3 DADPW. Application of N based on LCC registered higher growth, yield attributes and yield which were at par with STCR based nitrogen management practice.

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