Oryza Vol. 51 No.2, 2014 (136-142)

Response of rice to establishment methods and nutrient management practices in medium land

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ABSTRACT

Studies were conducted during wet seasons, 2009 and 2010 to assess the growth and productivity of wet season rice under three crop establishment techniques viz. system of rice intensification (SRI), sowing of sprouted seeds by a drum seeder (DS) and conventional transplanting (CT) under three nutrient management practices viz. recommended dose of fertilizer (RDF) (80:40:40 N: P_2O_5: K_2O kg ha^{-1}), integrated nutrient management (INM) i.e. 50% R.D.F. + 50% R.D.F. through organic sources (based on nitrogen requirement) and organic management (OM) i.e. 100% of R.D.F. through organic sources (based on nitrogen requirement). The system of rice intensification increased grain yield (6.65 t ha^{-1}) by 18.0 and 25.8% over CT and DS, respectively; whereas, the latter two treatments remained at par. INM registered the highest grain yield of 6.43 t ha^{-1} which was higher by 11.9 and 19.2% over RDF and OM, respectively. SRI grown under INM recorded the highest productivity of 7.30 t ha^{-1}. SRI fetched the highest gross return (₹ 77925 ha^{-1}), net return (₹ 43033 ha^{-1}) and return ₹ $^{-1}$ (2.28). The crop with INM practices realized the highest gross return (₹ 75586 ha^{-1}) and net return of (₹ 40570 ha^{-1}); but the net return was at par with RDF (₹ 40251 ha^{-1}). The return ₹ $^{-1}$ (2.45) was the highest with R.D.F. followed by INM (2.16). Maximum N, P and K uptake was observed with SRI method of establishment and integrated nutrient management practices.

Key words: *crop establishment, SRI, drum seeding, conventional transplanting, nutrient management*

Rice is cultivated in diverse ecosystems spread over 43.97 million ha in India with a production of 104.32 million tonnes of milled rice with average productivity of 2372 kg ha^{-1} (G.O.I., 2013). Method of stand establishment influences the performance of rice through its effect on growth and development. Although, transplanting has been reported to be the best establishment method (Singh *et al*., 1997), some alternatives like dry and wet direct seeding are being explored to reduce cost of cultivation on account of high labour and water requirement. Direct seeding of sprouted seeds on to puddled soil (wet seeding) by drum seeder holds special significance in the present day production systems by saving time, labour, energy and increasing profitability (Subbaiah and Balsubramanian, 2000). The recently developed system of rice intensification (SRI) method which decreases the use of inputs such as water and labour is reported to have 20-30% higher or even more grain yield compared to conventional method of cultivation in India (DRR, 2007).

Nutrient management provides an approach for feeding the plants with nutrients as and when required. Integrated use of organic manures and chemical fertilizers has advantages over use of only organic manures or chemical fertilizers (Kumar *et al*., 2009). Since sourcing of organic manure is difficult and the crop response to them during initial stages is not as spectacular, compared to the chemical fertilizers (Deka *et al*., 1996), an integrated approach of plant nutrition involving the judicious mix of organic, chemical and microbial sources could be helpful to sustain optimum yield and to restore the residual soil fertility. Keeping

this in view, the present study was undertaken to investigate the effect of crop establishment methods and nutrient management practices on growth and productivity of wet season rice in North Central Plateau Zone of Odisha.

MATERIALS AND METHODS

A field experiment was conducted at Shyamakhunta, Mayurbhanj under north central plateau agro-climatic zone of Odisha during the wet seasons of 2009 and 2010. The soil of the experimental site was sandy clay loam in texture having pH 5.63, organic carbon 0.46%, available N 221 kg ha^{-1}, available P 10.4 kg ha^{-1} and available K 139.3 kg ha^{-1}. The experiment was laid out in a split-plot design with nine treatments replicated thrice. Three crop establishment methods, *viz.* system of rice intensification (SRI), line sowing of pre-germinated paddy seeds by drum seeder (DS) and conventional transplanting (CT) were randomly allotted in three main plots and three nutrient management practices, *viz.* 100% recommended dose of fertilizer (RDF *i.e.* 80:40:40 N: P_2O_5: K_2O kg ha^{-1}) through inorganic fertilizers, organic manure (OM *i.e.*100% of RDF through organic sources based on nitrogen requirement) and integrated nutrient management (INM *i.e.* 50% of RDF through inorganic + 50% of RDF through organic sources were allotted in sub plots. The organic sources comprised of 50% RDF through farmyard manure (FYM), 25% through vermicompost and 25% through neem oil cakes. Each sub plot was 4 m x 3 m in size. Twenty five-day old rice *cv.* Pratikshya seedlings (2-3 $hill^{-1}$) were transplanted at 20 cm x 15 cm spacing in CT method and 12-day old were transplanted at 25 cm x 25 cm spacing in SRI method (one seedling $hill^{-1}$) while pre-germinated seeds were sown by using a four-row paddy drum seeder in a puddled soil with rows of 20 cm apart. The seed rates used for SRI, drum seeding and conventional transplanting were 5, 45 and 60 kg ha^{-1}, respectively. The same layout plan was used to conduct the experiment in both the years. One-fourth of nitrogen and full dose of P and K were applied as basal and remaining nitrogen was top dressed twice *i.e.* half at active tillering stage and one-fourth at panicle initiation stage for all the treatments. The N content of FYM, neem oil cake and vermicompost used were 0.48, 3.89 and 1.24 during 2009 and 0.48, 3.84 and 1.14 during 2010, respectively. The P_2O_5 content was 0.24, 0.88 and 0.41 during 2009 and 0.26, 0.84 and 0.48 during 2010 for FYM, neem oilcake and vermicompost, respectively. Similarly the K_2O content was 0.45, 1.02 and 0.60 during 2009 and 0.47, 0.98 and 0.58 during 2010 for FYM, neem oil cake and vermicompost, respectively. All the organic manures were incorporated immediately after layout of the experiment as per the respective treatments. Weeding was done thrice in SRI plots at 10-12 day intervals starting from 12-15 DAT using a cono weeder. Hand weeding was carried out twice at 25 and 50 days after drum seeding in drum seeded plots and once at 30 day after transplanting (DAT) in CT. Soil moisture saturation was maintained in SRI method till panicle initiation stage and thereafter a thin film of water was allowed over the beds. Water levels of 5 cm were maintained in CT and DS methods throughout the growing period except for the first four to five days in DS plots where the soil was kept moist after seeding. Plant protection measures were adopted as and when required. Growth and yield parameters were recorded as per standard procedures. The cost of cultivation, gross return, net return and return ₹$^{-1}$ invested were calculated on the basis of prevailing market price of different inputs and outputs. The N, P and K analysis in plant materials were done by micro-kjeldahl, vanadomolybdate acid yellow colour and flame photometric method, respectively (Jackson, 1973).

RESULTS AND DISCUSSION

Plant height, leaf area index and dry matter accumulation was significantly higher under SRI method when compared with DS and CT (Table 1). The tallest plants under SRI might be due to optimum plant population and geometry which led to availability of more resources to plants. The increased LAI in SRI was due to open plant structure giving more coverage to the ground area. Further, the lower angle of inclination of leaves in case of SRI results in more spread than CT (Thakur *et al.*, 2011). Among the nutrient management practices, INM recorded the highest plant height, numbers of tillers m^{-2}, LAI and dry matter accumulations and the plants supplied with sole organics recorded the lowest values. This might be due variation in respect of composition, C: N ratio, mineralization pattern etc. of different treatments imposed (Bhadoria and Prakash 2003).

In both the years of experimentation, SRI recorded significantly higher total spikelets $panicle^{-1}$

Table 1. Growth and development of rice as influenced by crop establishment methods and nutrient management practices

Treatments	Plant height (cm)			Tillers m^{-2}			Leaf area index (105 DANS)			Dry-matter accumulation (g m^{-2})		
	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled
Crop establishment												
SRI*	125.9	126.8	126.4	234	246	240	4.51	4.67	4.59	1203.25	1245.10	1224.17
DS	115.1	115.0	115.0	247	264	255	3.84	3.95	3.89	1066.51	1101.97	1084.24
CT	119.7	120.7	120.2	261	280	270	4.05	4.17	4.11	1088.16	1133.03	1110.60
CD (P<0.05)	7.3	8.1	4.5	NS	NS	NS	0.41	0.39	0.24	83.23	106.07	56.00
Nutrient management												
RDF*	121.9	122.5	122.2	248	268	258	1110.03	1156.56	1133.30	3.95	4.10	4.03
OM	116.1	116.3	116.2	225	237	231	1061.95	1094.68	1078.32	3.95	4.07	4.01
INM	122.7	123.8	123.3	268	284	276	1185.94	1228.86	1207.40	4.49	4.62	4.56
CD (P<0.05)	5.6	5.8	3.8	28	22	17	44.48	33.46	26.36	0.24	0.25	0.16

*SRI - System of rice intensification; DS - Drum seeding; CT - Conventional transplanting; *RDF (Recommended dose of fertilizer) - 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; OM - Organic management (50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM - Integrated nutrient management (½ RDF + ½ OM)

(199.9), test weight (23.92) and lower sterility % (13.88) when compared with CT and DS and the latter two were at par with each other (Table 2). The increase in yield attributes in SRI might be due to square geometry of hills with wider spacing, planting of single seedling $hill^{-1}$ which reduced the above and below ground competition, enhanced solar radiation interception and nutrient uptake. The plants receiving integrated crop nutrition produced higher yield attributes, because of its favourable influence on the growth parameters. INM produced the highest number of panicles m^{-2} (267.7), which was higher by 18.6% and 6.5% than that obtained with organic nutrition and RDF, respectively (Table 2). However, OM produced the minimum number of sterile grains. Further, it was found that the production of spikelets $panicle^{-1}$ and 1000- grain weight did not differ among different nutrient management practices of rice.

In both the years SRI method produced significantly higher grain yield which was 18% and 26% higher over CT and DS, respectively; while the latter two treatments produced statistically similar grain yields (Table 3). This was due to favourable yield attributes such as more number of spikelets $panicle^{-1}$, less sterility% and bolder grains in case of SRI. These findings corroborate earlier reports by Subbulaxmi *et al.* (2008) and Geethalaxmi *et al.* (2011). Straw yield

Table 2. Yield attributes of rice as influenced by crop establishment methods and nutrient management practices

Treatments	Panicles m^{-2}			Spikelets $panicle^{-1}$			Sterility (%)			1000-grain weight		
	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled
Crop establishment												
SRI*	227.0	239.5	233.3	199.3	200.5	199.9	13.76	14.00	13.88	23.37	24.48	23.92
DS	241.0	256.9	249.0	167.1	165.0	166.1	16.38	16.39	16.38	21.71	22.40	22.05
CT	252.9	271.8	262.3	169.4	165.9	167.6	15.70	15.58	15.64	21.80	22.44	22.12
CD (P<0.05)	NS	NS	NS	22.2	18.9	12.1	1.868	1.661	1.04	1.18	1.57	0.82
Nutrient management												
RDF*	242.5	260.0	251.3	180.3	178.1	179.2	16.51	16.35	16.43	21.90	22.56	22.23
OM	220.1	231.3	225.7	173.4	174.6	174.0	14.19	14.51	14.35	22.70	23.43	23.07
INM	258.3	276.9	267.7	181.9	178.7	180.3	15.13	15.11	15.12	22.28	23.33	22.80
CD (P<0.05)	26.1	21.4	16.0	NS	NS	NS	1.425	1.381	0.94	NS	NS	NS

Table 3. Yield and harvest index of rice as influenced by crop establishment methods and nutrient management practices

Treatments	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index (%)		
	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled
Crop establishment									
SRI*	6.34	6.96	6.65	7.63	7.48	7.56	45.30	48.17	46.74
DS	5.08	5.49	5.28	7.34	7.28	7.31	40.80	42.97	41.89
CT	5.40	5.87	5.64	7.26	7.27	7.26	42.54	44.56	43.55
CD (P<0.05)	0.76	0.89	0.49	NS	NS	NS	0.84	2.99	1.29
Nutrient management									
RDF*	5.50	5.99	5.75	7.38	7.42	7.40	42.66	44.63	43.64
OM	5.16	5.63	5.40	7.18	7.06	7.12	41.57	44.12	42.84
INM	6.15	6.71	6.43	7.67	7.55	7.61	44.42	46.95	45.68
CD (P<0.05)	0.34	0.40	0.25	0.34	0.39	0.24	0.49	0.81	0.45

did not differ significantly among the crop establishment methods which might be due to production of similar number of tillers per unit area by all the crop establishment methods. However, the harvest index differed with the different crop establishment methods with SRI recording the highest harvest index followed by CT and DS. It implied better translocation of photosynthates from source to sink in case of SRI. Significantly the highest grain yield (6.43 t ha^{-1}) was recorded with INM which could be attributed to combined effect of better growth and yield attributes due to balanced nutrition in this treatment. The integration of organic manures and inorganic fertilizers might have prevented leaching and volatilization losses and supplied nutrients in optimal congruence with crop demand improving synthesis and translocation of metabolites to various reproductive structures resulting in improvement in yield and yield attributes (Raju and Sreenivas, 2008 and Kumari *et al.,* 2010). The straw yield and harvest index were also the highest with INM practices though the straw yield was comparable with RDF, confirmed the superiority of INM practices over other two nutrient management practices of rice.

Among the interactions the highest grain yield (7.30 t ha^{-1}) and harvest index (47.77%) and the lowest grain yield (4.77 t ha^{-1}) and harvest index (39.94%) were recorded with SRI method coupled with INM and DS with OM, respectively (Table 3a and3b).

As regards economic analysis, the maximum gross return (₹ 77925 ha^{-1}), net return (₹ 43033 ha^{-1}) and return per rupee invested (2.28) were recorded with SRI method of cultivation (Table 4). This was mainly due to higher yields obtained in it as compared to the other two during both the years. The results corroborate earlier findings of Singh *et al.* (2008).

Table 3a. Interaction effect of crop establishment and nutrient management practices on grain yield (t ha^{-1}) of rice

Crop establishment	Nutrient management								
	2009			2010			pooled		
	RDF*	OM	INM	RDF	OM	INM	RDF	OM	INM
SRI*	5.793	6.271	6.960	6.348	6.920	7.638	6.071	6.596	7.299
Drum seeding	5.140	4.594	5.506	5.577	4.956	5.964	5.359	4.775	5.735
Conventional transplanting	5.585	4.628	6.009	6.065	5.030	6.532	5.825	4.829	6.270
CD (P<0.05)									
Main x Sub		903			1057			605	
Sub x Main		599			700			436	

Table 3b. Interaction effect of crop establishment and nutrient management practices on harvest index of rice

Crop establishment	Nutrient management								
	2009			2010			pooled		
	RDF*	OM	INM	RDF	OM	INM	RDF	OM	INM
SRI*	44.29	45.42	46.19	46.27	48.89	49.35	45.28	47.16	47.77
Drum seeding	41.19	39.00	42.22	43.40	40.87	44.65	42.30	39.94	43.44
Conventional transplanting	42.49	40.28	44.84	44.23	42.60	46.84	43.36	41.44	45.84
CD (P<0.05)									
Main x Sub		1.08			3.19			1.78	
Sub x Main		0.84			1.41			0.95	

*SRI - System of rice intensification; DS - Drum seeding; CT - Conventional transplanting; *RDF (Recommended dose of fertilizer) - 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; OM - Organic management (50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM - Integrated nutrient management (½ RDF + ½ OM)

Further, it was noticed that CT and DS returned at par values of all the above economic parameters which was reflective of their yields. The crop receiving sole organics became costlier (₹ 41970 ha^{-1}) than that of INM practices (₹ 35015 ha^{-1}) and RDF (₹ 27790 ha^{-1}) primarily due to higher cost of bulky organic manures such as FYM, vermicompost and neem oil-cake. The crop with INM practices realised significantly the highest mean gross return (₹ 75586 ha^{-1}), the net return was very much similar to that of RDF due to high cost of cultivation of the former as stated earlier. However, the higher gross returns could not compensate the high cost of cultivation and resulted in lower return per rupee invested for INM (2.16) than RDF (2.45). Rice cultivation with sole organics resulted in the lowest gross return, net return and return per rupee invested because of its lower grain yield and higher cost of cultivation as compared to other two nutrient management practices. The results corroborate the findings of Kumari and Reddy (2011).

As regards to interaction effect, SRI method with INM practices realised significantly the highest gross return followed by SRI with sole organics (Table 4a). The lowest gross return was obtained from DS with OM. So also the combination of SRI with INM fetched significantly the highest net return and the lowest was obtained from CT with OM (Table 4b).

The N, P and K content in grain and straw did not differ much numerically due to different crop establishment methods (Table 5). SRI method showed significantly the highest N, P and K uptake by grain.

Table 4. Effect of crop establishment methods and nutrient management practices on economics of rice production

Treatments	Cost of cultivation (₹ ha^{-1})			Gross return(₹ ha^{-1})			Net return (₹ ha^{-1})			Return ₹ $^{-1}$ invested		
	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled
Crop establishment												
SRI*	34708	35076	34892	74595	81254	77925	39888	46178	43033	2.19	2.37	2.28
DS	34428	34796	34612	60739	65214	62977	26312	30418	28365	1.82	1.94	1.88
CT	35088	35456	35272	64210	69274	66742	29123	33818	31470	1.90	2.03	1.96
CD (P<0.05)	-	-	-	8883	10082	5581	8883	10082	5581	0.27	0.30	0.17
Nutrient management												
RDF*	27790	27790	27790	65377	70705	68041	37586	42915	40251	2.35	2.54	2.45
OM	41601	42338	41970	61520	66514	64017	19919	24176	22047	1.48	1.57	1.53
INM	34831	35199	35015	72649	78523	75586	37817	43323	40570	2.09	2.23	2.16
CD (P<0.05)	-	-	-	4016	4634	2904	4016	4634	2904	0.12	0.14	0.09

Table 4a. Interaction effect of crop establishment and nutrient management practices on gross return (₹ ha^{-1}) of rice

Crop establishment	Nutrient management								
	2009			2010			pooled		
	RDF*	OM	INM	RDF	OM	INM	RDF	OM	INM
SRI*	68383	73749	81654	74454	80529	88778	71419	77139	85216
Drum seeding	61384	55346	65488	66049	59273	70321	63716	57310	67905
Conventional transplanting	66363	55464	70804	71612	59740	76469	68988	57602	73636
CD (P<0.05)									
Main X Sub		10474			11945			6919	
Sub X Main		6956			8026			5030	

Table 4b. Interaction effect of crop establishment and nutrient management practices on net return (₹ ha^{-1}) of rice

Crop establishment	Nutrient management								
	2009			2010			pooled		
	RDF*	OM	INM	RDF	OM	INM	RDF	OM	INM
SRI*	40626	32181	46856	46697	38224	53612	43662	35203	50234
Drum seeding	33907	14058	30970	38572	17248	35435	36239	15653	33203
Conventional transplanting	38226	13516	35626	43475	17055	40923	40851	15286	38274
CD (P<0.05)									
Main X Sub		10474			11945			6919	
Sub X Main		6956			8026			5030	

*SRI - System of rice intensification; DS - Drum seeding; CT - Conventional transplanting; *RDF (Recommended dose of fertilizer) - 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; OM - Organic management (50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM - Integrated nutrient management (½ RDF + ½ OM)

Table 5. Nutrient content and uptake in grain and straw of rice as influenced by crop establishment methods and nutrient management practices (pooled of two years)

Treatments	Nitrogen				Phosphorus				Potash			
	Content%		Uptake (kg ha^{-1})		Content%		Uptake (kg ha^{-1})		Content%		Uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Crop establishment												
SRI*	1.384	0.486	79.23	31.58	0.241	0.125	13.79	8.14	0.264	1.516	15.13	98.61
DS	1.374	0.487	62.47	30.61	0.241	0.124	10.95	7.82	0.264	1.504	12.02	94.65
CT	1.373	0.486	66.60	30.38	0.241	0.125	11.69	7.79	0.264	1.512	12.81	94.49
CD (P<0.05)	-	-	5.57	NS	-	-	1.02	NS	-	-	1.13	NS
Nutrient management												
RDF*	1.367	0.485	67.64	30.89	0.240	0.124	11.88	7.88	0.264	1.494	13.04	95.17
OM	1.383	0.489	64.25	29.95	0.242	0.126	11.21	7.71	0.265	1.523	12.29	93.34
INM	1.381	0.485	76.41	31.71	0.241	0.125	13.34	8.17	0.264	1.516	14.63	99.25
CD (P<0.05)	-	-	2.97	NS	-	-	0.52	NS	-	-	0.56	3.19

*SRI - System of rice intensification; DS - Drum seeding; CT - Conventional transplanting; *RDF (Recommended dose of fertilizer) - 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; OM - Organic management (50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM - Integrated nutrient management (½ RDF + ½ OM)

Nutrient uptake being a function of dry matter production, this significant increase was due to increase in grain and straw yield with SRI. The increased nutrient uptakes might be attributed to the favourable soil conditions and better root growth which might have enabled the crop to explore more volume of soil under SRI management practices. This finding was in agreement with Bommayasami *et al.* (2010). As regards to nutrient management, marginal improvement in nutrient contents under organic and INM could be ascribed to their slow release from organic sources which helps to prevent nutrient loss. This might have prolonged their availability in regulated quantities over a longer period of time (Kumari and Reddy, 2011). Uptake of N, P and K by grain was the highest under INM as these are positively correlated with biological yields. However, the N and P uptake by straw did not vary significantly with respect to different nutrient management practices.

Thus, it is concluded that SRI method of rice establishment with INM approach is the most suitable combination of stand establishment and nutrient management practice for rice cultivation in north central plateau zone of Odisha.

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