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Effect of Cultivation Methods and Nitrogen Management Strategies on Growth and Yield of Rice (*Oryza sativa* L.) Grown in Coastal Alluvial Soils of Southern India

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ABSTRACT

A field experiment was conducted to investigate the methods of cultivation and optimization of nitrogen requirement of rice crop in coastal alluvial soils, Karaikal, Pondicherry, India. Experiment was laid out in a split plot design with methods of rice cultivation as main plot treatment consisted of System of Rice Intensification (SRI), Integrated Crop Management (ICM), Line Planting (LP) and Random Planting (RP) and nitrogen managements strategies as subplot treatment consisted of without nitrogen as control, blanket recommendation, LCC 4, LCC 5, SPAD 35 and SPAD 37. The result showed that Plant height and tiller count were improved by cultivation methods. LCC 4 registered higher plant height, productive tillers number, longer and heavier panicles and harvest index. LP registered higher grain yield of 2.53 t ha⁻¹ which was 10.2 and 17.2 % higher than SRI and RP respectively. Among nitrogen managements, LCC 4 recorded highest grain yield of 2.66 t ha⁻¹ which was 11.1, 19.8, 26.4 and 40.7% higher than blanket, SPAD 35, SPAD 37 and control respectively. ICM recorded significantly highest straw yield (5.49 t ha⁻¹) which was the same as with SRI. The straw yield of ICM was 28.4 and 34.6 % higher than LP and RP respectively. Highest straw yield of 5.88 t ha⁻¹ was observed with LCC 5 which was 1.2, 15.4, 30.7, 53.7 and 59.2 % higher than LCC 4, Blanket, SPAD 35, SPAD 37 and control respectively. LP with LCC 4 was the superior combination than other treatment combinations with respect to growth and yield attributes. It was inferred that potential of SRI and ICM could be explored only when the soil quality is good enough to support vigorous tillering.

Keywords

Rice; Nitrogen management, SRI, ICM, grain yield.

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Introduction

Rice is the principal staple food for 65 per cent of the population in India. Rice occupies an area of 44 million hectare with an average production of 90 million tonnes with productivity of 2.0 tonnes per hectare. The

demand for rice is expected to rise due to increase in population (1.6 % year⁻¹) plus increased per capita income. It is estimated that in the year 2025 the requirement of rice would be 140 million tonnes. At the same

time the area under rice cultivation is expected to reduce to 40 million ha in the next 15–20 years (Shobharani *et al.*, 2010). To sustain present food self-sufficiency and to meet future food requirements, India has to increase its rice productivity by 3 per cent per year (Thiyagarajan, 2007).

To enhance productivity of any crop needs an integrated approach on soil, plant, water and climatic factors in appropriate manner. Among management strategies, fertilizer management accounts for 50 per cent of yield gap (Randhawa and Velayutham, 1989), plant density by 42-45 per cent; land preparation, pest, disease and weed management by 15-20 per cent; post harvest technologies by about 7-26 per cent (Duarisamy *et al.*, 2001).

System of Rice Intensification (popularly known as SRI), an alternative methodology for traditional flooded rice cultivation, developed in the 1980s in Madagascar (Laulanie 1993), has been promoted in countries around the world for more than a decade as a set of agronomic management practices for enhancing yield (Kabir and Uphoff 2007; Namara *et al.*, 2008; Senthilkumar *et al.* 2008). The agronomic changes involved in SRI includes, use of much younger seedlings, planting single seedlings in a square pattern with wide spacing, keeping the soil moist but not continuously flooded, applying increased quantity of organic manures and use of mechanical weeder that provides active aeration in topsoil. Yield of rice could be enhanced by 2 to 3 times in SRI method (Uphoff, 2002) and up to 1.5 t ha⁻¹ by ICM (Balasubramanian *et al.*, 2004) by enhancing tillering phase, root penetration and nutrient assimilation. Predicting N requirement during crop growth period in actual quantity is a difficult and challenging task. In recent times, innovative tools like Soil and Plant Analysis Department meter (SPAD meter) and Leaf

Colour Chart (LCC) are employed to regulate N supply for rice crop. The SRI and ICM require precise N management to exploit maximum benefit. Appropriate method of cultivation and nitrogen management strategy and their combination could perform better than conventional practices. Keeping these in view, the present study investigates the effect of different methods of cultivation and N management strategies on growth, yield and yield attributes of rice crop.

Materials and Methods

The experiment was conducted at research farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Union Territory of Puducherry, India. The site was 12 kms away from Bay of Bengal, geo-positioned between 10° 49' North latitude and 78° 43' East longitude and 4 meters above Mean Sea Level. This region is in 11th agro-climatic zone of India, classified as PC2-coastal deltaic alluvial plain zone, under tropical climate with average annual rainfall of 1437 mm with 56 rainy days. Soil samples were collected from 0-15 cm depth and the initial soil characteristics were assessed with standard procedures which are furnished in Table 1. The soil is sandy-clay-loam, classified as *Fluventic Haplustept* (Coastal alluvium). Regarding available nutrient status of experimental sites, the available N is low, available P is high and available K is medium in status. Soil of the study area is saline-sodic.

The experiment was conducted in Split Plot Design (SPD) with the four methods of rice cultivation in main plots and six nitrogen management strategies with two replications. The rice variety ADT-43 of 115 days duration was the test crop. All the 48 plots were surrounded by 0.5 m wide bund to prevent lateral water movement and nutrient diffusion between plots.

Seedlings raised in *dapog* nursery for SRI (M₁), modified mat nursery for ICM (M₂), and conventional nursery for LP (M₃), and RP (M₄), were transplanted at 19th Days after Sowing (DAS). In case of nitrogen management strategies, without nitrogen (as control) was N₁ and blanket recommendation of 120 kg N ha⁻¹ was N₂. The leaf colour chart (LCC) developed by Furuya (1987) in Japan was used for the treatment of N₃ and N₄ for deciding time of nitrogen application (top dressing). The LCC, which contain six strips of green colour starting from yellowish green shade (Critical value 1) to dark green shades (critical value 6), compared with growing paddy leaves and used as index of N demand by the crop. Darkness of green shade in LCC increases with increase of critical value. The measurements were taken at 10.00 a.m. by selecting the fully grown 3rd leaf from the top and placing it on the LCC strips, in order to compare the match of colour of leaf with LCC strips. The readings were taken in ten randomly selected plants and then averaged. When the mean value fell below critical value of 4 and 5 in treatments of N₃ and N₄ respectively, nitrogen was top-dressed at the rate of 30 kg ha⁻¹ starting from 14 DAT to 70 DAT at weekly intervals. In the case of treatment N₅ and N₆, SPAD meter was used for N management where the measurements were made from 14 DAT up to 70 DAT at weekly intervals by measuring the colour intensity of the leaf. In this method, the fully expanded leaf was chosen and the leaf blade is fed into the SPAD meter (either one side of the midrib of the leaf). However, in the early stage of crop growth, the midrib might have not developed fully, hence, the entire leaf may be considered for the measurement. By adopting the above said procedure, twenty five readings were taken from each plot at random and then mean value worked out. The measurements were taken at 10.00 AM same day of every week and care was taken to avoid falling of direct sunlight on the leaf

during measurement. When the mean value fell below the threshold value of 35 for N₅ and 37 for N₆, 30 kg N ha⁻¹ was top-dressed from early stage to maximum tillering stage, 45 kg N ha⁻¹ from maximum tillering to panicle initiation stage and 30 kg N ha⁻¹ from panicle initiation to flowering stage of crop growth (Babu *et al.*, 2000).

With respect to source of nutrients, nitrogen was applied as urea in all the treatments. Phosphorus as Single Super Phosphate, Potassium as Muriate of potassium were applied as per the soil test based recommendation, that is, 38 kg ha⁻¹ of P₂O₅, 38 kg ha⁻¹ of K₂O. Zinc was applied of ZnSO₄ at 25 kg ha⁻¹. The full dose of P and zinc and half the dose of potassium were applied as basal at the time of planting and the remaining half the dose of potassium was top dressed at the time of panicle initiation. Table 2 shows treatment details of the experiments. The biometric observations of plant height, number of tillers, number of productive tillers, panicle length, panicle weight, harvest index, grain and straw yield were recorded at harvest stage. The growth and yield attribute data collected were subjected to analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). Significant means were separated using critical difference at 5% level. Statistical analysis was executed using IRRISTAT statistical software.

Results and Discussion

Growth and yield attributes

The height of plant significantly differed by the methods of cultivation, nitrogen managements and their interactions. LP recorded highest plant height among methods of cultivation and LCC 4 recorded the highest plant height among N management. The multiple regression analysis revealed that the plant height was determined by the DMP at

critical stage of crop growth significantly to the tune of 47.2 per cent. Numbers of tillers were significantly influenced by methods of cultivation, nitrogen managements and their interactions. LP recorded highest number of tillers among methods of cultivation and LCC 5 recorded the highest number of tillers among N management (Table 3). Multiple regressions indicated that 82 per cent of variation in the number of tillers could be attributed to the DMP at different stages of crop growth. The number of productive tillers significantly altered by the methods of cultivation, nitrogen managements and their interactions. LP received highest number of productive tillers among methods of cultivation. The least number of productive tillers was observed in ICM method of cultivation. Among N managements, LCC 5 recorded the highest productive tillers and least number of productive tillers was in the control plot. The multiple regression analysis had further shown that 84.4 per cent of the variation in the number of productive tillers could be accounted for the DMP recorded at critical stages of the crop growth.

The length of panicle significantly differed by the methods of cultivation and nitrogen managements. RP registered higher panicle length followed by ICM and LP methods, which were comparable. N management strategies though resulted in significantly higher panicle length, they were comparable among themselves but superior to the control plots. The weight of the panicle was found to be unaffected by the various methods of cultivation, whereas application of N through LCC or by blanket recommendation had resulted in significantly higher panicle weight, though they were comparable. The interaction effect was significant, but did not follow any specific trend. The multiple regression analysis had further indicated that 37.40 per cent of the variation in the panicle weight could be explained by the available N

status of the soil at critical crop growth stages. The highest harvest index was recorded in LP followed by RP. In ICM and SRI methods, HI was comparable (Table 3). The control plot recorded the least harvest index value. All the N management strategies were comparable but superior to control. Similar trend was observed in the interaction effect. Multiple regression analysis showed that the variation in harvest index explained by the DMP to the tune of 57.5 per cent. Similarly, 44.1 per cent of the variation in the harvest index could be explained by the available N status of soil at critical crop growth stages.

Grain and straw yield

The result revealed that among the different methods of rice cultivation, LP registered significantly higher grain yield (2.53 t ha^{-1}) followed by ICM, SRI and RP. The grain yield of SRI and ICM were comparable. Lowest yield of 2.15 t ha^{-1} was recorded in RP (Table 4). The yield increase in LP was 10.2 and 17.2 % higher than SRI and RP respectively irrespective of N management strategies. In case of N management strategies, the highest grain yield of 2.66 t ha^{-1} was recorded with LCC 4 which was 11.1, 19.8, 26.4 and 40.7% higher than blanket, SPAD 35, SPAD 37 and control respectively irrespective of methods of cultivation. Grain yield of LCC 5 was comparable with LCC 4. Blanket application was comparable with SPAD 35 which is again comparable with SPAD 37. Lowest yield was recorded in control where no nitrogen was applied. Interaction of methods of cultivation and nitrogen managements on grain yield was significant. Among all the treatment combinations, SRI with LCC 4 recorded the highest grain yield than other combinations. Application of N through LCC 4 recorded highest grain yield under SRI and LP methods of cultivations and their grain yields were on par. Similarly, LCC 5 registered highest grain

yield in ICM and RP methods of cultivation and their grain yields were the same. In case of grain yield prediction with multiple regression, the growth and yield attributes such as plant height, number of tillers, productive tillers, panicle length, panicle weight, 1000 grain weight, per cent spikelet fertility, per cent spikelet sterility, harvest index, filled grains and unfilled grains were contributing 86.0 per cent.

The yield of straw was influenced by the methods of cultivation and N management strategies. It was observed that among methods of rice cultivation, ICM recorded significantly higher straw yield of 5.49 t ha⁻¹ followed by SRI, LP and RP. The straw yield of SRI and ICM were comparable. Lowest yield of 4.07 t ha⁻¹ was recorded in RP (Table 4). The straw yield of ICM was 28.4 and 34.6 % higher than LP and RP respectively. Among N management strategies, the highest straw yield of 5.88 t ha⁻¹ was observed with LCC 5 which was 1.2, 15.4, 30.7, 53.7 and 59.2 % higher over LCC 4, Blanket application, SPAD 35, SPAD 37 and control respectively. Interaction of methods of cultivation and nitrogen management strategies on straw yield was significant. Among all the treatment combinations, SRI with LCC recorded the highest straw yield than other treatment combinations. Application of N through LCC 5 recorded highest straw yield under SRI and RP methods of cultivations. LCC 4 under LP combinations registered higher straw yield. Blanket application of nitrogen under ICM combinations recorded the higher straw yield. Straw yield prediction with multiple regression, the growth and yield attributes such as plant height, number of tillers, productive tillers, panicle length, panicle weight, 1000 grain weight, per cent spikelet fertility, per cent spikelet sterility, harvest index, filled grains and unfilled grains were contributing 79.5 per cent.

Growth and Yield Attributes

Growth of plant is considered as basic criteria upon which final economic yield depends on. The various growth and yield attributes found higher in LP than SRI and ICM (Table 3). The trend was most pronounced for plant height, number of tillers and productive tillers and panicle length. The reason might be LP was able to produce more tillers due to higher population (66 plants m⁻²) against SRI (20 plants m⁻²), ICM (16 plants m⁻²) and RP (30-33 plants m⁻²). The SRI and ICM methods could not produce more productive tillers due saline-sodic condition of soil.

Similarly, growth and yield attributes were found higher with LCC method of N management which is comparable with SPAD. The advantage of using either LCC or SPAD for monitoring leaf N content by real time measurement ensures N supply as per crop requirements with appropriate time with maximum N use efficiency. Similar results of higher growth and yield attributes by LCC method of N management was reported by Gunasekhar (2003) and Budhar (2005).

Grain and Straw Yield

LP recorded highest grain yield while SRI, ICM and RP were comparable (Table 4). This result of SRI quite against the results from Uphoff and Randriamiharisoa (2002), McHugh *et al.*, (2002), Hossain *et al.*, (2003), Uphoff (2003), and Sathayanarayana *et al.*, (2004). The yield increase in SRI might be due to better phyllochron pattern (Moreau, 1987), reduced transplanting shock by early planting, better aeration through square planting, non-hypoxic soil condition by intermittent irrigation. Deep rooting provided by conducive soil conditions (Barison, 2002) supports for the expression of the plant's full genetic potential for tillering, shoot growth and grain filling (Uphoff, 2003).

Table.1 Characterization of the experimental soil

Properties	Values*
Texture	
Clay (per cent)	21.65
Silt (per cent)	6.75
Fine sand (per cent)	58.75
Coarse sand (per cent)	10.25
Textural class	Sandy clay loam
Taxonomic unit	<i>Fluventic Haplustept</i>
Apparent specific gravity (Mg m^{-3})	1.33
Absolute specific gravity (Mg m^{-3})	2.59
Pore space (per cent)	48.06
Electrical conductivity (dS m^{-1}) (1:1 Soil water suspension)	4.64
pH (1: 2 Soil water suspension)	7.85
Organic carbon (g Kg^{-1})	0.54
Cation exchange capacity ($\text{cmol (p}^+) \text{kg}^{-1}$)	24.45
Exchangeable Calcium ($\text{cmol (p}^+) \text{kg}^{-1}$)	11.25
Exchangeable magnesium ($\text{cmol (p}^+) \text{kg}^{-1}$)	8.16
Exchangeable sodium ($\text{cmol (p}^+) \text{kg}^{-1}$)	4.15
Exchangeable potassium ($\text{cmol (p}^+) \text{kg}^{-1}$)	0.31
SAR	0.943
ESP (per cent)	16.31
Total N (per cent)	0.059
$\text{KMnO}_4\text{-N}$ (kg ha^{-1})	168.0
Olsen-P (kg ha^{-1})	24.00
$\text{NH}_4\text{OAc-K}$ (kg ha^{-1})	279.5

***Mean of three samples**

Table.2 Treatment details of field experiments

Main plot treatments: Methods of rice cultivation							
No.	Notation	Treatment	Nursery	Spacing (cm)	Seedling per hill	Irrigation	Weeding
M ₁	SRI	System of Rice Intensification	Dapog	22.5 × 22.5	1	Alternate wetting and drying	Cono weeding thrice at 10 days intervals
M ₂	ICM	Integrated Crop Management	Modified mat	25 × 25	2		
M ₃	LP	Line Planting	Conventional	15 × 10	2-3	2.5cm up to tillering and 5 cm thereafter	i. pre-emergence herbicide 5 th DAT ii. One hand weeding on 40 th DAT
M ₄	RP	Random Planting	Conventional	Random spacing	3-4	As per the need	
Sub plot treatments: Nitrogen management							
No.	Notation	Treatment	N application				
N ₁	C	Control	No nitrogen				
N ₂	BN	Blanket N	120 kg ha ⁻¹				
N ₃	LCC4	Leaf Colour Chart critical value 4	**if LCC value <4	30 kg ha ⁻¹ (From 14 th to 70 th DAT)9999			
N ₄	LCC5	Leaf Colour Chart critical value 5	**if LCC value <5				
N ₅	SPAD35	*SPAD meter 35	**if SPAD meter critical value <35	i.Early to maximum tillering stage - 30 kg ha ⁻¹ ii.Maximum tillering to panicle initiation - 45 kg ha ⁻¹ iii.Panicle initiation to flowering stage - 30 kg ha ⁻¹			
N ₆	SPAD37	*SPAD meter 37	**if SPAD meter critical value <37				

** Weekly observation from 14 DAT to 70 DAT

*SPAD: Soil and Plant Analysis Department

Table.3 Growth and yield parameters under different methods of cultivation and N management strategies

N ↓ M →	Plant Height (cm)*					No. of tillers*					No. of productive tillers*				
	SRI	ICM	LP	RP	Mean	SRI	ICM	LP	RP	Mean	SRI	ICM	LP	RP	Mean
Control	59.90	62.10	66.60	61.80	62.60	189.0	190.4	445.4	322.0	286.7	115.9	113.6	319.9	202.0	187.9
Blanket	65.00	65.30	76.80	71.90	70.50	435.8	305.6	593.3	295.0	407.4	288.4	216.0	426.6	323.2	313.5
LCC 4	71.40	65.85	76.80	72.50	71.64	421.9	335.2	660.0	310.0	431.8	301.5	232.0	446.6	270.9	312.7
LCC 5	66.70	71.10	70.30	70.00	69.53	406.8	352.0	726.7	395.0	470.1	273.1	246.4	486.6	263.4	317.4
SPAD 35	69.90	67.80	65.20	71.00	68.47	335.8	300.0	603.3	369.0	402.2	244.9	235.6	443.3	192.0	279.0
SPAD 37	56.30	71.50	70.80	62.00	65.40	405.5	328.8	686.2	416.5	459.2	281.0	228.8	442.5	282.0	308.6
Mean	64.87	67.28	71.75	68.20		365.8	302.1	619.1	351.3		250.8	212.1	427.6	255.0	
	M	N	NxM	MxN		M	N	NxM	MxN		M	N	NxM	MxN	M
S. Ed	0.83	1.86	3.37	3.71		24.7	18.4	43.9	36.7		10.4	11.2	23.1	22.4	10.4
C.D (P=0.05)	2.64	3.87	7.37	7.74		78.5	38.3	114.3	76.6		33.0	23.4	56.0	46.7	33.0
	Panicle length (cm)*					Panicle weight (g)*					Harvest Index (%)				
Control	16.07	16.28	16.51	16.93	16.5	0.945	0.947	1.008	1.086	0.996	26.10	26.40	34.90	30.03	29.35
Blanket	17.88	18.88	21.03	20.26	19.51	1.135	1.064	1.325	1.353	1.219	27.62	31.55	40.32	33.10	33.14
LCC 4	18.00	19.04	19.54	21.47	19.51	1.307	1.159	1.180	1.407	1.263	33.02	29.29	33.85	34.28	32.61
LCC 5	18.36	21.75	20.11	21.78	20.50	1.392	1.473	1.043	1.182	1.272	29.07	33.27	35.48	37.74	33.89
SPAD 35	17.42	20.02	18.18	20.72	19.09	1.125	1.142	0.994	1.122	1.096	29.99	29.46	36.55	33.24	32.31
SPAD 37	17.60	19.33	18.19	20.27	18.85	1.176	1.234	1.020	1.000	1.107	32.94	32.23	39.37	26.24	32.69
Mean	17.56	19.22	18.93	20.24		1.180	1.170	1.095	1.191		29.79	30.36	36.74	32.44	-
	M	N	NxM	MxN		M	N	NxM	MxN		M	N	NxM	MxN	
S. Ed	0.31	0.52	0.98	1.05		0.035	0.058	0.109	0.115		0.556	1.325	2.394	2.649	
C.D (P=0.05)	0.98	1.09	NS	NS		NS	0.120	0.246	0.240		1.77	2.76	5.21	5.53	

*Mean of ten samples, NS, Non significant

Table.4 Yield of rice crop under different methods of cultivation and N management strategies

Treatments	Grain yield (kg ha ⁻¹)					Straw yield (kg ha ⁻¹)				
	SRI	ICM	LP	RP	Mean	SRI	ICM	LP	RP	Mean
Control	1640	1904	2170	1839	1888	3344	4594	3532	3312	3696
Blanket	2091	2518	2712	2248	2392	5657	6635	3937	4156	5096
LCC 4	3119	2189	2966	2353	2657	6783	6531	5719	4219	5813
LCC 5	2229	2976	2535	2675	2604	6850	6472	5300	4909	5883
SPAD 35	2440	2056	2288	2137	2230	5750	4375	3563	4313	4500
SPAD 37	2107	2110	2502	1690	2102	3774	4344	3625	3563	3827
Mean	2271	2292	2529	2157		5360	5492	4279	4079	
	M	N	NxM	MxN		M	N	NxM	MxN	
S. Ed	66.2	96.5	185.8	193.0		65.6	137.7	251.3	275.4	
C.D										
(P=0.05)	211	201	426	403		205	287	552	575	

In the present investigation, the major constraints which were faced in the SRI method of cultivation is that when the seedlings were grown in the *dapog* nursery, the germination and establishment was relatively slow due to salt raise up by capillarity causing salt injury to the young seedlings. In the main field also the young seedlings were unable to revive from the transplantation shock for a week due to minimum water level maintained to avoid floating of seedlings which had resulted in salt injury. It was also seen that the number of tillers, number of productive tillers and harvest index were significantly lower than the LP method in the present study obviously due to the above said reasons. The above inference is in line with Krupakar Reddy *et al.*, (2004), who reported SRI and conventional planting are comparable. It was also seen from the results of Andriankaja (2001) that the SRI method was better expressed in clay soil than in loamy soil. It was even reported by Uphoff (2003), while summarizing the results of SRI trials from various countries, there are certain places where SRI recorded lower yields than conventional methods.

The ICM was also found to be inferior to LP and comparable with SRI and RP methods.

As discussed in the case of SRI, the ICM did not result in higher grain yield due to the saline-sodic condition of soil. Among the N management strategies, the LCC method of N management recorded higher grain yield followed by the blanket recommendation and SPAD methods (Singh *et al.*, 2008). It was further revealed that there were no marked difference between LCC 4 and 5 leading to the conclusion that LCC 4 itself is sufficient to meet the crop requirements. Similar results of N management were reported by Porpavai *et al.*, (2002), Budhar and Tamilselvan (2003), Budhar (2005) and Witt *et al.*, (2005). It was further seen that SPAD method did not result in higher yield as compared to the LCC method, but was comparable to the blanket recommendation. In case of the straw yield ICM and SRI had recorded higher straw yield as compared to LP and RP, which were comparable possibly due to poor translocation of photosynthates from source to sink in SRI and ICM. However, increased straw yield in SRI has been reported by Sathayanarayana *et al.*, (2004) and that of ICM by Balasubramanian *et al.*, (2004). Higher straw yield was recorded in LCC N management, also reported by Coumaravel (2002), Gunasekhar (2003) and Budhar (2005).

In conclusion, the present investigation concludes that line planting method of cultivation with nitrogen management through LCC 4 performed better due to more number of plant population which resulted in more productive tillers. Plant population in line planting was highest among methods of cultivation. Among N management strategies LCC 4 & 5 performed better because of need based application of nitrogen as and when it required, which reduced the N loss in saline sodic soil and increased the N use efficiency. Poor performance in SRI and ICM due to optimum plant population in these methods of cultivation become insufficient to produce required number of productive tillers. Moreover, the saline-sodic condition of soil could not allow the tillers to become productive tillers. Hence, line planting is better than SRI, ICM and random planting when soil quality is poor. Application of nitrogen based on LCC 4 is better than LCC 5, blanket recommendation, SPAD 35 and SPAD 37.

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