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Consequences of integrated nutrient management and cultivation methods on nitrogen use efficiency and sustainable yield index of lowland rice (*Oryza sativa*)

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ABSTRACT

Nitrogen use efficiency (NUE), sustainable yield index (SYI) and selected parameters were evaluated in a field experiment involving integrated nutrient management (INM) for two consecutive years (2014 and 2015) of rice (Oryza sativa L) cultivation in a Typic Haplusterts of Annamalainagar (T.N). Experiment was laid out in split plot design with two main plot treatments [system of rice intensification (SRI) and conventional system of cultivation (CSC)] and seven sub plots treatments (Integrated nitrogen management practices) and replicated thrice. Persistent application of various INM practices illustrated clear enhancement in the nitrogen use efficiency, crop yields and nitrogen uptake with application of soil test cop response based integrated plant nutrient supply (NPK + 12.5 t ha^{-1} FYM +Azospirillum and PSB) under SRI. Overall effect of INM treatments reflected significant increase in sustainable yield index of rice and it was proved that nitrogen use efficiency was increased up to 40 - 48 per cent.

Keywords: FYM, IPNS, nitrogen use efficiency, STCR, SRI, sustainable yield index

INTRODUCTION

Food security is well linked to nutrient availability for cropping, but its sustainability is directly linked to nutrient use efficiency. Nutrient management is one of the vital activities in enhancing crop productivity. Managing nitrogenous sources in lowland rice helps in proper application of its sources and avoids losses by enhancing its use efficiency. Rice (*Oryza sativa* L.) is primary staple food for millions of people in India. Crop improvement and management played an important role in increasing the production of major food crops. There is no doubt that the task of making gains becomes even more difficult when rice yield has already been at a high level. The system of rice intensification (SRI) is reported to haveadvantages like lower seed requirement, less pest attack, shorter crop duration, higher water use efficiency and the ability to withstand higher degree of moisture stress than traditional method of rice cultivation. Apart from the agronomical approaches, nutrient management practices also play an important role in crop production. However, lacking, imbalanced, inappropriate/excessive use of synthetic fertilizer in agricultural systems remains a concern which results low nutrient use efficiency (Tarafdar *et al.,* 2015). Because, indiscriminate and widespread use of synthetic fertilizer and agro-chemicals has leads to severe soil degradation, which results to loss of soil humus and organic matter content and thus soil becomes infertile. Chemical fertilizers are costly to produce and apply, both economically and environmentally. These conditions imply optimum use of fertilizer and use efficiency of applied nutrients by crops is essential pre-requisite for sustainable agriculture. The present advancement towards solving agricultural production problems is well associated with integrated nutrient management (INM), which is not meant to remove synthetic fertilizer totally but to maintain soil organic pool as well as sustain soil biome (Mohanty *et al.*, 2013).Hence, it warrants an urgent need to maximise efficiency of applied nutrients by agronomic and fertilizer management approaches. The most common principles for nutrient use efficiency are one which relates the increase in yield per unit of nutrient applied to soil. Among the macro nutrients, nitrogen plays a vital role in rice production, which has low use efficiency under different soil conditions and irrigation methods. The efficient use of fertilizer/ manural N for crop production depends on several transformations that it may undergo. By enhancing N use efficiency and uptake in asustainable manner rice production can be increased in large percentage to meet out the

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growing demand of rice. Therefore, the present investigation was carried out with rice to assess the performance of integrated nutrient management practices under two different methods of rice cultivation on the yield, N uptake, N use efficiency and sustainability index of rice in Vertisol of Tamil Nadu.

MATERIALS AND METHODS

Field experiments were conducted in kharif seasons of 2014 and 2015 at Experimental Farm, Annamalai University, Annamalai Nagar (Tamil Nadu).The experimental site is situated at 11°24' N latitude and 74°44' E longitude at an altitude of + 5.79 m above mean sea level in the southern part of India. Temperature and relative humidity during the experiment ranged from 28.5 to 38.5 ºC and 78.0 to 96.0 %, respectively. Soil of the experimental farm is classified as *Typic Haplusterts* (clay) having water holding capacity of 36.8 %, neutral in reaction (pH 7.4) organic carbon content 6.1 g kg^{-1}, CEC of 22.5 c mol (P+) kg $^{-1}$, low available N (232 kg ha^{-1}), medium available P (20.8 kg ha^{-1}), high available K (279 kg ha^{-1}); DTPA extractable Fe, Zn, Mn and Cu 20.4,2.4,3.4 and 1.2 mg kg^{-1}, respectively. Experiment was laid out at split plot design with two methods of cultivation (SRI and CSC) as main plot treatments and seven sub plot treatments viz., one inorganic alone applied treatment (100 % RDF) and six integrated nutrient management treatments (STCR based IPNS(144:64:60 NPKkg ha^{-1} + FYM 12.5 t ha^{-1} + Biofertilizer @ 2 kg ha^{-1}), based on 100 % RDF two levels of fertilizer nitrogen (75and 50 per cent) in combination with two levels of N (25 and 50 per cent) through organic manures *viz.,* Farmyard manure (FYM), enriched farmyard manure (EFYM) and 50 % Green manure (GM) as sub plot treatments, and replicated thrice. CO-43 rice variety was used as test crop, RDF @150-50-50 kg N, P, and K ha^{-1}, and 8 kg Zn ha^{-1} were added through urea, single superphosphate, muriate of potash, and zinc sulfate, respectively. System of rice intensification (SRI) and conventional system cultivation (CSC) were established as per the standard protocols. The grain and straw yields were recorded at 14 % moisture level. Formula to calculate various indices are given below,

$$\text{Sustainable yield index} = \frac{\text{Mean yield– Standarddeviation}}{\text{Maximum yield}}$$

$$\text{Agronomic Nutrient Use Efficiency (ANUE)} = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Amount of nutrient applied (kg ha}^{-1})}$$

$$\text{conomic Nutrient Use Efficiency (ENUE)} = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Amount invested on fertilizer (Rs. ha}^{-1})}$$

$$\text{Nutrient Efficiency Ratio (NER)} = \frac{\text{Dry matter yield at harvest (kg ha}^{-1})}{\text{N accumulation at harvest (kg ha}^{-1})}$$

$$\text{Nutrient Productivity (NP)} = \frac{\text{Biological Yield (kg ha}^{-1}\text{) / Total crop nutrient uptake (kg ha}^{-1})}{\text{Total duration of the crop in days}}$$

The data generated were subjected to statistical analysis. The data were tested for their level of significance at *P=0.05* as per method of Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Nitrogen uptake

Noticeably higher uptake of N was registered in SRI compared to conventional system at all growth stages except straw which was higher in CSC (Table 1). SRI recorded N uptake of 55.7, 134.4, 67.0 and 43.2 kg ha^{-1} while conventional system recorded 42.9, 113.2, 48.8 and 52.9 kg ha^{-1} at tillering, flowering, grain and straw, respectively. This might be attributed to favorable soil conditions (alternate wet dry), wider spacing, well developed and strong root structure which plays an important role in uptake and translocation of nutrients from soil solution through SRI. Similar findings were reported by Sandeep Kumar *et al.* (2015).Among the nutrient management practices application of STCR based IPNS (T_2) recorded higher uptake of N (64.4,1144.6,81.8,49.7 and 49.6,121.5,60.0,60.5 kg ha^{-1}) at tillering, panicle initiation and grain and straw under SRI and CSC, respectively and it was on par with T_5 (75% fertilizer N + 25 % inorganic N through EFYM) and T_3 (75 % fertilizer N + 25 % organic N through FYM). This could be ascribed to proportionate increase in N content of rice grain and straw led to higher uptake of nitrogen. Similar results were reported by

Radha Kumari and Reddy (2011). Treatment T_7 (50% fertilizer N + 50 % inorganic N through GM) recorded the lowest values of N uptake (35.9, 108.7, 34.8 and 35.4 kg ha^{-1}) under both methods of cultivation.

Table 1: Influence of integrated nutrient management and cultivation methods on N uptake (kg ha^{-1}) during different stages of rice

Treatments	Tillering		Flowering		Harvest (grain)		Harvest (straw)	
	SRI	CSC	SRI	CSC	SRI	CSC	SRI	CSC
T_1	47.4	36.5	124.1	104.8	51.8	37.4	36.6	45.2
T_2	64.4	49.6	144.6	121.5	81.8	60.0	49.7	60.5
T_3	61.7	47.6	140.6	118.2	78.2	57.3	47.5	58.0
T_4	57.2	44.0	136.9	115.2	69.1	50.4	44.9	54.9
T_5	63.1	48.6	142.6	119.9	80.1	58.7	48.6	59.3
T_6	55.5	42.8	134.2	113.0	67.0	48.8	43.5	53.3
T_7	40.5	31.2	117.7	99.7	40.6	29.1	31.5	39.4

	Tillering M	Tillering S	Tillering M x S	Flowering M	Flowering S	Flowering M x S	Harvest (grain) M	Harvest (grain) S	Harvest (grain) M x S	Harvest (straw) M	Harvest (straw) S	Harvest (straw) M x S
CD(P=0.05)	7.49	1.37	7.50	15.71	6.57	NS	10.23	3.74	NS	6.80	2.44	NS

T_1-100% RDF , T_2 -STCR Based IPNS , T_3 -75% fertilizer N+25 % organic N (FYM), T_4 -50% fertilizer N+ 50 % organic N (EFYM), T_5-75% fertilizer N+25 % organic N (EFYM) , T_6-75% fertilzer N +25 % organic N (GM), T_7-50% fertilizer N + 50 % organic N (GM)

Nitrogen use efficiency

It is evidenced from the pooled data (Table 2) that the N use efficiency was significantly enhanced by SRI method and also registered 5.83, 0.53,6.71, 12.9 and 0.05 per cent higher values of agronomic nitrogen use efficiency (38.7 %), economic nutrient useefficiency (3.57 Kg re^{-1}), nutrient efficiency ratio (126.9 kg kg^{-1}), nutrient harvest index (60.4 %) and nutrient productivity (0.94 kg $kg^{-1}day^{-1}$) over conventional method of cultivation. This would have attributed to better soil atmospheric conditions, favorable root system, higher root and shoot ratio activity facilitated more microbial biomass and activities (aerobic and anaerobic) under SRI (Kumar *et al.*,2013). Application of STCR based IPNS(T_2) registered the highest AUE and NHI (47.1, 40.1 and 62.2,49.8 %) values and the lowest NER and NP (119.1,114.1 kg kg^{-1} and 0.88,0.85 kg kg^{-1} day^{-1}) followed by 75% fertilizer N + 25 % organic N through FYM / EFYM (Table 2).

Table 2: Influence of nutrient management and cultivation methods on nitrogen use efficiency of rice

Treatments	Agronomic use efficiency(%)		Economic nutrient use efficiency(kg re^{-1})		Nutrientefficiency ratio(kg kg^{-1})		Nutrient harvest index(%)		Nutrient productivity(kg kg^{-1} day^{-1})	
	SRI	CSC	SRI	CSC	SRI	CSC	SRI	CSC	SRI	CSC
T_1	31.21	26.26	2.88	2.42	133.6	125.4	58.61	45.22	0.99	0.93
T_2	47.12	40.22	4.35	3.71	119.1	114.1	62.18	49.76	0.88	0.85
T_3	44.31	37.80	4.09	3.49	122.1	116.8	62.21	49.65	0.90	0.87
T_4	38.92	33.07	3.59	3.05	122.8	116.8	60.59	47.87	0.91	0.86
T_5	44.79	38.22	4.13	3.53	120.5	115.4	62.20	49.71	0.89	0.85
T_6	38.34	32.56	3.54	3.01	125.0	118.7	60.61	47.79	0.93	0.88
T_7	26.05	21.77	2.40	2.01	145.1	134.0	56.33	42.39	1.07	0.99

These results might be attributed due to enhanced availability of applied nutrients from different sources and levels to the crop and its captivating power of converting the nutrients from source to sink helped in improving the efficiency by the crop. Results indicated that the capacity of yield increase per kilogram pure N declined with increasing N application in AUE and NHI in contrary to NER and NP where the capacity of yield increase per kilogram pure N increased in fact with decreasing N application. Thereby, results proved scientifically that there was no use of more or less application of N and better to keep use balanced or STCR based nutrient levels. The present results are in line with the findings of Nayak *et al.* (2015). The lowest values of AUE, NHI and highest values of NER and NP were recorded in 100 % RDF treatment. It might be due to of inorganic fertilizer alone application and its susceptibility to different types of losses leads to delayed growth and development processes in early stages thus affected dry matter production and uptake. So, lesser nitrogen use efficiency is victim with lower level of N application through inorganic sources proved evidently.

Crop yields

SRI produced distinctly more grain and straw yield (5761.3 and 7758.3 kg ha^{-1}) compared to conventional system of cultivation (4891.8 and 6810.5 kg ha^{-1}). Planting younger seedlings with wider spacing helps to develop larger root system and crop canopy which facilitated the enhanced nutrient uptake, photosynthetic activity and remobilization of photosynthates to grain which resulted in higher yield attributes and yield under SRI. The results are in accordance with the findings of Sridevi and Chellamuthu (2015). Application of STCR based IPNS treatment (T_2) registered higher grain yield of 6289.0 kg ha^{-1}. Straw yields under different treatments followed the similar trend as grain yields. Maximum grain yields under STCR based IPNS might be attributed to higher microbial population and increased nutrient availability throughout the crop growth which resulted in improved yield attributes. Further, improved nutrient supply and soil properties (physico-chemical and biological) with organics (FYM or GM application) which in turn increased the nutrient availability and ultimately enhanced the grain and straw yields of rice. These findings are in harmony with the results of Shahane *et al.*(2019). Application of 50 % fertilizer N + 50% N through green manure (T_7) registered lower grain and straw yields, which may be due to less number of tillers produced per hill, comparatively weaker root and shoot stimulatory effects (Pramanik and Bera , 2015).

Table 3: Influence of integrated nutrient management on rice yield, harvest index and sustainable yield index of rice

Treatments	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Harvest index		Sustainable yieldindex	
	SRI	CSC	SRI	CSC	SRI	CSC	SRI	CSC
T_1	4681	3938	6890	6049	0.40	0.38	0.53	0.51
T_2	6786	5792	8562	7516	0.43	0.42	0.84	0.83
T_3	6646	5669	8385	7361	0.43	0.42	0.82	0.81
T_4	5838	4960	7886	6922	0.42	0.40	0.70	0.69
T_5	6719	5733	8477	7441	0.43	0.42	0.83	0.82
T_6	5752	4884	7770	6820	0.42	0.40	0.68	0.67
T_7	3908	3266	6339	5564	0.37	0.36	0.41	0.39

	M	S	M x S	M	S	M x S	M	S	MxS	M	S	M x S
CD(P=0.05)	604.8	347.8	NS	659.2	267.0	NS	0.012	0.009	NS	0.009	0.055	NS

Harvest Index and sustainable yield index

Harvest index and sustainable yield index were higher under SRI (0.42 and 0.69) over conventional system (0.40 and 0.68), respectively (Table 3). Higher harvest index under SRI may be attributed to better soil aeration, translocation of photosynthates from vegetative parts to grains as compared to CSC. STCR based IPNS registered higher harvest index and sustainable yield index values (0.43 and 0.83). Application of 50% fertilizer N+ 50% organic N through GM (T_7) recorded the lowest HI of 0.36. These results are in conformity with the findings of Singh *et al.* (2017). The methods of cultivation showed significant variations in SYI, but at the same time the nutrient management practices showed noteworthy observation .This would have effected through nutrient sources which respond better with respect to soil environmental condition. Soil conditions differed completely under SRI and CSC of rice establishment methods but the nutrient sources and levels played their role independently by enhancing sustainable yield index. Application of STCR based IPNS registered highest SYI and application of 50 % fertilizer N + 50% N through green manure (T_7) recorded the lowest SYI. This might be ascribed duly increased grain and straw yields through enhanced nutrient uptake and use efficiency. Further, sustainability of rice production increased significantly through addition of organics and organic inputs increased the nutrient status, microbial activity and productivity of soil compared to use of only chemical fertilizers in a cropping system resulted in poor microbial activity index and sustainability index. These findings are in agreement with Singh *et al.* (2015) and Shahane *et al.* (2019).

On the basis of the results, it may be concluded that STCR based IPNS (combined application of fertilizer N + 12.5 t ha^{-1} FYM + bio-fertilizers or 75 % N through fertilizers + 25 % N through FYM / EFYM can be recommended to low land rice grown in Vertisol under system of rice intensification (SRI) to enhance the N uptake, N use efficiency and also to sustain the crop yields.

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