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Yield, uptake and availability of micronutrient cations in rice (*Oryza sativa*) as influenced by nutrient sources and cultivation methods

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ABSTRACT

Field experiment was conducted at Experimental farm, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India during kharif season to study the effect of nutrient management practices on uptake and availability of micronutrient cations in rice (Oryza sativa) under SRI and conventional system of cultivation. The data revealed that the best results were obtained with STCR based RDF (144:64:60 kg NPK ha^{-1} along with 12.5 t ha^{-1} FYM + Azospirillum + PSB) by registering significantly higher grain and straw yield (6785.9 and 5792.1 and 8561.6 and 7515.8 kg ha^{-1},respectively in SRI and CSC). The higher values of micronutrient (Fe, Mn, Zn and Cu) uptake in grain (455.7, 273.9, 145.4, 37.5 g ha^{-1}) and straw (570.1, 342.8, 308.3, 54.4 g ha^{-1},respectively) were recorded in SRI method of cultivation and lower values of yield and uptake in inorganic alone applied under CSC. Application of STCR based RDF plus IPNS resulted in higher soil available micronutrient (Fe, Mn, Zn and Cu) status, while the lower in sole application of 100 % RDF through inorganic nutrient sources both under SRI and conventional system of cultivation (CSC). It is concluded that STCR based IPNS practice under SRI create favorable conditions for better availability of micronutrients and increases their uptake in rice grown soil sequentially enhances productivity.

Key words: IPNS, Micronutrients, rice, SRI, STCR, Uptake

INTRODUCTION

Rice (*Oryza sativa*.L) the prince among cereals is the premier food crop not only in India but world too. Integrated use of organic and inorganic nutrient sources to food grain crops including rice is one of the important considerations in providing food security to the burgeoning Indian population and promoting soil fertility in sustainable intensive agriculture (Singh *et al.*, 2013). Since the very inception of green revolution, introduction of high yielding varieties, extension of irrigated areas and use of high analysis micro-nutrient free NPK fertilizers which increasingly catalyze the depletion of finite reserves of soil micronutrients leading to the occurrence of widespread multi-micronutrient deficiencies. Significance of these nutrients has been realized during past decades when their widespread deficiencies, especially Zn, Fe and B were observed in most of the soils in India (Katyal, 2018). Enhancing the availability of micronutrients along with macronutrients in rice cultivation could improve the quality and yield and thus micronutrients are more important for sustainable rice production (Chauhan *et al.* 2017). Indian soils are becoming poorer in respect of organic matter content. The depletion of primary, secondary and micronutrients like Zn, Mn, B and Fe has also become more conspicuous in decreasing the productivity of crops which can be alleviated either by external application of organic matter or any other application of suitable sources to sustain productivity and quality of produce besides soil health and fertilizer use efficiency. Using organic sources is one of the options to maintain dynamic and sustainable rice production system, in addition cut down ground water pollution. But, it is not feasible to use only organics in the modern agricultural system, which demands both quality and quantity. The mandatory of sustainable agriculture is supplying plant nutrients in a balanced way. This could be possible by adopting integrated nutrient management, which includes the use of organic manures along with inorganic nutrient sources in order to make the soil well supplied with all plant nutrients in the readily available form for escalating the crop yield through better nutrient uptake. Further, research reports proved beyond suspicion that the balanced use of organic and inorganic sources of plant nutrients can sustain the best possible crop yields and perk up the soil health.

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SRI is an emerging water-saving technology, which can help to make rice cultivation more efficient in terms of returns on farmers' investments as well as in the use of scarce resources such as water, seed and fertilizers. The SRI principles encourage the use of organic manure instead of inorganic fertilizers (Termel *et al.,* 2011) to harness optimum crop potential. However, much of the available literature suggests that integrated nutrient management with a judicious combination of organic manure and inorganic fertilizer as per the resources available with the farmers is the best option for higher soil and crop productivity by enhancing nutrient availability and uptake. Alternate wetting and drying method of irrigation and broader spacing would facilitate the soil environment better for growth and development of roots which in turn makes crop duly uptake of essential nutrients at right time and quantity compared to conventional method of rice cultivation. Information on effects of INM on rice under SRI and its comparison with conventional system of cultivation (CSC) with regard to micronutrient uptake and its availability in Indian soils is still limited. The present experiment was conducted to investigate micronutrient uptake by rice and its availability by comparing the plants grown with different methods of rice cultivation (SRI and CSC).

MATERIALS AND METHODS

Field experiment was conducted in kharif season during 2013 at Experimental Farm, Annamalai University, Annamalai Nagar Tamil Nadu, India. 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 holding capacity of 36.8 per cent, 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 soil content of 20.4,1.2,3.4 and 2.4 mg kg^{-1}, respectively. Experiment was laid in split plot design with two methods of cultivation (SRI and CSC) as main plot treatments and seven sub plot treatments *viz.,*T_1-100 % RDF (150:50:50 kg NPK ha^{-1}) ,T_2 - STCR Based RDF (144:64:60 kg NPK ha^{-1} along with 12.5 t ha^{-1} FYM +*Azospirillum* + *PSB* as soil treatment), 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% fertilizer N +25% organic N (GM), T_7 - 50% fertilizer N + 50% organic N (GM), and replicated thrice. The rice variety used was CO-43 which matures normally in 135 days, the total nutrients were supplied through organic sources inorganic fertilizers were given at the rate of 150-50-50 kg N, P, and K ha^{-1}, and 8 kg Zn ha^{-1} through urea, single super phosphate, muriate of potash, and zinc sulfate, respectively. Nitrogen was given in three equal splits at basal, maximum tillering, and panicle initiation stages, while P, K, and Zn were given as basal doses. For SRI-organic treatments, the N dose was adjusted to the recommended level based on the moisture content and total N concentration of the organic sources. In the SRI plots (both organic and inorganic), 10–12-day-old seedlings were transplanted, while 30-day-old seedlings were transplanted for CSC. CSC plots were kept flooded whenever required to maintain a layer of 5–6-cm depth of water during the vegetative stage. SRI plots were kept saturated, but with no standing water during the vegetative stage. After panicle initiation, both SRI and CSC plots were maintained with 2–3-cm depth of water and all the plots were drained 15 days before harvest. Weeding in SRI plots (both organic and inorganic) was done four times by cono-weeder to incorporate weeds into the soil at 10, 20, 30, and 40 days after transplanting (DAT), while the CSC plots were hand weeded twice at 25 and 40 DAT. The grain and straw yields were recorded at 14 per cent moisture level. The Total Fe, Mn, Zn, and Cu content in grain and straw were determined by using Atomic Absorption Spectrophotometer (di-acid extract). The nutrient uptake was computed by grain and straw yield with respective nutrient content. The collected soil samples were analyzed for Fe, Zn, Mn and Cu as per the procedure of Lindsay and Norvell (1978). All the data were statistically analyzed by analysis of variance (ANOVA) as applicable to a completely randomized block design (Gomez and Gomez, 1984). The significance of the treatment effect was determined by F tests, and to determine the significance of the difference between the means of the treatments, least significant difference (LSD) was calculated at the 5 % probability level.

RESULTS AND DISCUSSION

Yield of rice

Under both methods of cultivation the different nutrient levels had significant influence on grain and straw. SRI produced distinctly more grain and straw yield ranging from 3908 - 6785.9 and 6338.7 -8561.6 kg ha^{-1}, respectively compared to conventional system of cultivation (3265.8 - 5792.1 kg ha^{-1}) (Table 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 under SRI when compared to planting older seedling with closer spacing, under submergence (CSC).This is in accordance with the findings of Chandrapala *et al.* (2010), Sridevi and Chellamuthu (2015). Straw yield followed similar trend as that of grain yield. Application of STCR based IPNS treatment (T_2) registered higher grain and straw yield of 6785.9 and 5792.1 kg ha^{-1} ; 8561.6 and 7515.8 kg ha^{-1}, respectively in SRI and CSC (Table 1). This might be attributed to higher microbial population and increased nutrient availability throughout the crop growth which resulted in improved yield. This might be due to, comparatively weaker root and shoot stimulatory effects which resulted in lower uptake of nutrients at different developing stages of crop growth, irrespective of cultivation methods compared to the performance of higher levels inorganic fertilizer N combined with organic manures with or without enrichment, green manure and or 100 % RDF of NPK in splits facilitated the initial growth and development of crop with added fertilizer nutrients (Chandrapala *et al.* 2010).

Table 1: Effect of nutrient sources and cultivation methods on yield of rice (kg ha^{-1})

Treatments	Grain yield		Straw yield	
	SRI	CSC	SRI	CSC
T_1 - 100% RDF	4681.1	3938.3	6890.3	6048.6
T_2 - STCR Based IPNS	6785.9	5792.1	8561.6	7515.8
T_3 - 75% fertilizer N + 25 % organic N (FYM)	6646.0	5669.3	8385.1	7360.8
T_4 - 50% fertilizer N + 50 % organic N (EFYM)	5837.7	4959.8	7885.7	6922.4
T_5 - 75% fertilizer N + 25 % organic N (EFYM)	6718.6	5733.1	8476.7	7441.3
T_6 - 75% fertilzer N + 25 % organic N (GM)	5751.6	4884.2	7769.5	6820.4
T_7 - 50% fertilizer N + 50 % organic N (GM)	3908.0	3265.8	6338.7	5564.4
SEd±	140.6	168.5	153.2	129.4
CD (P=0.05)	604.8	347.8	659.2	267.0

Uptake of micronutrients

Methods of cultivation exerted significant influence on uptake of Fe, Mn, Zn and Cu in grain and straw. SRI method registered higher values of Fe, Mn, Cu and Zn by grain (392.5, 238.6, 125.0, 32.2 g ha^{-1}) and straw (514.3, 312.9, 277.5, 48.9 g ha^{-1}) compared to conventional method (293.7, 177.9, 93.2, 24.0 and 396.3, 241.2, 213.8, 37.6 g ha^{-1}) respectively (Table 2). This might be attributed due to favorable soil conditions (alternate wet dry), wider spacing well developed and strong root structure plays an important role in uptake and translocation of nutrients from soil solution (Kumar *et al.*, 2007 and Bommayasami *et al.*, 2010). Micronutrient uptake in rice plants facilitated through SRI agronomic practices might have resulted uptake than conventional method of cultivation. Similar findings had also been reported by Sandeep Kumar *et al.* (2015).

Further, amount and rate of xylum exudates and exudation $hill^{-1}$ were higher under SRI over recommended management practices reported by Thakur *et al.* (2010). Uptake of Fe, Mn, Zn, Cu in grain and straw were noticed in the order of Fe > Mn > Zn > Cu (Zn uptake was higher in grain compared to straw). Among the nutrient sources tried, higher values of Fe, Mn, Zn and Cu uptake in grain and straw were registered in STCR based IPNS treatment T_2 (455.7, 273.9, 145.4, 37.5 and 570.1, 342.8, 308.3, 54.4 g ha^{-1}) and it was comparable with T_5 (75% fertilizer N + 25 % inorganic N through

Table 2: Effect of nutrient sources and cultivation methods on uptake of micronutrient cations (g ha^{-1}) by rice grain

Treatments	Fe		Mn		Zn		Cu	
	SRI	CSC	SRI	CSC	SRI	CSC	SRI	CSC
T_1 - 100% RDF	252.0	186.1	157.8	116.6	79.8	59.0	20.5	15.1
T_2 - STCR Based IPNS	521.0	390.3	313.1	234.6	166.2	124.6	42.9	32.1
T_3 -75% N + 25 % organic N (FYM)	499.7	374.2	300.3	224.9	159.5	119.4	41.2	30.8
T_4 -50% N + 50 % organic N (EFYM)	360.3	268.7	221.8	165.4	114.4	85.4	29.5	22.0
T_5 -75% N + 25 % organic N (EFYM)	510.7	382.5	306.9	229.9	163.0	122.1	42.1	31.5
T_6 - 75% N + 25 % organic N (GM)	349.7	260.7	215.3	160.5	111.1	82.8	28.6	21.3
T_7 - 50% N + 50 % organic N (GM)	254.3	186.5	154.8	113.6	81.0	59.4	20.8	15.3
SEd±	16.1	16.9	9.8	9.8	3.5	2.8	1.3	1.4
CD (P=0.05)	69.4	35.0	42.2	20.4	15.2	5.8	5.7	2.9

EFYM) and T_3 (75 % fertilizer N + 25 % organic N through FYM) followed by T_4, T_6 (both on par) and T_7 under both methods of cultivation (Table 3). This might be due to the continuous supply of micronutrients by the application of STCR based IPNS compared with other levels and sources of nutrients. Further combined application of inorganic and organic manures resulted in production of chelating agents from soluble complexes which were efficiently utilized by rice plants in terms of higher micronutrient uptake (Mukesh Kumar *et al.*, 2012). The performance STCR based IPNS applied plots were closely followed by 75% or 50% fertilizer N + 25 % or 50% organic N through EFYM or FYM and75% fertilizer N + 25 % organic N through GM. This might be due to synergistic effects of both inorganic and organic sources at different levels, chelation of micronutrients, which in turn produced improved soil physical and chemical environment in rhizosphere, induced better availability of these nutrients (Uma Shankar *et al.* 2013).

Table 3: Effect of nutrient sources and cultivation methods on uptake of micronutrient cations (g ha^{-1}) by rice straw

Treatments	Fe		Mn		Zn		Cu	
	SRI	CSC	SRI	CSC	SRI	CSC	SRI	CSC
T_1 - 100% RDF	363.4	280.1	227.7	175.5	195.0	150.3	34.2	26.3
T_2 - STCR Based IPNS	643.9	496.2	387.2	298.4	348.2	268.3	61.4	47.3
T_3 -75% N + 25 % organic N (FYM)	617.7	476.0	371.4	286.2	334.0	257.4	58.9	45.4
T_4 -50% N + 50 % organic N (EFYM)	476.8	367.4	293.6	226.3	256.6	197.8	45.2	34.8
T_5 -75% N + 25 % organic N (EFYM)	631.2	486.4	379.6	292.5	341.3	263.0	60.2	46.4
T_6 - 75% N + 25 % organic N (GM)	462.8	356.6	285.0	219.6	249.1	192.0	43.8	33.8
T_7 - 50% N + 50 % organic N (GM)	404.1	311.4	246.1	189.7	218.1	168.1	38.3	29.5
SEd±	19.0	16.6	11.6	9.5	8.6	4.7	1.8	1.6
CD (P=0.05)	82.0	34.4	49.9	19.7	37.3	9.7	7.8	3.3

The lower values of Fe, Mn, Zn and Cu uptake were found in T_1 (100% RDF) 219.1, 137.2, 69.4, 17.8 and 321.8, 201.6, 172.7, 30.3 g ha^{-1}, respectively in SRI and CSC (Table 2 and 3). This might be due to unavailability of micronutrients from inorganic straight fertilizers unlike organic sources. Treatment T_2 recorded highest value under SRI (166.2 and 348.2 g ha^{-1}) and least value in T_1 under conventional system (59.0 and 150.3 g ha^{-1}) in grain and straw respectively. Whereas application of 100 % RDF through fertilizers (T_1) egistered the poorest performance among different nutrient management practices (inorganic alone and inorganic combined with organic) tried under both methods of cultivation. Further, humic and fulvic acid contents increased with addition of organic manures which able to interact with metals, oxides and hydroxides and clay minerals to form metallo organic compounds, act as ion exchangers and stockers of nutrients which was absent in inorganic fertilizer application alone in rice (Ramalakshmi *et al.*, 2013).

Table 4: Effect of nutrient sources and cultivation methods on post harvest soil available Fe, Mn, Zn and Cu (mg kg^{-1})

Treatments	Fe		Mn		Zn		Cu	
	SRI	CSC	SRI	CSC	SRI	CSC	SRI	CSC
T_1 - 100% RDF	15.68	13.77	2.53	2.22	1.01	0.89	1.33	1.16
T_2 - STCR Based IPNS	24.23	21.27	3.76	3.30	1.55	1.36	2.04	1.79
T_3 -75% N + 25 % organic N (FYM)	23.73	20.83	3.68	3.23	1.52	1.33	1.99	1.75
T_4 -50% N + 50 % organic N (EFYM)	21.59	18.96	3.34	2.94	1.36	1.20	1.79	1.57
T_5 -75% N + 25 % organic N (EFYM)	23.99	21.06	3.72	3.27	1.53	1.35	2.02	1.77
T_6 - 75% N + 25 % organic N (GM)	21.28	18.68	3.30	2.89	1.34	1.18	1.77	1.55
T_7 - 50% N + 50 % organic N (GM)	17.24	15.25	2.26	2.09	1.22	1.10	1.62	1.45
SEd±	0.92	0.28	0.06	0.09	0.023	0.03	0.08	0.02
CD (P=0.05)	NS	0.58	0.26	0.19	0.11	0.06	NS	0.04

Status of available micronutrients

Cultivation methods did not exert any significant manipulation on soil available micronutrients except Mn and Zn. Zinc availability was higher under SRI (1.36 mg kg^{-1}) over conventional system (1.20 mg kg^{-1}). SRI registered a little higher Mn availability of 3.23 mg kg^{-1} than conventional system (2.85 mg kg^{-1}).This difference might be due to changes in soil atmospheric conditions. At the same time CSC recorded higher availability of Fe and Cu. This might be influenced by soil water management and bio-fortification of agronomic practices changes soil Eh and pH, which control the availability of micronutrients in soil (Fong *et al.*,2015). Better availability of Fe, Mn, Zn, Cu were registered in treatment T_2 (STCR based IPNS) to the extent of 22.75, 3.53, 1.45, 1.91 mg kg^{-1}, respectively (Table 4). It might be due to organic manures decomposition produce several biochemical substances viz., organic acids, poly phenols, amino acids and poly saccharides and enhanced synergetic nutrient interaction ,which stimulated the solubility, transport and availability of these micronutrients. This is in conformity with those of Ramalakshmi *et al.* (2013). Treatment T_2 was comparable with T_5 (75% fertilizer N + 25 % inorganic N through EFYM) and T_3 (75 % fertilizer N + 25 % organic N through FYM). Next higher values were registered by T_4 (50% fertilizer N+50 % inorganic N through EFYM - 22.28, 3.46, 1.42, 1.87 mg kg^{-1}) , T_6 (75% fertilizer N + 25 % inorganic N through GM) both on par with each other and followed by T_7 (50 %n fertilizer N+50 % organic N through GM).Whereas lowest values were noticed in T_1(100 % RDF of NPK) as in the order of Fe, Mn, Zn, Cu (14.73, 2.37, 0.95, 1.24 mg kg^{-1}) respectively (Table 4) under both methods of cultivation. This would indicate the role of organic manures and biofertilzers in enhancing the release of these nutrients and organic acids increased with addition of organic manures enhanced the microbial properties of soil and available nutrients compared to inorganic fertilizer application alone (Ramalakshmi *et al.* 2013).

From the results it can be concluded that application of STCR based IPNS (144:64:60 kg NPK ha^{-1} along with 12.5 t ha^{-1} FYM + *Azospirillum +PSB* as soil treatment) under system rice intensification (SRI) proved significantly superior with respect to yield, micronutrients (Fe, Mn, Zn and Cu) uptake and availability compared to CSC in deep clay soil .

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