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Does Various Crop Establishment Methods and Zn Sources Change Dynamics of Nutrient Uptake and Economics of Rice (*Oryza sativa* L.)?

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A field experiment was conducted during the rainy (*Kharif*) season in 2013 at Agricultural Research Farm, Institute of Agricultural Sciences, Varanasi, to evaluate the various crop establishment methods and different sources of Zn on dynamics of nutrient uptake and economics of rice (*Oryza sativa* L.). The result of the experiment indicate that, the treatment combinations M_1Z_1 (SRI+ Zn-EDTA-12% Zn) was found to be the best with respect to yield, nutrient uptake and economics of rice. The highest grain yield (51.95 q ha^{-1}), straw yield (60.96 q ha^{-1}), N uptake in grain (46.55 kg ha^{-1}) and straw (26.58 kg ha^{-1}), P uptake in grain (13.25 kg ha^{-1}) and straw (9.45 kg ha^{-1}) and Zn uptake in grain (183.42 g ha^{-1}) and straw (756.62 g ha^{-1}) was found higher with SRI method of transplanting as compare to other methods of crop establishment but the highest K uptake in grain (13.75 kg ha^{-1}) and straw (91.40 kg ha^{-1}) was noticed with Farmer's practice method of transplanting. In case of sub plot treatments, the highest grain yield (54.31 q ha^{-1}), straw yield (61.56 qha^{-1}), N uptake in grain (48.60 kg ha^{-1}) and straw (27.23 kg ha^{-1}), P uptake in grain (13.64 kg ha^{-1}) and straw (9.49 kg ha^{-1}), K uptake in grain (13.71 kg ha^{-1}) and straw (93.21 kg ha^{-1}) and Zn uptake in grain (195.94 g ha^{-1}) and straw (828.71 g ha^{-1}) was examined with Zn-EDTA-(12% Zn) application @ 1.0 kg h^{-1}. Highest gross return (Rs. 92608.03 ha^{-1}), Net return (Rs. 56184.37 ha^{-1}) and B: C ratio (1.54) was observed with M_1Z_1 (SRI+ Zn-EDTA-12% Zn) and minimum gross return (Rs. 76516.67 ha^{-1}), Net return (Rs. 38362.95 ha^{-1}) and B:C ratio (0.92) was observed with M_3Z_0 (Farmer's practice method with control). The performance of Zn sources was Zn-EDTA > $ZnSO_4.7H_2O$ > $ZnSO_4.H_2O$.

Key words: SRI, Wetland, Economics, Net return, Yields, and Nutrient uptake.

Rice (*Oryza sativa* L.) is one of the most staple food crops in Asia and other parts of the world. In India, it is cultivated in an area of 43.97 million ha with a production of 104.32 mt and average productivity of 2372 kg ha^{-1} (http://agricop.nic.in/agristatics.html, 2011-2012) At present, rice is one of the most important staple foods for more than half of the world's population (IRRI, 2006) and influences the livelihoods and economies of several billion people. System of Rice Intensification (SRI) is an alternative practice to solve the water crisis and as a methodology for increasing the productivity of irrigated rice by changing the management of plant, soil, water and nutrients (Natarajan *et al.*, 2008). The SRI method appears to be a viable methodology for rice cultivation that saves expensive inputs, improves soil health besides optimum water use efficiency.

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This system seems to be promising to over- come the storage of water in irrigated rice (Kumar and Shivay, 2004). Conventional system of crop establishment; accounting for 21% of the operational cost, critically taking energy of 30 person's ha^{-1} day^{-1}. As the rice production system in Asia undergoes major adjustments in response to the rising scarcity of land labour, capital and water, major adjustment is to be made in the method of establishment. Zinc (Zn) deficiency in soil and human has recently received global attention. Zinc is now recognized as the fifth risk leading factor in the production of crops. Currently, millions of hectares of cropland are affected by Zn deficiency and approximately one third of the human population suffers from an inadequate intake of Zn.

Cereal crops play an empirical role in satisfying daily calorie intake in developing world, but they are inherently very low in grain Zn concentrations, particularly when grown on Zn deficient soils (Cakmak, 2008) and it is more deficient in the case of hybrids. Although Zn deficiency to some extent can be cured by Zn supplementation and improvement in dietary composition, it is better to increase the Zn content in cereals, the staple food in south and South East Asia. Zinc is essential for several biochemical processes in the rice plant, such as cyto-chrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation, and membrane integrity (IRRI, 2000). Severe Zn deficiency causes loss of grain yield, and rice grain with low Zn content contribute to human nutritional Zn deficiencies (Johnson, 2009) Zinc-deficient soils mainly affect rice and wheat. Zn deficiency in crops resulting in severe yield loss was reported in Bangladesh (Alloway, 2008). The problem seems to be more acute for rice as around half of the total rice area, found is severely affected by Zn deficiency since rice is grown mostly on submerged soils where availability of Zn is affected adversely. Zn plays a vital role in different plant metabolism process like development of cell wall, respiration, photosynthesis and other bio-chemicals functions etc.

Zinc is an indispensable micronutrient for proper plant growth and development. Zinc deficiency is corrected through the application of an inorganic salts, $ZnSO_4.7H_2O$, which interacts with various soil components like clay, organic matter, sesquioxides etc. fixing or forming its insoluble complexes, which ultimately decrease the availability of Zinc in soils vis- a- vis uptake by the plants . Chelated forms of Zn such as Zn-EDTA, Zn-DTPA etc. are able to supply substantial amount of Zn to the plant without interacting with soil. The chemical fertilizers are considered as essential part of modern farming and their use in different countries has increased considerably day-by–day. Their application directly or indirectly causes series of changes in physical, chemical and biological properties of soil (Divya and Bengali, 2012). Chelated Zn is at least 5 times more effectives than inorganic Zn salts although it is costly (Katyal and Randhawa, 1983). Keeping above facts in view, the present investigation was under taken to study the effect of "Does various crop establishment methods and zn sources change dynamics of nutrient uptake and economics of rice (*Oryza sativa* L.)" with observing the fertility status of soil.

MATERIAL AND METHODS

The field experiment was conducted during rainy season in 2013 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The geographical situation of the farm is $25^0 18'$ N latitude, $88^0 03'$ E longitude and at an altitude of 128.93 meters from the mean sea level in the Northern Gangetic Alluvial plains. The soil of the experimental site was sandy clay loam in texture having pH 7.2, organic carbon 0.41% and Diethylene Triamine Penta Acetic Acid (DTPA) extractable Zn in soil was 0.71 mg kg^{-1} of soil. The critical level of DTPA extractable Zn for crops grown on alluvial soils in the rice-wheat belt of north India varies from 0.38-0.90 mg Kg^{-1} soil, available nitrogen 198.05 kg ha^{-1}, phosphorus 23.64 kg ha^{-1}, and potash 207.5 kg ha^{-1}. The experiment was laid out in Split Plot Design comprised three crop establishment methods *viz*. SRI (M_1), Wetland (M_2) and Farmer's practice (M_3) and 4 level of different Zinc sources *viz*. 0 kg Zn ha^{-1} (Z_0), 1 kg Zn (Zn-EDTA -12% Zn) ha^{-1} (Z_1), 5 kg Zn ($ZnSO_4$. H_2O - 33% Zn) ha^{-1} (Z_2) and 10 kg Zn ($ZnSO_4.7H_2O$ -21% Zn) ha^{-1} (Z_3) with three replications and twelve treatment combinations. The methods of Zn application were half as soil and rest half as foliar spray (0.5 % and 1%). In addition to this a uniform dose of 120 kg N, 60 kg P_2O_5, 60 kg K_2O ha^{-1} was applied in all the plots through urea, DAP and MOP respectively. Half of total N and full dose of P_2O_5 and K_2O were applied as basal while the remaining half dose of N was top dressed in two equal splits at active tillering (30 DAT) and panicle initiation stages (55 DAT), respectively.

'Pusa-44' non aromatic rice seedlings of 12 days in SRI methods, 25 days in Wetland methods and 35 days in Farmer's practice were transplanted, keeping 1 seedling hill^{-1} at 25x25 cm spacing in SRI method of transplanting and 2-3 seedling hill^{-1} at 20x15 cm under wetland methods of transplanting under puddle conditions. The crop was harvested in the first fortnight of November. The other agronomic practices were followed as per standard recommendations.

Statistical analysis

The data obtained from the different treatments were computed to determine the mean values. The mean values after suitable transformation were subjected to statistical analysis to test significance as per as Gomez and Gomez (1984) for the interpretation of the results.

Nutrient uptake

Nutrient uptake removal in grain and straw of the crop were calculated in kg ha^{-1} in relation to yield ha^{-1} by using the following formula (Jackson, 1967)

Nutrient uptake (kg ha^{-1}) = Nutrient content (%) × yield (q ha^{-1})

RESULTS AND DISCUSSION

Yield and Yield attributes

A perusal of the data presented in Table: 2 revealed that, The Grain yield (51.95q ha^{-1}) was observed significantly higher in SRI method of transplanting as compared to rest of the treatments. The lowest Grain yield (47.67 q ha^{-1}) was quantified with Farmer's practice method of transplanting. Straw yield (60.96 q ha^{-1}) was revealed higher with SRI method of transplanting as compared to other method of transplanting. The lowest straw yield (54.83 q ha^{-}1) was observed under Farmer's practice method of transplanting. No significant difference was analysed in harvest index over all method of transplanting. Yield attributes of rice were significantly higher, when it was grown in SRI methods as compared to other methods. Profuse high rooting due to wider spacing, transplanting of young seedlings and higher biological N fixation (BNF) in the roots and rhizosphere of rice in SRI method could contribute to yield increase. This is in conformity with the results of Latif *et al.* (2004).

From the data it was found that, Grain yield (54.31q ha^{-1}) was found significantly higher with Zn-EDTA treatments as compared to other rest of treatments. The minimum grain yield (44.04 q ha^{-1}) was observed with control followed by the other treatments. Straw yield (61.56 q ha^{-1}) was observed significantly higher in Zn-EDTA treatments as compared to $ZnSO_4.7H_2O$, $ZnSO_4.H_2O$ and control. Zn application invariably enhanced translocation of photosynthates which was responsible for realization of higher grain and straw yields confirm the findings of Tripathi and Tripathi (2004). The minimum straw yield (52.04 q ha^{-1}) was examined in case of control plot followed by the other treatments. Chelated Zinc showed high solubility and stability of Zn and the increased the movement of Zn ions in to the plants to increase the grain yield. The favourable influenced of applied Zn on yield may be due to its catalytic or stimulatory effect on most of the physiological and metabolic process of plants. These results

Table 1. Physico-chemical properties of soil of experimental field

Properties	Measured value	Properties	Measured value
Textural class	Sandy clay loam	EC (dSm^{-1}) at 25^{0}C	0.245
Sand (%)	50.51	CEC (C mole kg^{-1} P)	11.94
Silt (%)	25.83	Organic carbon (%)	0.41
Clay (%)	22.64	Available N (kg ha^{-1})	198.05
Bulk density (gcm^{-3})	1.45	Available P_2O_5 (kg ha^{-1})	23.64
Particle density (gcm^{-3})	2.63	Available K_2O (kg ha^{-1})	207.5
pH	7.25	Available Zinc (ppm)	0.50

Table 2. Effect of crop establishment method and Zn fertiliser sources on the grain and straw yields, harvest index, nutrient uptake in grain and straw of rice

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)	Nutrient uptake (kg ha^{-1})							
				N uptake (kg ha^{-1})		P uptake (kg ha^{-1}		K uptake (kg ha^{-1})		Zn uptake (g ha^{-1})	
				Grain	straw	Grain	straw	Grain	straw	Grain	straw
(A) Method of Crop Establishment											
SRI	51.95	60.96	46.42	46.55	26.58	13.25	9.45	13.11	91.40	183.42	756.62
Wetland	49.53	56.73	46.41	44.98	26.24	12.79	8.82	13.23	89.72	146.15	699.61
Farmer's practice	47.67	54.83	46.33	44.50	26.21	12.58	8.73	13.75	87.96	134.40	659.30
SEm±	0.32	0.78	0.40	2.48	0.88	1.43	0.50	0.72	5.50	7.09	12.68
CD (P=0.05)	1.25	3.04	NS	NS	NS	NS	NS	NS	NS	27.84	49.78
(B) Different Sources of Zn											
Control	44.04	52.04	45.84	41.29	25.39	12.16	8.39	12.89	84.71	107.02	550.78
Zn-EDTA (12% Zn)	54.31	61.56	47.10	48.60	27.23	13.64	9.49	13.71	93.21	195.94	828.71
ZnSO4.H2O (33% Zn)	48.59	57.26	45.88	44.97	26.16	12.82	9.28	13.33	89.33	149.42	700.55
ZnSO4.7H2O (21 %Zn)	51.92	59.17	46.72	46.51	26.60	12.88	9.39	13.52	91.52	166.26	740.67
SEm±	0.26	0.65	0.35	2.44	1.08	1.45	0.65	0.73	4.83	5.57	10.23
CD(P=0.05)	0.77	1.94	NS	NS	NS	NS	NS	NS	NS	16.56	30.39

M_1-SRI, M_2-Wetland, M_3- Farmer's practice, Z_0-Control, Z_1 - Zn-EDTA, Z_2-$ZnSO_4.H_2O$ and Z_3-$ZnSO_4.7H_2O$

corroborate with those reported by Mandal *et al*. (2009.). There was found no significant differences in harvest index among rest of all the Zn fertilizer sources, Zn–EDTA chelated Zn was found most significantly influenced on yield attributes. The application of $ZnSO_4.7H_2O$ was second best treatment on yield attributes of rice after EDTA-chelated Zn. The performance of Zn sources in terms of crop establishment methods and various source of Zn were in the following order; EDTA-chelated Zn > $ZnSO_4.7H_2O$ > $ZnSO_4.H_2O$.

Nitrogen uptake (kg ha^{-1})

Data of the present study, the data presented in Table-2 revealed that the values of nutrient uptake followed by the patterns of yield obtained in different treatments. The various method of crop establishment was found no significant effect on N uptake in grain and straw (kg ha^{-1}). The maximum N uptake was evaluated in grain (46.55kg ha^{-1}) and straw (26.58 kg ha^{-1}) with SRI method of transplanting as compared to other method of transplanting. The minimum N uptake was recorded in grain (44.50 kg ha^{-1}) and straw (26.21 kg ha^{-1}) with Farmer's practice. Data pertaining to revealed that the N uptake in grain and straw (kg ha^{-1}) was recorded no significant responses under sub plot treatments results was also conformity with the work of Thakur *et al*., 2013. The maximum N uptake was observed in grain (48.60 kg ha^{-1}) and straw (27.23 kg ha^{-1}) with Zn – EDTA treatment applied @ 1.0 (kg Zn ha^{-1}) half as basal and half as foliar spray (0.5%) as compared to rest of the treatment. Thus, the beneficial effect of zinc on photosynthesis and metabolic process auguments the production of photosynthates and their translocation to different plant parts including grain which ultimately increased the uptake of nitrogen in grain and straw. Similar results were also found by Singh and Bhatt, 2013.

Table 3. Economics of treatment combinations

S. No.	Treatment	Total cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
1	M_1Z_0	30983.66	75664.17	44680.51	1.44
2	M_1Z_1	36423.66	92608.03	56184.37	1.54
3	M_1Z_2	33683.54	83697.43	50013.89	1.48
4	M_1Z_3	34583.66	87467.08	52883.42	1.52
5	M_2Z_0	33593.66	72664.33	39070.67	1.16
6	M_2Z_1	39033.45	87961.67	48928.22	1.25
7	M_2Z_2	36293.66	78805.83	42512.17	1.17
8	M_2Z_3	37193.45	84784.17	47590.72	1.27
9	M_3Z_0	35453.72	68417.50	32963.78	0.92
10	M_3Z_1	40893.24	84733.33	43840.09	1.07
11	M_3Z_2	38153.72	76516.67	38362.95	1.0
12	M_3Z_3	39053.72	81610.00	42556.28	1.08

M_1-SRI, M_2-Wetland, M_3- Farmer's practice, Z_0-Control, Z_1 - Zn-EDTA, Z_2-$ZnSO_4.H_2O$ and Z_3-$ZnSO_4.7H_2O$
Sale price of rice grain = Rs. 13.45 kg^{-1}, Sale price of rice straw = Rs. 2.50 kg^{-1}

Phosphorus uptake (kg ha^{-1})

It is clear from the data; Maximum phosphorus uptake was marked in grain (13.25 kg ha^{-1}) and straw (9.45 kg ha^{-1}) in case of SRI method of transplanting with rest of other treatments (Table-2). The minimum Phosphorus uptake was revealed in grain (12.58 kg ha^{-1}) and straw (8.73 kg ha^{-1}) under Farmer's practice method of transplanting. There was also found no significant responses in case of P uptake in grain and straw (kg ha^{-1}) with various sources of zinc application but maximum P uptake was examined in grain (13.64 kg ha^{-1}) and straw (9.49 kg ha^{-1}) under the Zn- EDTA treatments as compared to rest of the treatments. Phosphorus uptake first increased due to increase in yield but at the higher levels of zinc, it decreased due to reduced p content in the grain and straw. The decrease in p uptake with higher dose of zinc might be due to antagonistic effect between P and Zn. These results are in conformity with the results obtained by Sadeghzadeh, 2013.

Potassium uptake (kg ha^{-1})

There was found also no significant marked variation in K uptake in grain and straw (kg ha^{-1}). The maximum K uptake was quantified in grain (13.75 kg ha^{-1}) and straw (87.96 kg ha^{-1}) in case of Farmer's practice method of transplanting as compared to rest of other treatments (Table-2). The minimum K uptake was recorded in grain (13.11 kg ha^{-1}) and straw (91.40 kg ha^{-1}) under SRI method of transplanting as compared to rest of the treatments. These results are in line with the findings of Prasad *et al.*, 2010.

Similarly, No significant difference was analysed with various sources of zinc in case of K uptake in grain and straw (kg ha^{-1}). The maximum K uptake was quantified in grain (13.71 kg ha^{-1}) and straw (93.21 kg ha^{-1}) with application of Zn-EDTA @ 1.0 kg Zn ha^{-1} as compared to rest of the treatments. The minimum K uptake was closed in grain (12.89 kg ha^{-1}) and straw (84.71 kg ha^{-1}) in case of control plot followed by the other treatments. Increased accumulation of nutrients in vegetative plant parts with improved metabolism led to greater translocation of these nutrients to reproductive organs of the crop and ultimately increased the contents in grain and straw. These results are in conformity with the results obtained by Singh *et al*., 2012. Increased uptake of N, P, and K seems to be due to the fact that uptake of nutrient is a product of biomass accumulated by particular parts and its nutrient content.

Zn uptake (g ha^{-1})

Data pertaining to Zn uptake in grain and straw (g ha^{-1}), the maximum Zn uptake was observed significantly higher in grain (183.42 g ha^{-1}) and straw (756.62 g ha^{-1}) with SRI methods of transplanting as compared to other crop establishment methods (Table-2). The minimum Zn uptake was evaluated in grain (134.40 g ha^{-1}) and straw (659.30 g ha^{-1}) under Farmer's practice method of transplanting. These results confirm the findings of Karak *et al.* (2006).

The application of Zn as $ZnSO_4.7H_2O$ @10 kg ha^{-1} revealed that the effect of integration was apparent with increasing levels of integration and thus by integration of maximum input resources i.e. inorganic and organic fertilizers along with bio- fertilizers and micronutrients, could improve the NUE of N, P, K and Zn in rice (Sahu *et.al.,* 2014). It is clear from the data, The Zn uptake was found significantly superior in grain (195.94 g ha^{-1}) and straw (828.71 g ha^{-1}) with Zn-EDTA treatments as compared to rest of the treatments and minimum Zn uptake was recorded in grain (107.02 g ha^{-1}) and straw (550.78 g ha^{-1}) in case of the control plot followed by the other treatments. The results of present study are in agreement with the finding of Ishimaru *et al.* (2011). The positive influenced of Zn application on nutrient content and uptake in the crop appears owing to improved nutritional level both in the root zone and plant system. The increased availability of these nutrients in root zone coupled with increased metabolic activity at cellular level might increase nutrient uptake and their accumulation in vegetative plants parts results was also supported by Farooq *et al*., 2012 he reported that micronutrient application helps in its uptake of nutrient both in roots and shoots of the plant. The application of ZnSO4.7H2O was second best treatments on Zn uptake in rice grain and straw, respectively.

Economics

Acceptation of any advanced agro-technique by the farmers directly depends on economic status of the farmer and economic feasibility of the technique. Therefore, it is essential to analyze the results from the economic point of view. The cost of cultivation, gross return, net return and output- input ratio were worked out and the data are presented in (Table-3). The gross returns, net returns, and benefit: cost ratio of rice was influenced significantly by various crop establishment method and different source of Zn. It is clear from the data, the total cost of cultivation (Rs. 40893.24 ha^{-1}) was observed maximum with M_3Z_1 (Farmer's practice + Zn-EDTA) treatments followed by rest of the treatments. The minimum total cost of cultivation (Rs. 30983.66 ha^{-1}) was analysed with M_1Z_0 (SRI + Control) followed by other treatments. The maximum gross returns (Rs. 92608.03 ha^{-1}) was examined with M_1Z_1 (SRI + Zn-EDTA) treatments as compare to other treatments. The minimum gross returns (Rs. 68417.50 ha^{-1}) was revealed in M_3Z_0 (Farmer's practice + Control) followed by rest of the treatments. In case of net returns, the highest net returns (Rs. 56184.37 ha^{-1}) was found in M_1Z_1 (SRI + Zn-EDTA) followed by other treatments. The minimum net returns (Rs. 32963.78 ha^{-1}) was examined with M_3Z_0 (Farmer's practice + Control) and the maximum benefit: cost ratio (1.54) was noticed under M_1Z_1 (SRI + Zn-EDTA) treatments followed by rest of the treatments. The lowest benefit: cost ratio (0.92) was recognised in case of M_3Z_0 (Farmer's practice + Control).

Hence, it may be concluded that growing of the rice crop with incorporation of 1.0 kg (Zn-EDTA ha^{-1}) in conjunction with SRI method of transplanting holds great promise for increase production and productivity of rice crop.

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