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EFFECT OF DIFFERENT MODES OF ZINC APPLICATION WITH NPK ON RICE AND SOIL FERTILITY STATUS IN SUB-HUMID VINDHYAN PLATEAU REGION

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ABSTRACT

Field experiment was conducted in sandy loam soil to study the effect of RDF along with zinc application in rice (*Oryza sativa*) summer (*kharif*) season of 2020 at Shivrampur village of *Kaimur* district. The maximum grain yield of rice was found in T_3 (RDF + soil application of zinc sulphate heptahydrate) followed by treatment T_2 (RDF (N:P:K:: 100:40:20 + foliar spray of zinc sulphate monohydrate: 2.5 kg zinc + 2.5 kg lime ha^{-1}) which had 17 and 15% higher yield, respectively over farmers' practice (N:P:K:: 130:50:25). As compared to the soil properties in T_1 (Farmers' Practice), pH did not change, while EC increased with the application of RDF along with soil application of zinc and foliar spray of zinc. Organic carbon content in soil increased significantly by RDF with soil application of zinc with RDF along with foliar spray of zinc. Differential pattern of nutrients buildup was recorded with respect to post harvest rice soil. Application of RDF with soil application of zinc increased Zn in soil.

(Key words : Foliar application, inorganic fertilizer, nutrient management, soil fertility, Oryza, zinc)

INTRODUCTION

Rice is the most important staple food crop for more than half of the world's population, providing 21% of the total calorie intake (Singh *et al.,* 2017a). In India, it occupies an area of 43.8 million ha and a production of 105 million tonnes (mt), with average productivity of 2.21 t ha^{-1} (Kumar *et al.,* 2016a). Demand for rice growing is increasing every year, and it is estimated that by 2025 AD, its requirement would be 140 mt (Kumar *et al.,* 2016b). To sustain the present food self-sufficiency and to meet the future food requirement, India has to increase rice productivity by3% annum^{-1} (Kumar *et al.,* 2016c).The conventional method of crop establishment in rice is manual transplanting of seedling into puddled soil. It requires a large amount of water, energy, labour, which are becoming increasingly scarce and expensive (Bohra and Kumar, 2015). Moreover, continuous puddling of rice fields over decades has led to the deterioration of soil physical properties, through structural breakdown of soil aggregates, capillary pores and clay dispersion, thereby restricting germination and rooting of succeeding crops (Mandal *et al.,*2011; Roy *et al.,* 2011), due to loss of organic matter which bind the soil particles to form aggregates.

The productivity of rice has been stagnant, mostly because of inadequate and imbalanced supply of plant nutrients. The erratic rainfall due to climate change (Kanwal *et al.,* 2019) and poor economic status of the rice farmers are major causes of low dose of fertilizers. Under certain situation, cost of cultivation exceeds the net realization, making it an un profitable. Yield enhancement has been the major challenge (Kumar *et al.,* 2018) which has to come through increased productivity in the back backdrop of imbalanced nutrition (Tiwari *et al.,* 2020). Apart from many improved production technologies, imbalanced use of chemical fertilizers leading to the emergence of multiple nutrient deficiencies are major constraints in achieving higher yield (Rai *et al.,* 2016). As per All India Coordinated Research Project (AICRP) on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (Shukla *et al.,* 2016), 39.9% of 169,290 soil samples collected from all over the country and 32.4% of 8,072 samples from Uttar Pradesh are deficient in available Zn. However, latest estimate (Shukla *et al.,* 2018) showed a decline in Zn deficiency (36.5%) in Indian soils. Proper Zn nutrition of the crop is needed for maintaining crop and productivity (Cakmak, 2004). Cereals contain high Zn in grain when grown on soils having high content of plant available Zn (Fauzdar and Sharma 2013). In order to achieve desirable quantities of grain. Zn concentration in rice for human nutrition, rice requires more Zn in soil than it needs for maximal grain yield. Soil and foliar application of zinc significantly enhanced grain yield

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and zinc concentration in grain over farmer's practice in rice (Mabesa *et al.,* 2013).

Nutrient management should be aimed at achieving the main goal of sustainable productivity (Rai *et al.,* 2014, Rani *et al.,* 2015). Enhancing the productivity of rice in this region for achieving sustainable yield increases to meet the growing demand of the population and for this the rescheduling of NPK along with zinc fertilizers have been conceptualized wherein lowland rice-growing soils. The rescheduling NPK and zinc is an effective nutrient management technology for increasing the productivity of rice and nutrient- use efficiency (Ezung *et al.*, 2020). It is not only for obtaining higher yield but also a cost-effective nutrient-management technique of lowland rice farmers. The site-specific nutrient management system is lacking in the region. Therefore, this study was undertaken to evaluate the right scheduling of NPK and zinc on growth and yield of rice.

MATERIALS AND METHODS

Present investigation was conducted, at Shivrampur village of Kaimur District. The experimental site lies between 25°08' N latitude and 83°37' E longitudes. The site falls under sub-humid tropics with an average annual rainfall of 1177 mm and a mean annual air temperature of 29°C. Out of total annual rainfall, about 80 per cent is received from South-West monsoon (June to September), while the rest from North-East monsoon (October and November). Agro-ecologically, the study region lies in Vindhya plateau region (Zone-III (A)) having sub-humid climate.Data regarding initial characteristics of the experimental soil are presented in Table 1. The soil of the experimental site is clayey in texture (TypicHaplusterts) with 25.2, 18 and 56.8 per cent of sand, silt and clay, respectively. Initially, the soil (0 to 15 cm depth) was low in soil organic carbon (2.93 g kg^{-1}), low in available N (189 kg ha^{-1}), medium in available P (21kg ha^{-1}) and medium in available K (135 kg ha^{-1}) (Table 1). The soil was slight alkaline in reaction (pH 7.76) with 0.31dS m^{-1}electrical conductivity.The experiment was conducted in randomized block design with three treatments in eight replications. The experiment consisted of Farmers' Practice (N:P:K:: 130:50:25), RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}), RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1} as T_1, T_2, and T_3, respectively.The soil samples were collected after the harvest of rice crop from each experimental plot from 0-15 cm depth. The soil was mixed thoroughly and samples of about 0.5 kg were obtained by quartering technique and stored in neatly labelled polythene bags for further soil analysis. The post-harvest soil samples were analyzed for pH in 1:2.5 soil: water suspension (Jackson, 1973); organic carbon by methods of Walkley and Black (1934); available N by alkaline potassium permanganate (Subbiah and Asija 1956); $NaHCO_3$ extractable- P (Olsen *et al.,* 1954) by spectrophotometer, ammonium acetate extractable K (Hanway and Heidel, 1952) by flame photometer and DTPA extractable Zn (Lindsay and Norwell, 1978) following the procedure outlined by Sparks (1996).At harvesting stage of rice plant, observations on plant height, number of tillers per m^2, number of effective tillers per m^2, panicle length, grains $panicle^{-1}$ were recorded. The harvested crop from each plot was bundled separately and sun-dried for 4 days, weighed and threshed. The threshed grains were cleaned and sun dried to a constant weight before recording the grain yield (t ha^{-1}). After the straw yield was obtained as difference between net bundle weight and threshed grain weight (t ha^{-1}).Harvest Index was calculated according to the following formula: Harvest index (%) = Grain yield / Biological yield × 100. The B:C ratio was calculated as the ratio of gross return (Rs ha^{-1}) to the cost of cultivation (Rs ha^{-1}).

RESULTS AND DISCUSSION

Growth parameters

The plant height at harvest was significant among farmer's practice and RDF along with application of zinc (Table 2). The number of effective tillers increased significantly, minimum being in the farmer's practice and the maximum (184.88) in RDF + foliar application of zinc at harvest, which was 15% higher over the farmer's practice. Saha *et al.*(2013) also reported that soil + foliar application of Zn was more effective in increasing plant height over farmer's practice. Ezung *et al.* (2020) reported that the application of 100% recommended dose of nitrogen through vermicompost had significantly increased plant growth, dry weight of crops, LAI of rice.

Yield parameters

The highest panicle length (22.73 cm) was recorded with the application of RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1} followed by RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}) (22.50 cm) which was 9 and 7% increased over farmer's practice (20.93 cm). Application of RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1} was recorded maximum grains $panicle^{-1}$ (90.50) which was significantly 13% increased over farmer's practice (79.88).Grain yield of rice increased significantly (Table 2), the maximum was in RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1} which yielded 17 and 2% higher than RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}), and farmer's practice, respectively. Rice grain yields recorded under treatments RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1} and RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}) were statistically similar (Table 2). The straw yield was maximum in RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1} which was about 16% higher than that in the farmer's practice. The treatment RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1} and RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}) increased the straw yield by 16 and 12%, respectively over the farmer's practice. It has been observed (Table 3) that application of Zn by more than one method had higher grain yield than with any one mode of application. It appears that regular supply of Zn is maintained throughout the life cycle of rice through conjoint application RDF which may be considered as a probable explanation for a greater number of productive tillers hill^{-1} and higher Zn uptake resulting increased grain yield. Imran *et al.*(2015) reported that the grain weight seed^{-1} was 32% greater over control when Zn is applied with soil + foliar application followed by sole zinc application to soil and foliage, respectively.He also reported an increase of 28% straw yield in soil+foliar application of Zn followed by 22% increased with soil Zn application alone. Das *et al.* (2019) reported that the maximum grain yield was obtained when Zn was applied by all the three methods RDF+soil application +root dipping +foliar spray followed by RDF+ root dipping +foliar spray.

The data (Table 2) revealed that a significant effect on the harvest index was observed among the RDF with application of foliar spray of zinc and RDF with soil application of zinc treatment. The highest 1000 grain weight (22.59 g) was recorded (Table 2) for the RDF with the application of foliar spray of zinc and RDF along with zinc application of soil as the amount of 21.26 g, which was the second highest treatment. The combined application of Zn with organic manures and foliar application with respect to increment in plant growth, yield and productivity was also reported by Yashona *et al.* (2018).

Soil chemical parameters

Application of RDF with foliar spray of zinc and RDF with soil application of zinc sources did not affect significantly soil pH and electrical conductivity (Table 3). A significant increase in organic carbon content (Table 3) with the application of RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1}(4.60 g kg^{-1}) and RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}) (4.23 g kg^{-1}) as compared to farmer's practice (3.33 g kg^{-1}) was recorded. The increase in N content with RDF along with soil application of zinc and RDF along with foliar spray of zinc was 30 and 27%, respectively, over the farmer's practice. The soil-available P increased by 78 and 56% for RDF with soil application of zinc, RDF + foliar spray of zinc fertilizer, respectively over the farmer's practice. Significantly higher concentration of available P in RDF with zinc fertilizer might be attributed to higher addition through zinc fertilizer with RDF (RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1}). The lowest K content in soil was in the farmer's practice and the highest in RDF with the soil application of zinc fertilizer. The K content in soil under RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1}, RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}) was increased by 18 and 7% higher over the farmer's practice, respectively. The maximum Zn content was observed in RDF + soil application of zinc being 109 % higher over the farmer's practice. The high concentration of Zn in RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1}might be due to the soil application of zinc sulphate heptahydrate @ 25 kg ha^{-1}. Gour *et al.* (2015) reported that high concentration of Zn in RDF + S-Zn-B might be due to the application of $ZnSO_4$ @ 5 kg ha^{-1}. Higher content of Zn in soil might be due to higher content of these metals in sewage sludge and also due to chelation of these metals by organic matter. A significant change in soil fertility in one season observed under present study may be attributed to the reduced condition prevailing under rice cultivation during *kharif* season.

Economics

Treatment T_2 RDF (N:P:K: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}) showed higher B:C ratio (4.26) compared to all other treatments (T_1 and T_3), but the net return in T_3 (RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1}) was also higher than RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1}) (T_2) and farmer's practice (T_1) (Table 4). Singh *et al.* (2017a) also reported that application of RDF along with micronutrient gave maximum net return and B:C ratio. Jondhale*et al.* (2021) also reported that the management of zinc nutrition helped to acquire higher net return, gross return and benefit:cost ratio.

Based on this study it can be concluded that the application of RDF along with foliar application of zinc fertilizer (2.5 kg zinc + 2.5 kg lime ha^{-1}) had very beneficial effect on the growth and grain yield of rice. Foliar application of the zinc does not only reduce the amount of the inorganic fertilizer load in the soils but also improves the fertilizer use efficiency. It is therefore, recommended that there is needed to apply the recommended dose of fertilizer and micronutrients as zinc on the basis of soil test.This study also provides some indication that the higher economic gain is linked to the foliar application of the nutrients through reduction in the cost of fertilizers. The judicious use of inorganic fertilizer with efficient application technology not only reduce the negative impact on Indian economy while intricating the main goal of achieving sustainable development. Future studies should investigate the mechanism by which foliar applied nutrients may help in biofortification and the right time and amount of the foliar application with varied doses of fertilizers for effectiveness of their use in the field are needed to promote evergreen agriculture.

Table 1. Initial physical and chemical properties of experimental soil (0-15 cm)

Properties	Value
Sand (%)	23.6
Clay (%)	22.0
Silt (%)	54.4
pH(1:2)	7.66
EC(1:2) dS m^{-1}	0.38
Organic carbon (g kg^{-1})	2.93
Available N (mg kg^{-1})	189
Available P (mg kg^{-1})	21
Available K (mg kg^{-1})	135
Available Zn (mg kg^{-1})	0.31

Table 2. Effect of application of RDF along with zinc on plant height at harvest, no. of tillers, panicle length, grains panicle^{-1}, grain yield, straw yield, harvest index and test weight in rice

Treatments	Plant height at harvest (cm)	No. of tillers m^{-2}	No. of effective tillers m^{-2}	Panicle length (cm)	Grains panicle^{-1}
Farmers' Practice (N:P:K:: 130:50:25)	87.16	190.88	164.38	20.93	79.88
RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1})	95.39	210.25	182.25	22.50	89.50
RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1}	97.91	213.50	184.88	22.73	90.50
SE(m)±	0.436	1.654	1.805	0.182	0.521
CD (5%)	1.299	4.923	5.379	0.544	1.558

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)	Test weight (1000 grain wt.) (g)
Farmers' Practice (N:P:K:: 130:50:25)	5.58	5.86	48.74	19.86
RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1})	6.43	6.59	49.38	21.26
RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg/ha	6.55	6.81	49.02	22.59
SE(m)±	0.150	0.135	0.162	0.212
CD (5%)	0.447	0.402	0.483	0.632

Table 3.Effect of application of RDF along with zinc on post-harvest soil of pH, EC, OC, N, P, K and Zn in rice

Treatments	pH	EC (d S m^{-1})	OC (g kg^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Zn (mg kg^{-1})
Farmers' Practice (N:P:K:: 130:50:25)	7.50	0.34	3.33	171	23	117	0.21
RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1})	7.98	0.37	4.23	217	36	125	0.37
RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1}	8.00	0.33	4.60	222	41	138	0.44
SE(m)±	0.181	0.019	0.091	4.636	1.82	1.649	0.016
CD (5%)	-	-	0.264	13.815	5.405	4.914	0.047

Table 4.Effect of application of RDF along with zinc on economics in rice

Treatments	Yield (t ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
Farmers' Practice(N:P:K:: 130:50:25)	5.58	111216	429600	337360	3.86
RDF (N:P:K:: 100:40:20) + foliar spray of zinc sulphate monohydrate (2.5 kg zinc + 2.5 kg lime ha^{-1})	6.43	110916	472800	388680	4.26
RDF (N:P:K:: 100:40:20) + zinc sulphate heptahydrate 25 kg ha^{-1}	6.55	111204	468800	384430	4.21

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