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Influence of ZN-fertilization on nutrient uptake and soil nutrient dynamics in basmati rice (*O. sativa* L.)

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Abstract

Field experiment was conducted to evaluate the “Effect of zinc ferti-fortification on yield and quality of basmati rice (*O. sativa* L.) under subtropical region of Jammu” at Sher-e-Kashmir University of Agricultural Science and Technology, Chatha, Jammu during *kharif* season 2015. The experiment was laid out in randomized block design with 12 treatments and three replications. The nutrient uptake by rice crop in terms of N, P, K and Zn was significantly influenced by different Zn-fertilization treatments. Significantly highest N, P, K and Zn uptake by grain and straw was recorded with the application of 4% Zn through ZnSO₄.7H₂O coated urea + 0.2% Zn foliar spray (ZnSO₄.7H₂O) + recommended P₂O₅ and K₂O. The different zinc fortification treatments showed non-significant effect on soil fertility status after crop harvesting. Our results clearly indicated that application of 4% Zn through ZnSO₄.7H₂O coated urea + 0.2% Zn foliar spray (ZnSO₄.7H₂O) + recommended P₂O₅ and K₂O is excellent sources of N and Zn for vital for the nutrient turnover, which improved long-term productivity of Basmati rice.

Keywords: ZN-fertilization, nutrient uptake, soil nutrient dynamics, basmati rice, *O. sativa* L.

Introduction

Rice (*O. sativa* L.) is one of the most important cereal crops and is staple food for more than 50% of the world’s population (Fageria *et al.*, 2008) [2], whereas 90% of the global rice grown and consumed in Asia. Basmati rice is a geographical indicator of a special type of rice grown in South-Asia for its cooking quality parameters. Considering its uniqueness, good will among consumers and growers, and due to changing dietary needs, the demand for such rice is increasing every year in western countries, middle-East, and Asia. Basmati rice fetching premier prices in domestic as well as in international markets. As per an estimate, these cultivars covering maximum acreage under basmati rice grown in north-western Indian states, *i.e.* Haryana, Punjab, Western Uttar Pradesh, Jammu & Kashmir, Uttarakhand and Delhi (Pooniya and Shivay, 2013) [9].

The low availability of zinc (Zn) is one of the widest ranging abiotic stresses in rice-wheat growing belt throughout the world, especially in India and China. In India, its deficiency is more prevalent in rice-wheat belt of northern India. The general recommendation for rice-wheat system in India is soil application of 10-25 kg Zn through ZnSO₄.7H₂O. Several Zn products are available in the market but these are beyond the reach of farmers, resulting in reduced crop productivity. Some new sources of Zn like Zn-coated urea etc. are also alternative, which supply substantial amount of Zn to the plants without interacting with soil components. (Singh and Shivay, 2015) [13]. Foliar spray either through Zn sulphate or Zn-oxide is an alternative strategy to fortify seed with Zn and also helps in improving human and animal nutrition and health (Prasad *et al.*, 2014) [11]. Soils Zn application through ZEU (zinc-enriched urea) and foliar sprays are simple and effective solution to combat Zn deficiency in rice, which is inherently low in Zn content. Thus, ferti-fortification of rice through Zn fertilization is an economically viable strategy. As low soil Zn status is an important limiting factor responsible for poor nutrient uptake, it is imperative to evaluate the response of Zn nutrition on basmati rice productivity *vis-a-vis* its economics. Since not much work has been done to assess the response of promising basmati rice varieties to Zn fertilization irrespective of sources and methods, an experiment was conducted to evaluate the effect of zinc ferti-fortification on yield and quality of basmati rice (*O. sativa* L.) under subtropical region of Jammu.

Materials and Methods

Details of experimental field

The field experiment was conducted at Agronomy Research Farm of SKUAST-J, Chatha, site located at 32°40' N latitude and 74°58' E longitude with an altitude of 332 meters above mean sea level in the Shiwalik foothills of North-Western Himalayas. The soil of the experimental field was a sandy loam of pH 7.85 (1:2.5 soil: water ratio) with 0.43% of organic carbon (OC), alkaline KMnO₄-oxidizable-N 240.27 kg/ha, 0.5 M NaHCO₃-extractable P 12.82 kg/ha, and 1 N NH₄OAc-extractable K 143.62 kg/ha. Diethylene triamine pentaacetic acid (DTPA)-extractable zinc in soil was 0.56 ppm.

Experimental design and treatments

The experiment was laid out in randomized block design with 12 treatments and three replications. The treatments consisted of;

- T1: Recommended dose N, P₂O₅ and K₂O only (Control),
 T2: Control + 20 Kg. ZnSO₄.7H₂O soil applications,
 T3: 2% Zn through ZnO Coated Urea + recommended P₂O₅ and K₂O,
 T4: 2% Zn through ZnSO₄.7H₂O Coated Urea + recommended P₂O₅ and K₂O,
 T5: 4% Zn through ZnO Coated Urea + recommended P₂O₅ and K₂O,
 T6: 4% Zn through ZnSO₄.7H₂O Coated Urea + recommended P₂O₅ and K₂O,
 T7: 0.2% Zn Foliar spray (ZnO) + recommended dose N, P₂O₅ and K₂O,
 T8: 0.2% Zn foliar spray (ZnSO₄.7H₂O) + recommended dose N, P₂O₅ and K₂O,
 T9: 2% Zn through ZnO Coated Urea + 0.2% Zn foliar spray (ZnO) + recommended P₂O₅ and K₂O,
 T10: 2% Zn through ZnSO₄.7H₂O coated urea + 0.2% Zn foliar spray (ZnSO₄.7H₂O) + recommended P₂O₅ and K₂O,
 T11: 4% Zn through ZnO coated urea + 0.2% Zn foliar spray (ZnO) + recommended P₂O₅ and K₂O and
 T12: 4% Zn through ZnSO₄.7H₂O coated urea + 0.2% Zn foliar spray (ZnSO₄.7H₂O) + recommended P₂O₅ and K₂O.

For basmati-370 cultivar fertilizer was applied at the rate of 30: 20: 10 kg N: P₂O₅: K₂O/ha respectively, through simple urea, zinc coated urea (ZnSo₄.7H₂O & ZnO), DAP, SSP and MOP. Half dose of nitrogen, full dose of phosphorus, potassium and 20 kg ZnSo₄.7H₂O were applied as basal application at the time of puddling. Remaining dose of nitrogen was applied in one split dose at 30 DAT as per treatments. Zinc was also applied as foliar spray through zinc sulphate @ 0.2 % Zn and zinc oxide @ 0.2 % Zn at 40 DAT as per treatments. Twenty-eight-day-old seedling of rice variety 'Basmati 370' were transplanted at 20 X 10 cm spacing keeping 2 seedlings hill. Throughout the cropping seasons, the crop was kept under submerged conditions (5-6 cm standing water). Basmati rice was grown as per recommended practices and was harvested in the first fortnight of November.

Nutrient uptake

The grain of rice was also taken for uptake studies from each plot. The samples were oven dried, then finely ground with electric grinder and analyzed for nitrogen, phosphorus, potassium and zinc concentration. One gram grain and straw sample was digested in di-acid mixture of HNO₃ and HClO₄ in the ratio of 3:1 (Piper, 1966) [8].

The digested material was transferred to 100 ml. volumetric flask and the volume made with double distilled water. The solution filtered and analysed for P, K and Zn using spectrophotometer for P, flame photometer for K and atomic absorption spectrophotometer for Zn. Nitrogen was determined by Kjeldahl procedure. Nitrogen, phosphorus, potassium and zinc uptake in grain and straw samples were calculated by multiplying per cent nutrient content with their respective dry matter accumulation as per the formula given below:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{Grain and straw yield (kg/ha)}}{100}$$

Nutrient status

After harvesting of rice crop treatment wise samples from all the plots were taken from the surface (0-15 cm) for determination of available nitrogen, phosphorus, potassium and zinc. The samples were dried under shade, grounded and passed through 2 mm sieve and were used for analysis of available N, P, K and Zn.

Available nitrogen

Available nitrogen was determined by modified alkaline permanganate method as described by Subbiah and Asija (1956) [15] and was expressed in kg/ha.

Available phosphorus

Available phosphorus was determined using method described by Olsen *et al.* (1954) [7] and measured by ascorbic acid blue colour method at 420 mμ using spectrophotometer and was expressed in kg/ha.

Available potassium

Available K was extracted with neutral normal ammonium acetate solution as described by Jackson (1973) [4] and potassium was determined by flame photometer and expressed as K kg/ha.

DTPA-Zn

Available Zn was determined using with DTPA-extractant as described by Lindsay and Norvell (1978) [5]. The soil sample of 10 g was shaken with 20 ml of DTPA solution for two hours. The suspension was filtered in a polythene bottle and Zn was analysed by atomic absorption spectrophotometer and expressed as Zn ppm or mg/kg of soil.

Statistical analysis

All the data obtained Basmati rice were analyzed statistically using the F-test, as per the procedure given by Gomez and Gomez (1984) [3]. LSD values at P = 0.05 were used to determine the significance of difference between treatment means.

Results

Nutrient uptake

Different zinc fortification treatments showed significant influence with respect to nutrient uptake like N, P, K and Zn over the control (Table 1). The highest N, P and K uptake of rice grain and straw was recorded in T₁₂ treatment, which was statistically at par with T₁₁, T₁₀, T₂, T₉ and T₆ and significantly superior over rest of the treatments. In case of Zn uptake T₁₂ treatment gave superior result also and was found statistically at par with T₁₀ and T₁₁ only. Among the zinc fortification treatments, the lowest N, P, K and Zn uptake by grain as well as straw was recorded with control treatment.

Table 1: Effect of zinc ferti-fortification on N, P, K and Zn uptake in grain and straw of basmati rice

Treatments	Grain				Straw			
	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (g/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (g/ha)
T ₁	29.48	7.45	6.62	64.66	25.01	5.75	70.50	340.11
T ₂	37.94	9.81	9.84	101.32	32.41	7.48	103.57	550.49
T ₃	32.48	8.29	7.79	75.70	28.13	6.47	83.78	409.18
T ₄	33.62	8.65	8.39	84.22	29.45	6.77	89.23	454.37
T ₅	34.32	8.83	8.72	86.31	29.99	6.89	93.85	474.15
T ₆	35.32	9.09	9.21	92.78	31.64	7.16	99.94	504.54
T ₇	33.35	8.58	8.44	90.55	29.08	6.69	89.22	488.79
T ₈	34.24	8.81	8.71	97.01	30.00	6.84	93.21	528.84
T ₉	35.90	9.24	9.52	102.37	31.04	7.14	101.30	551.09
T ₁₀	38.00	9.77	9.91	114.24	32.32	7.43	103.85	595.79
T ₁₁	38.51	9.88	10.10	110.15	32.93	7.53	106.20	588.59
T ₁₂	40.09	10.32	10.89	125.99	34.20	7.86	114.04	666.04
SEm (±)	1.71	0.43	0.59	6.23	0.89	0.27	5.34	28.59
LSD (p=0.05)	5.01	1.27	1.73	18.28	2.61	0.79	15.66	83.84

Available nutrients

The available soil nutrient status data presented in Table 2 reveals that zinc fortification treatments had not significant influence on the available N, P, K and Zn content of soil after harvest of rice crop. Numerically highest available N, P, K

and Zn also in soil were recorded with treatment T₁₂ with their corresponding values of 243.23, 13.48, 136.31 kg/ha and 0.60 mg/kg of soil, respectively and lowest values was observed under control.

Table 2: Effect of zinc ferti-fortification on available N, P, K and Zn after harvest of basmati rice

Treatments	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (mg/kg)
T ₁	232.95	11.87	128.08	0.55
T ₂	240.56	13.20	134.31	0.60
T ₃	234.85	11.94	129.28	0.57
T ₄	236.29	12.60	131.35	0.59
T ₅	236.65	12.66	132.52	0.59
T ₆	238.10	13.25	135.22	0.58
T ₇	234.14	11.89	128.74	0.56
T ₈	234.81	11.95	129.14	0.56
T ₉	236.08	12.01	130.80	0.57
T ₁₀	239.65	12.73	133.05	0.58
T ₁₁	240.40	12.93	134.42	0.59
T ₁₂	243.23	13.48	136.31	0.60
SEm (±)	5.06	0.62	4.48	0.03
LSD (p=0.05)	NS	NS	NS	NS
Initial status	240.27	12.82	143.62	0.56

Discussion

Nutrient uptake

Nutrient uptake being functions of dry matter production and partly due to increase in nutrient concentration. It is apparent from the Table 1 that highest total uptake of N, P, K and Zn was recorded with T₁₂ and the lowest uptake with T₁. Results might be due to increased concentrations of the nutrients in rice grain and straw and also increased yield of rice grain and straw. Synergistic effect of Zn and N are mainly attributed to increased availability of Zn in soil due to acid forming effect of N (Prasad, 2005) [5]. Zn fertilization also significantly affected P uptake in grain and straw of rice. This might be due to increase in the N levels in plants due to ZnSO₄·7H₂O coated urea and higher yields of Basmati rice which finally led to increased higher total P uptake. These results are in conformity with the findings of Pooniya and Shivay, 2013 and Shivay *et al.*, 2015 [9, 13]. Application of Zn-coated urea had the advantage of split application and banding of Zn close to the growing rice plants, which increased its uptake before applied Zn reacted with water and CO₂ in soil solution and converted it to ZnCO₃, which makes it less available to plants as pointed out by Yoshida *et al.*, 1971. Nayyar *et al.* (1990) [16, 6] also showed that ZnO was inferior to ZnSO₄. The foliar application of zinc sulphate solution resulted in significant

increase in Zn concentration and uptake (Dhaliwal *et al.*, 2010) [1].

Nutrient status

The data presented in Table 2 reveals that the zinc fortification treatments had non-significant effect on available N, P, K and Zn content of soil after harvest of rice crop. This might have happened due to the higher growth and development of rice plants with all Zn application treatments resulting into higher root biomass production, which recycled these nutrients into the soil. Pooniya *et al.* (2012) [10] also reported the similar findings.

Conclusion

Our year field study clearly demonstrated the significant beneficial effects of N and Zn through ZEU was better sources of nutrient uptake by Basmati rice (grain + straw), which also improved soil quality in Basmati rice field. This is an important finding for increased nutrient recycling and sustaining soil fertility for long-term productivity of Basmati rice.

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