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Effect of zinc application on its fractions and their Contribution in plant zinc uptake in rice (*Oryza* sativa)

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ABSTRACT

A green house experiment was conducted at Raja Balwant Singh College Bichpuri, Agra to study the effect of zinc application on its fractions in soil and their relationship with yield, content and uptake of zinc in rice (Oryza sativa). The experiment was laid out in factorial randomized design with five levels of zinc (0, 2.5, 5.0, 7.5 and 10.0 mg kg^{-1}) and four replications. The rice crop responded significantly to zinc application and superiority of 5 mg Znkg^{-1} was well established. The content and uptake of zinc by crop were also increased significantly with its application. All the fractions of zinc studied increased significantly with its application in post harvest soil. Dry mater yield and plant zinc content were significantly correlated with almost all the forms of zinc in soils. The uptake of zinc by the crop was significantly correlated with WSEX, OC and AMOX fractions of zinc. Significant positive correlation was observed between WSEX – Zinc and plant zinc uptake, plant zinc concentration and dry matter yield suggesting that water soluble plus exchangeable zinc fraction is of great importance in zinc nutrition of rice.

Keywords: Zinc, fractionations, zinc, uptake, yield, rice

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important cereal food crop for more than half of the worlds' population. Rice is usually grown in soils under flooded condition. Rice is more responsive to zinc as it is essential element for plant growth and metabolism. The availability of this nutrient to plants is governed by dynamic equilibrium involving these different forms rather than its total content per se in soil. Widespread occurrence of zinc deficiency in rice soils suggests that both native and applied zinc react with inorganic and organic phases in the soil and thereby affect its availability. When zinc is applied to the soil from external sources to correct its deficiency it undergoes transformation to various chemical forms, the nature and magnitude of which, however, may differ in different soils depending upon their properties and associated environmental conditions. The amount and rate of transformation of these forms determine the rate of the labile zinc pool. The normal yield of crops could not be achieved despite judicious use of NPK fertilizers due to deficiency of micronutrients in soil in general and that of zinc in particular. Plants absorb zinc from soil solution which is replenished by various zinc fractions. Therefore, for sustained agricultural productivity on a long term basis, proper appraisal of different zinc forms and their relationships with Zn uptake on crops is essential. Hence the present investigation was carried out to study the effect of zinc application on Zn fractions in alluvial soil and their influence on plant uptake of zinc.

MATERIALS AND METHODS

A green house experiment was conducted at Raja Balwant Singh College Bichpuri Agra during kharif season using rice as test crop. The soil used in experiment was sandy loam in texture having pH 8.0, organic carbon 3.3 g kg^{-1}, available N 85 mg kg^{-1}, available P 5.2 mg kg^{-1}, available K 65 mg kg^{-1} and DTPA Zn 0.56 mg kg^{-1}. The experiment was conducted in factorial ramdomized design with four replications. The required earthen pots of similar size and shape were selected, cleaned and lined with polythene sheets. After mixing the soil-lot thoroughly, five kg soil was filled in the pots. Zinc was applied through zinc sulphate. The basal dose of nitrogen, phosphorus (P_2O_5) and potassium (K_2O) at the rate of 75 mg N kg^{-1}, 30 mg P_2O_5 kg^{-1}, and 30 mg K_2O kg^{-1} were applied through urea, di-ammonium phosphate and muriate of potash, respectively at the time of transplanting. At appropriate moisture level, the soil of each pot was pulverized and transplanted with 5 paddy seedlings (Pant 10) in first week of July. The pots were irrigated with deionized water. Moisture level was maintained at submergence by daily adjustment. The plants were allowed to grow up to 45 days after planting. After harvesting, dry matter yield was recorded. The harvested plants were washed with distilled water and rinsed twice with double glass distilled water before drying in an oven at 70°C. The plant samples were ground in willey mill. The finely ground material was then subjected to chemical analysis. The plants sample was digested with HNO_3 and $HClO_4$. Zinc was estimated in acid extract by atomic absorption spectrophotometer. The uptake of zinc by rice crop was calculated by multiplying content values with corresponding dry matter yield data. The soil samples collected after harvest of rice crop were analysed for zinc fractions by adopting standard procedures (Iwasaki and Yoshikawa 1990).

RESULTS AND DISSCUSSION

Yield

A study of Table 1 reveals that the dry matter yield of rice increased significantly with increase in zinc levels up to 7.5 mg Zn kg^{-1}. This increase in yield of the crop was significant for each level of zinc as compared to no zinc level (control). However, this increase in yield was statistically non-significant over 5 mg Zn kg^{-1} treatments. The increases in dry matter yield of rice due to 2.5,5.0and 7.5 mg Zn kg^{-1} soil over control were 12.5, 74.0 and 75.0%, respectively. Thereafter a reduction in yield was noted with 10 mg Zn kg^{-1} over 7.5 mg Zn kg^{-} This increase in dry matter yield of rice may be attributed to lower level of zinc content in experimental soil. Response of crop to zinc has also been reported by Singh and Singh (2017) and Pandey and Kumar (2017).

Zinc content

The zinc content in plants of the crop as affected by zinc application is presented in Table 1. The zinc content in rice crop significantly increased with zinc application over control. There was a gradual increase in Zn content with increasing levels of zinc and maximum values were recorded at 7.5 mg Zn kg^{-1} soil. The zinc content in rice plants increased from 24.0 mg kg^{-1} at control to 56.0 mg kg^{-1} at 7.5 mg Zn kg^{-1} soil. This increase in zinc content in crop may be attributed to increased availability of zinc as a result of its addition. Similar results were also reported by Varshney *et al.* (2008), Singh and Singh (2017) and Kandoli *et al.* (2016).

Table 1: Effect of added zinc on dry matter yield, zinc content and uptake in plants

Zinc levels (mg kg^{-1})	Dry matter yield (g pot^{-1})	Zinc Content (mg kg^{-1})	Zinc Uptake (µg pot^{-1})
0	2.00	24.0	48.00
2.5	2.25	34.5	77.62
5.0	3.48	49.0	170.52
7.5	3.50	56.0	196.00
10.0	3.35	50.6	169.51
SEm±	0.21	1.62	11.0
CD (P=0.05)	0.45	3.4	23.0

Zinc Uptake

A further study of Table 1 reveals that the uptake of zinc by the crop increased significantly with zinc addition over control. The maximum uptake values of zinc were noted at 7.5 mg kg^{-1}. The utilization of zinc by the crop increased significantly with increasing levels of zinc up to 7.5 mg kg^{-1}, the increase in Zn uptake by the crop was from 48.0µg at control to 196.0 µg per pot with 7.5 mg Zn kg^{-1} soil. Thereafter, a reduction in Zn uptake was recorded at 10mg Zn kg^{-1} soil. This increase may be ascribed to higher yield of crop as well as improvement in zinc content of the crop due to zinc addition. Similar results were also reported by Mishra *et al.* (2009) and Singh and Singh (2017).

Zinc fractions in soil

Data on amounts of various Zn fractions in soil after the harvest of rice crop are presented in Table 2. Increased Zn rates increased Zn in all fractions indicating that the transformation of applied Zn in to residual or mineral form in a short period of time is negligible. This residual fraction is considered to consist mainly of Zn present in primary and secondary silicate minerals or associated with refractory organic materials and is, therefore, extremely inert and completely unavailable to plants. The increase in the amounts of different fractions of Zn with increasing rates of Zn application was higher when Zn was added at 10 mg kg^{-1} soil. The increases in WSEX, MnOX, OC, AMOX and CRYOX-Zn fractions with 10 mg Zn kg^{-1} were from 0.14 to 0.50, 0.29 to 0.68, 1.02 to 2.00, 1.78 to 2.63 and 2.17 to 4.0 mg kg^{-1}, respectively. Thus, the maximum values of these fractions of Zn in soil after the harvest of crop were noted at 10mgZn kg^{-1} soil. Application of 10 mgZn kg^{-1} proved significantly superior to 2.5 and 5.0 mg Zn kg^{-1} levels in respect of various Zn fractions. The minimum values of these Zn fractions in soil after the harvest of crop were noted under no zinc treatment (control). Prasad *et al.* (1995) and Kandali *et al.* (2016) reported similar results.

Table 2: Effect of zinc levels on zinc fractions (mg kg^{-1}) in soil after harvest

Zn (mg kg^{-1})	WSEX	Mn OX	OC	AMOX	CRYOX
0	0.14	0.29	1.02	1.78	2.17
2.5	0.30	0.38	1.31	1.98	2.56
5.0	0.37	0.47	1.55	2.12	2.95
7.5	0.46	0.55	1.88	2.40	3.55
10.0	0.50	0.68	2.00	2.63	4.00
SEm±	0.07	0.10	0.1 9	0.20	0.26
CD (P= 0.05)	0.14	0.21	0.39	0.41	0.54

Availability of fractions

The WSES, OC, and AMOX fractions were positively and significantly correlated with zinc uptake by rice crop. The correlation coefficients were highest with OC-Zn for rice crop followed by those with WSES and fractions (Table 3).

Table 3: Linear correlation coefficients of zinc concentration uptake and dry matter yield with different zinc fractions

	Zn uptake	Dry matter yield	Forms of zinc				
			WSEX	OC	Mn OX	AMOX	CRYOX
Plant zinc	0.95**	0.92**	-0.61**	-0.36**	0.05	-0.35*	-0.61
Zn uptake		0.99**	-0.56**	-0.49**	0.27	-0.49*	-0.60
Dry matter yield			-0.46*	-0.44*	0.37*	-0.54*	0.64**

**and **significant at P > 0.05 and 0.01, respectively*

Prasad *et al.* (1995) also reported similar relationship. Organically bound Zn was positively correlated with Zn uptake and dry matter yield of rice. These results suggest that the complexed from of Zn is a major source of plant available zinc in soil and that Zn on exchange complex is also made available to plants (Prasad *et al.* 1995). The relationship between the residual Zn fraction and Zn uptake by the crop was not significant. The effect of OC-Zn on Zn uptake by rice was observed indicating that OC-Zn fraction was released due to reduction of Fe and Mn oxides leading to Zn availability to rice crop. These results suggest that organically bound Zn and occluded Zn are important sources of Zn for rice crop in alluvial soil treated with zinc levels. However, it may be noted that the rates of changes in equilibria are low especially under natural soil conditions. Zinc is taken up by plant from soil solution and the results indicate that the amount present in OC-Zn fraction was likely to be insufficient to maintain adequate plant growth under intensive cropping system. The equilibria postulated above indicate meant of replenishment of Zn in soil solution from soil Zn reserves. It is clear from size of different zinc fractions that bulk of soil zinc was located in alluvial soil treated with zinc levels.

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