RESEARCH PAPER | Agriculture | Volume : 3 | Issue : 5 | May 2013 | ISSN - 2249-555X

Response of Rice Genotypes to Zinc Fertilization in Typic Haplustert Soil

KEYWORDS: rice genotype, zinc, yield, zinc uptake, zinc use efficiency

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ABSTRACT *Zinc deficiency of lowlands rice has been identified as the major cause of low yield. A large population of the world as a result of this also lacks adequate zinc nutrition. A pot culture study was conducted on Kondal series Typic Haplusterts) deficient in zinc to evaluate the response of rice genotypes to zinc addition. Ten rice genotypes was tested at two (0, 5 mg kg^{-1}) levels of zinc. Genotypes differed significantly in grain yield, zinc uptake and zinc use efficiency due to zinc addition. The percent increase in grain yield ranged from 4.2 to 13.5 among rice genotypes on addition of 5 ppm Zn over control. Overall there was 5.75% increase in grain yield when 5 ppm Zn was applied. Similar effect was also noticed with respect to Straw. Zinc uptake among rice genotypes ranged from 422.7 to 2035 µg / pot due to 5 ppm Zn addition. . The percent increase in grain Zn uptake ranged from 46.49 to 94.7 and straw Zn uptake ranged from 31.4 to 50.99 among rice genotypes on addition of 5 ppm Zn over control. Wide variation exited among genotypes with respect to zinc use efficiency. Genotype ADT 48 registered the highest zinc sufficiency in all except apparent Zn recovery. Apparent Zn recovery had significant linear relationship with grain yield and grain Zn uptake.*

Introduction

The need to increase food production has become a major concern considering the rate at which population is increasing resulting intensification of land use leading to faster depletion of macro and micronutrients (Shehu and Jamala, 2010).Further attention has been given more to macronutrients rather than micronutrients. Zinc deficiency was first diagnosed in rice on calcareous soils of North India (Nene, 1966).It was subsequently found to be widespread phenomenon in lowland rice areas of Asia. Zinc deficiency is now considered the most widespread nutrient disorder in lowland rice (Neue and Lantin, 1994.; Quijano-Guerta et al., 2002; Fageria et al., 2002).The submerged soils are well recognized for less zinc availability to the plant due to reaction of zinc with free sulfides (Mikkelsen and Shiou, 1977). Under submerged condition of rice cultivation, zinc (native or applied) is changed into amorphous sesquioxide precipitates of franklinite $ZnFe_2O_4$ (Sajwan and Lindsay, 1988). The region with zinc deficient soil are also region where Zn deficiency in human beings is widespread for eg., India , Pakistan, China, Iran and Turkey (Alloway, 2004; Hotz and Brown , 2004). The zinc requirement can be easily met by a genotype or cultivar that is efficient in uptake and utilization of low levels of soil available Zn. Different cultivar response grown under low soil Zn concentration has been reported in maize, millet, rice and wheat (Fageria 2001; Chaab et al., 2011). Genotypic differences for zinc use efficiency have been reported for several crop species (Graham et al., 1992; Rengel and Graham 1995). Research efforts are therefore required to screen the rice genotypes for zinc efficiency (Lindsay 2000). Hence the present pot experiment was contemplated to study the response of rice genotypes to zinc fertilization in a zinc deficient soil.

Materials and Methods

A pot experiment was conducted in glass house of experimental farm of Annamalai University to study the response of rice genotypes to zinc application. The experimental soil belonged to Kondal series (Typic Haplusterts). The physicochemical characterization of the soil was clay loam , pH- 8.02, EC- 0.72 dSm^{-1}, organic carbon-6.74 g kg^{-1} ,$CaCO_3$ content-2.27%, $KMnO_4$-N -283 kg ha^{-1} , Olsen P – 26 kg ha^{-1}, NH_4OAc-K-320 kg ha^{-1} and DTPA Zn- 0.70 mg kg^{-1}. The experimental soil was deficient in Zn (critical limit of Zn- 0.84 mg kg^{-1} – Muthukumararaja and Sriramachandrasekharan, 2012). The treatments consisted of ten rice genotypes (ADT 36, ADT 37, ADT 45, ADT38, CO 45, ADT 43, ADT 46, ADT 39, CO 43, ADT 48) and two Zn levels(0 and 5 ppm) applied through zinc sulfate. Each pot was filled with 10 kg of processed soil sample. All the pots received uniform dose of 100:50:50 kg N, P_2O_5 and K_2O applied through urea, superphosphate and muriate of potash respectively. The experiment was conducted in factorial CRD with three replications. To determine grain, straw yield and zinc uptake, crops were harvested at maturity. Dried grain and straw samples were ground and digested in triple acid mixture and zinc concentration was determined in atomic absorption spectrometer. Zinc uptake in grain and straw was calculated by multiplying the grain and straw yield with respective zinc concentration. Based on grain yield and grain Zn uptake, following zinc use efficiency parameters were worked out as per Fageria et al., (2011)

1) Agronomic efficiency (mg/mg)

$$= \frac{\text{Grain yield with Zn} - \text{Grain yield without Zn}}{\text{Zn rate (mg/kg)}}$$

2) Physiological efficiency (µg/µg)

$$= \frac{\text{Grain + Straw yield with Zn} - \text{Grain + straw yield without Zn}}{\text{Grain + straw Zn uptake with Zn} - \text{Grain+ straw Zn uptake without Zn}}$$

3) Agrophysiological efficiency ((µg/µg)

$$= \frac{\text{Grain yield with Zn} - \text{Grain yield without Zn}}{\text{Grain + Straw Zn uptake with Zn} - \text{Grain + Straw Zn uptake without Zn}}$$

4) Apparent Zn recovery (%)

$$= \frac{\text{Grain+ straw Zn uptake with Zn} - \text{Grain +straw Zn uptake without Zn}}{\text{Zn rate (mg/kg)}} \times 100$$

5) Zn Utilization efficiency ((µg/µg) = Physiological efficiency x apparent Zn recovery

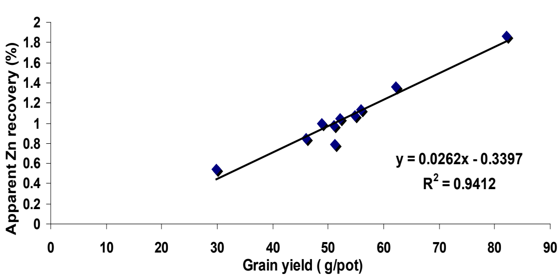
Results and Discussion

Grain and straw yield of rice responded significantly to zinc application (Table 1). The rice genotypes produced significantly (p= .0.05) different grain and straw yield. The grain yield ranged from 29.87 g/pot) to 82.10 g/pot and straw yield ranged from 50.89 g/pot to 107.6 g/pot due to zinc application. The highest grain yield (82.10 g/pot) and straw yield (107.6 g/pot) was noticed with genotype ADT 43 and the minimum grain yield (29.87 g/pot) and straw yield (50.89 g/pot) was observed with ADT 48. The grain yield response varied from 2.10 g/pot to 3.80 g/pot among rice genotypes due to application of 5 ppm. Zn The per cent increase in grain yield due to zinc application among rice genotypes varied from 4.2 to 13.5 over control, while in straw yield percent increase among rice genotypes ranged from 1.8 to 11.33 .On an average 5 ppm Zn caused 5.75% and 4.69% increase in grain and straw yield respectively over control. The increase in grain and straw yield with application of zinc was attributed to adequate supply of zinc that might have increased the availability and uptake of other essential nutrients resulting in improvement in metabolic activities (Hafeez et al., 2010) and also due to the effect of zinc on the proliferation of roots so that uptake rate from soil was increased and supplying it to the aerial part of the plant. This was confirmed by the positive significant linear relationship between grain Zn uptake and grain yield (Fig 1) and also by significant positive linear relationship between grain yield and Zn recovery efficiency (Fig.2) Yaseen et al., (2000) and Rehman et al., (2001) reported similar results. Pandey et al., (2005) reported poor grains could be produced in zinc deficient plants. The variation in the potential grain yield among rice genotypes demonstrates that genotype is an important contributor to overall variability and has to be considered in Zn fertilization management (Khoshgoftarmanesh et al., 2009). Differences in growth among cultivars have been related to the absorption, translocation, shoot demand, DMP potential per unit of nutrient absorbed (Baligar et al., 1990). Large genotypic variation in response to Zn deficiency have been reported among rice (Hafeez et al., 2010) and wheat (Khoshgoftarmanesh et al., 2004)

Table 1. Effect of zinc fertilization on grain and straw yield among rice genotypes

Rice genotypes	Grain yield (g/pot) Zinc levels (mg/kg)		Mean	Straw yield(g/pot) Zinc levels (mg/kg)		Mean
	Zn_0	$Zn_{5.0}$		Zn_0	$Zn_{5.0}$	
ADT 36	53.23	56.31	54.77	69.55	73.88	71.72
ADT 37	50.90	53.06	51.98	66.06	68.44	67.25
ADT 45	50.34	53.83	52.08	67.49	70.32	68.90
ADT 38	50.15	52.25	51.20	67.0	69.01	68.01
CO 45	54.78	57.06	55.92	71.43	74.68	73.03
ADT43	80.30	83.90	82.10	106.7	108.58	107.6
ADT 46	60.56	63.73	62.14	81.09	84.13	82.61
ADT 39	47.32	50.45	48.88	64.40	68.31	66.36
CO 43	44.49	47.61	46.05	62.60	66.22	64.41
ADT 48	27.97	31.77	29.88	48.16	53.62	50.89
Mean	52.0	54.99		70.44	73.71	
	Zn	G	Zn x G	Zn	G	Zn x G
SE_d	0.28	0.62	0.88	0.28	0.62	0.88
CD(p=0.05)	0.56	1.26	1.78	0.56	1.27	1.78

Fig.1. Linear relationship between grain yield and grain zinc uptake



There was a significant (p=0.05) main and interactive effect of different rice genotypes and zinc application on uptake of Zn in grain and straw. The grain Zn uptake ranged from 422.7 to 2039.6 µg/pot and straw Zn uptake ranged from 1216.7 to 4025.7 µg/pot among rice genotypes due to Zn addition.(Table 2) Per cent increase in total Zn uptake ranged from 45.2 to 72.1 among rice genotypes due to 5 ppm Zn over control. The percent increase in grain Zn uptake ranged from 46.49 to 94.7 and straw Zn uptake ranged from 31.4 to 50.99 among rice genotypes. Among rice genotypes, much variation was noticed in grain Zn uptake rather than in straw Zn uptake. On an average addition of 5 mg/kg Zn caused 62.9% and 46% increase in grain and straw zinc uptake over control respectively. Both under control and adequate Zn supply, zinc uptake was maximum with ADT43 and minimum in ADT 48. The genotypic differences in the ability to increase Zn availability in the rhizosphere for subsequent uptake have focused on the active release of Zn mobilizing substance from rice roots. Zhang et al., (1998) detected phytosiderophores in root exudates of rice. The highest Zn uptake by ADT 43 followed by ADT 46, CO 45 and ADT 36 under Zn stress condition indicated that these genotypes might have the ability to absorb its zinc requirement form other pools in addition to the most readily available form. Similar view was reported by Sakal et al., (1989) who observed that the resistant rice variety was able to extract Zn from complexed and organically bound form whereas the susceptible variety absorbed Zn only from readily available form.

Table 2. Effect of zinc fertilization on grain and straw Zn uptake among rice genotypes

Rice genotypes	Grain Zn uptake (µg/ pot) Zinc levels (mg/kg)		Mean	Straw Zn uptake (µg/ pot) Zinc levels (mg/kg)		Mean
	Zn_0	$Zn_{5.0}$		Zn_0	$Zn_{5.0}$	
ADT 36	884.2	1417.9	1151.1	1820.1	2748.3	2284.2
ADT37	796.6	1287.8	1042.2	1653.5	2451.5	2052.5
ADT 45	824.6	1346.8	1085.7	1768.2	2555.4	2161.8
ADT 38	851.0	1246.7	1048.9	1639.5	2360.8	2000.2
CO 45	966.3	1530.3	1248.3	1982.2	2944.2	2463.2
ADT43	1575.5	2503.6	2039.6	3291.2	4760.1	4025.7
ADT 46	1128.2	1803.6	1465.9	2375.9	3504.0	2939.9
ADT 39	584.4	1086.2	835.3	1468.3	2145.6	1806.9
CO 43	538.3	960.8	749.6	1464.2	1998.5	1731.4
ADT 48	286.9	558.5	422.7	974.8	1458.5	1216.7
Mean	843.6	1374.2		1843.8	2692.7	
	Zn	G	Zn x G	Zn	G	Zn x G
SE_d	0.28	0.63	0.89	0.34	0.76	1.08
C D (p=0.05)	0.59	1.27	1.79	0.69	1.54	2.18

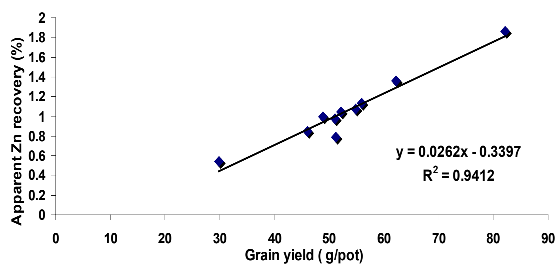


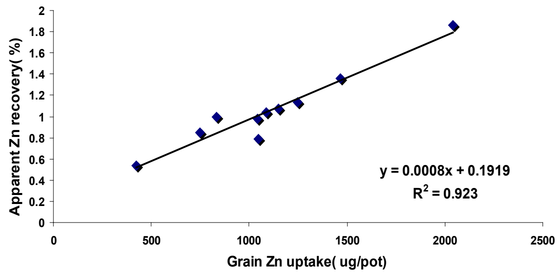
Fig.2. Linear relationship between grain yield and apparent Zn recovery

Wide variation existed among rice genotypes with respect zinc use efficiency (Table 3). It ranged from 42 to 76 mg/mg(agronomic efficiency), 3879 to 13991 µg/µg(physiological efficiency), 1494 to 5031 µg/µg (agro physiological efficiency), 0.54 to 1.86%(apparent Zn recovery) and 43.1 to 75.6 µg/µg(utilization efficiency). Among rice genotypes, ADT 48 registered the highest zinc use efficiency except apparent Zn recovery where ADT 43 recorded the highest value. There was significant positive linear relationship between Zn uptake and apparent Zn recovery (Fig 3) indicating that increase in Zn efficiency caused enhanced Zn uptake. Further it showed that not only enhanced Zn uptake but also enhanced internal utilization of Zn played an important role in expression of Zn efficiency. Multiple regression analysis showed that Zn uptake is the most important factor statistically explaining variation in Zn efficiency among the considered rice genotypes (Hajiboland and Salehi, 2006). Utilization efficiency may be linked to differences in the ability of a genotype to maintain an optimal activity of the important zinc regulated enzymes viz., superoxide dismutase (SOD) and carbonic anhydrase (CA) (Singh et al., 2005). Difference in internal utilization or mobility of Zn has been known to be involved in expression of Zn efficiency (Gokham et al., 2003). Lowland rice genotypic difference in Zn use has been reported earlier (Clark, 1990, Xiaopeng et al., 2005)

Table 3. Effect of zinc fertilization on zinc use efficiency among rice genotypes

Rice genotypes	Agronomic efficiency (mg/mg)		Agro		
ADT 36	61.6	5771	3086	1.06	61.2
ADT37	43.2	4397	1675	0.98	43.1
ADT 45	69,8	6683	2665	1.04	69.5
ADT 38	42.0	5307	1880	0.79	52.5
CO 45	45.6	4043	1494	1.13	45.7
ADT-43	72.0	3879	1502	1.86	72.1
ADT 46	63.4	4694	1758	1.36	63.8
ADT 39	62.6	6238	2655	1.00	62.4
CO 43	62.4	7385	3261	0.85	62.8
ADT 48	76.0	13991	5031	0.54	75.6

Fig.3. Linear relationship between grain Zn uptake and apparent Zn recovery



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