Effect of Zinc Application on Rice Growth and Zinc Uptake

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INTRODUCTION

Zinc (Zn) is one of the necessary micro-nutrients both for the growth of plants and for human beings. Reports show that 30% soils in the world exhibit Zn deficiency to different extents (Cakmak, 1999), and more than two billion people cannot be supplied with sufficient Zn. The problem of Zn deficiency is serious in China, with total areas of Zn deficiency exceeding one-third of agricultural land (Gao, 2005).

Rice is the primary resource of caloric value and nutrition for Chinese people, hence it is important to increase the content of Zn in rice, especially in brown rice, by application of Zn fertilizers so as to prevent Zn deficiency in humans.

MATERIALS AND METHODS

Field trials were conducted in 2008 and 2009 in Anhui province, on paddy soils with medium fertility. The pH of topsoil (0-20 cm) was 6.0 and 6.1, respectively and soil DTPA-Zn was 0.76 and 0.91 mg kg^{-1} before rice transplanting.

The experiment was designed as a randomized complete block, and replicated four times with five treatments including four kinds of different Zn application methods and a control: (1) Zn-0 (CK, no Zn), (2) Zn-S (soil application of 50 kg ha^{-1} $ZnSO_4.7H_2O$), (3) Zn-F (foliar application, 1350 kg $ha^{-1}$of 0.5% w/w $ZnSO_4.7H_2O$ solution was sprayed), (4) Zn-S-F (soil $ZnSO_4.7H_2O$ application+foliar $ZnSO_4.7H_2O$), (5) Zn-F-F (foliar application of 0.5% liquid Zn fertilizer, with 27% w/v Zn content, supplied by the International Zinc Association). Nitrogen was applied as urea (200 kg N ha^{-1}), of which 50% was applied as basal fertilizer, and 50% at tillering stage. Thirty five kg P ha^{-1} as $NH_4H_2PO_4$ and 125 kg K ha^{-1} as K_2SO_4 were applied as basal fertilizers before transplanting. Plots were 15 m^2 (5×3 m), were kept free of weeds, and water management was similar to local practice.

Rice plants were sampled twice. The first was at the tilling stage when two 50 cm segments of a row were sampled, and shoot samples from these two segments bulked. The second was at the physiological maturing stage, and 4 m^2 in the center of each plot harvested to determine grain and straw yield. Samples were washed in tap water followed by de-ionized water. Total dry matter and grain weight were comfirmed by oven drying the sampled plants at 70°C for 72h. After grinding, the samples were digested in acid mixture (HNO_3+ $HClO_4$). Zinc in plant digests was analyzed using an atomic absorption spectrometer.

Statistical analysis of the data was performed using the SPSS analytical software (SPSS, 2001), and LSD ($P < 0.05$) was used to test the difference among treatments.

RESULTS AND DISCUSSION

Effect of Zn Application on Rice Growth and Grain Yield

Total dry matter: Soil Zn application promoted rice growth. At tillering stage, dry shoot matter increased significantly over controls by 5.5-14.2%.

Yield and yield components: Applying Zn promoted rice ear growth in anaphase (Table 1). The number of seeded ears, the length and weight of ears, the number of full and total seeds increased significantly, percent of seeded seeds and weight per thousand seeds raised, and yield components were improved compared to the control. Rice grain yield increased ($P<0.01$) by 5.9-13.3% and 5.8-8.8%, averaging 9.1% and 7.4% respectively in two years compared the treatments of different Zn application methods with the control. The treatment of Zn-S-F attained the highest grain yield with mean increases of 11%.

Table 1. Effect of Zn application on yield components of rice.

Treat.	Seeded ear (×10^4/ha)	Length of ear (cm)	Wright of ear (g)	No. of full seed per ear	No. of total seed per ear	Rate of seeded (%)	Weight per 1000 seeds (g)	Grain yield (t ha^{-1})
Zn-0	243.0 a	22.1 b	148.9 c	232.9 b	292.5 b	79.62 a	28.65 a	9.58 b B
Zn-S	248.4 a	23.2 ab	164.4 b	262.9 a	330.0 a	79.68 a	29.20 a	10.27 a A
Zn-F	254.6 a	22.7 ab	178.0 ab	276.1 a	346.3 a	79.71 a	29.12 a	10.30 a A
Zn-S-F	251.2 a	24.4 a	190.9 a	284.7 a	353.5 a	80.53 a	29.50 a	10.64 a A
Zn-F-F	245.6 a	23.0 ab	189.4 a	269.7 a	342.9 a	78.66 a	28.61 a	10.27 a A

Note: Different small and capital letters mean significant at 5% or 1% level in this table and Table 2.

Effect of Different Zn Application Methods on Zn Concentration and Zn Uptake

Zinc application raised Zn concentrations and uptake by shoots and grain at different growth stages (Table 2). At tillering stage, Zn concentrations increased by 45.7% and 45.8%, and Zn uptake increased by 66.4% and 63.5%, compared to the soil Zn application treatments Zn-S or Zn-S-F to the control Zn-0. At rice maturity, Zn concentrations in grain fertilized by foliar Zn increased by 147.4-163.6%, and Zn uptake increased by 164.8-198.8% compared to the control, much higher than that of soil Zn treatments.

Table 2. Effect of Zn application on the concentration and uptake of Zn in rice.

Treat.	Concentration of Zn (g kg^{-1})				Total Zn uptake (Zn g hm^{-2})			
	Booting		Mature period		Booting		Maturity period	
	Shoot	Seed	Straw	Total	Shoot	Seed	Straw	Total
Zn-0	15.64 b	18.23 c	31.90 b	24.80 c	383.9 b	170.2 d	275.8 b	446.0 d
Zn-S	22.79 a	22.88 b	35.91 a	29.11 b	638.7 a	232.2 c	334.0 a	566.2 c
Zn-F	16.25 b	45.11 a	32.40 ab	39.03 a	403.2 b	457.4 b	301.7 ab	759.1 b
Zn-S-F	22.81 a	48.06 a	35.01 a	41.85 a	627.6 a	508.6 a	336.6 a	845.2 a
Zn-F-F	15.56 b	45.56 a	34.13 ab	40.07 a	414.2 b	450.7 b	312.2 a	762.9 b

CONCLUSIONS

Applying Zn promotes the growth and nutrition of rice in prophase and ear forming in anaphase, and increases grain yield. Application of both soil and foliar Zn attained the highest grain yield with average increases of 11% over control. Zinc application increased Zn concentrations and uptake in shoot, grain, and straw with foliar application being most effective. Application of Zn increased the average concentration of Zn in brown rice grain and hulls by 36.4% and 452.5%, respectively.

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