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RICE CROP RESPONSE TO ZINC APPLICATION IN LOW HUMIC GLEY SOILS OF LOW COUNTRY INTERMEDIATE ZONE

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ABSTRACT

Next to NPK, zinc is the most important micronutrient that limits the grain yield of rice in some Sri Lankan soils. Therefore, a field experiment was conducted for 3 seasons to determine a suitable source and a level of zinc fertilizer to increase the grain yield of rice grown in Low Humic Gley (LHG) soils of Low Country Intermediate Zone (LCIZ). Zinc sulfate and zinc oxide as zinc sources both at the rates of 0.0, 2.5, 5.0, 7.5, 10.0 Zn kg Zn/ha were tested for Bg 403 and Bg 352 with recommended NPK fertilizers at Batalagoda research farm in LCIZ. Residual effects of applied zinc were observed in succeeding season using the same plots. Soil analysis revealed that soil was deficient in zinc, and application of zinc increased the available zinc in soil. Plant tissue data from zinc treated plots showed that the tissue zinc increased to the level beyond the critical concentration, i.e., 10 ppm. Application of both $ZnSO_4.7H_2O$ and ZnO increased the grain yield but higher yields were given by zinc sulfate than zinc oxide at all added zinc levels. The rate 5.0 Zn kg/ha gave maximum yield increase of 19% but it is not significantly different from the yield increase of 16.5% by 2.5 kg Zn/ha. Therefore, it can be concluded that 2.5 kg Zn/ha in either $ZnSO_4.7H_2O$ or ZnO form is the optimum level to obtain a higher yield of rice grown in LHG soils of LCIZ. It also showed that one application of zinc greater than 2.5 kg Zn/ha was sufficient for 2 crops of rice showing its residual effects on second rice crop.

KEYWORDS: *Oryza sativa*, Zinc, LHG Soils, Intermediate Zone.

INTRODUCTION

The zinc deficiency of rice plants was first reported by Nene (1966) on paddy fields in India. After that Yoshida (1968) and Yoshida *et al.*, (1973) studied on zinc nutrition in rice plant. He introduced the idea that the disorder of rice plant known as "hadda" in Pakistan is due to zinc deficiency. Since then zinc deficiency was recognized as widespread and as an important plant nutritional problem throughout the rice growing countries such as Japan, USA, Brazil and Philippines (Deb, 1992).

The symptom of zinc deficiency of rice plants was first reported by Takahashi *et al.*, (1984). According to him, at about the tillering stage, mid ribs of leaves of the lower or middle part of plant turn to light green, then brown colored stripes and brown spots appear between veins of leaves. After that, the leaves of the lower part of plants wither up. Yoshida (1981) elucidated that the zinc deficiency of rice may be triggered by high pH of soil. Randhawa and Katyal

(1982) have reported that a lowland rice field having marginal or medium status of available zinc might become zinc deficient under waterlogged conditions. Zinc deficiency is also shown in highly weathered acid and coarse textured soil containing small amount of available Zn (Misra *et al.*, 1985).

Many research works have been done on availability and behavior of zinc in rice soils and alleviation of zinc deficiency in many rice producing countries in the world (Deb, 1992). Nagarajah *et al.* (1983) studied the responses of fertilizer zinc in farmers field at Gampolawela and Kandepelella in mid country wet zone of Sri Lanka. At Kandepelellala where soil was poorly drained and low in available zinc, a significant response to Zn application was observed but at Gampolawela where the soil was moderately well drained and high in available Zn, no responses to applied Zn was obtained. Bandara and Silva (2000) studied the response of rice crop to micronutrient in low humic gley soils at Polonnaruwa and Maha Illuppallama in low country dry zone and in same soils at Batalagoda and Pothuhera in low country intermediate zone and significant response to zinc was observed. However rate of zinc to be applied to supplement the zinc requirement for the rice crop grown in Low Humic Gley (LHG) soil have not been formulated. The LHG soils where rice crop is intensively grown are found throughout the lowland of intermediate zone of Sri Lanka and rice yields in these soils could not be increased during last few years and however response to zinc application was observed (Bandara and Silva, 2000) but response level of Zn had not been determined.

Objective of this study was to find out a suitable zinc source and a level of zinc fertilizer to supply the zinc requirement to increase the growth and grain yield of rice grown in LHG soils of Low Country Intermediate Zone (LCIZ).

MATERIALS AND METHODS

Field experiments were conducted for 3 seasons (1998/1999 *maha*, 1999 *yala* and 1999/2000 *maha*) in imperfectly drained LHG soils (Plinthaqults), which are the lower members of the drainage catena in association with red yellow podzolic (RYP) soils (Panabokke, 1996) at Batalagoda in IL_1 Agro-climatic region of the LCIZ.

A two factor factorial experiment with 2 sources of zinc ($ZnSO_4.7H_2O$ and ZnO each contains 21 and 78% of Zn respectively) and five levels of zinc fertilizer (*viz.* 0, 2.5, 5.0, 7.5 and 10.0 kg of Zn/ha) were carried out in a randomized complete block design with 3 replicates. Eighteen-day old seedlings of rice variety Bg 403 for first and second seasons and Bg 352 for third season were transplanted with 3 plants per hill (at the spacing of 15 x 20cm and 15 x 15 cm respectively for Bg 403 and Bg 352) on ploughed and leveled lowland plots of 6m x 3 m which were surrounded by 30cm wide bunds.

Phosphorous and potassium fertilizers were applied at the rate of 28.0 kg/ha of P_2O_5 and 22.5 kg/ha of K_2O respectively as triple super phosphate and muriate of potash. Varying amounts of elemental S, *i.e.* 5.4, 4.05, 2.70, 1.35 and 0 kg/ha, were added respectively to the plots receiving 0.0, 2.5, 5.0, 7.5, 10.0 kg/ha of Zn as $ZnSO_4.7H_2O$. A constant level of elemental S, *i.e.* 5.4 kg/ha was added to all the plots receiving ZnO as the Zn source. Elemental S addition was done to compensate the S effect (added with $ZnSO_4.7H_2O$) on growth and grain yield of rice. Phosphorus, potassium, sulfur and zinc fertilizers were broadcast and incorporated into soil by puddling just before transplanting. Nitrogen as urea was applied in split, 37.5 kg/ha as basal for both varieties, 50 kg and 137.5 kg/ha respectively at 3 and 5 weeks after planting for Bg 352 and 50 kg, 50 kg and 137.5 kg urea per hectare respectively at 3, 5 and 7 weeks after transplanting for Bg 403. Manual weed control and chemical methods of pest control were practiced.

Plant growth was measured by taking tiller counts, plant height, biomass production and yield components of rice (culm length, panicle length, number of panicles per square meter, number of filled grains per panicle and thousand grain weight). Soils were analysed to determine the fertility level of the experimental fields. Soils were extracted with relevant extracting solutions listed in table 1 for each micronutrient. Concentration of Zn, Fe, Cu in soil extracts were determined by atomic absorption spectrophotometer. Plant samples taken at maximum tillering stage were dried in an oven at 85°C for 8 hours and ground in a stainless steel mill to 1.0mm size particles. Each sample of 1.0g was digested in diacid mixture (HNO_3:$HClO_4$ 1:1) and Zn was determined by atomic absorption spectrophotometry. Trial was conducted in 2 sites with Bg 403 and one site with Bg 352 at Batalagoda research farm. Experiment was repeated in same plots without application of zinc to observe the residual effects of applied zinc for the second crop, only N, P and K fertilizer were applied. Experimental procedure and data recording were as same as for the first crop.

RESULTS AND DISCUSSION

Soil properties

Soils of the experimental sites were sandy clay loam classified as imperfectly drained low humic gley (LHG) soils of low base status. They were low in organic matter (1.6-1.9%) neutral in reaction (table 2). These soils contained high level of iron, marginal level of Cu and low extractable P. Cation exchange capacity was also low in all sites (table 2).

Table 1. Extraction and analytical methods of each micronutrient.

Micronutrient	*Method of soil extraction*	*Analytical method*
Cu	AAAC-EDTA	AASP
Fe	AAAC at pH 4.8	AASP
Mn	AAAC-EDTA	AASP
Zn	0.05N HCl	AASP
Zn	AAAC-EDTA	AASP

AAAC-Acid ammonium acetate; EDTA - Ethylene diamine tetra acetic acid; AASP- Atomic absorption spectrophotometry

Table 2. Some chemical properties of the soils of experimental sites at Batalagoda in LCIZ.

Property	*Site 1*	*Site 2*	*Site 3*	*Deficient level*
pH (1:5 soil: water)	6.15	6.30	6.25	-
Total N % (Kjeldahl method)	0.08	0.09	0.10	-
Organic matter (%) (Walkley and Black method)	1.65	1.82	1.90	-
Olsen P (mg/kg)	8.30	8.50	9.2	-
CEC (meq/100g soil) (1N Ammonium acetate extraction at pH 7.0)	10.2	10.6	12.3	-
Exchangeable cations (meq/100g soil) (1M NH_4 OAC at pH 7.0)				
Ca	1.8	2.0	1.70	-
Mg	0.72	0.80	1.1	-
K	0.10	0.09	0.08	-
Na	0.07	0.06	0.10	-
Fe (mg/kg)	301	295	238	<2.0
Mn (mg/kg)	9.3	13.2	14.1	<2.0
Cu (mg/kg)	1.28	1.02	1.2	<1.0
Zn (AAAC-EDTA)	0.92	0.83	0.93	<1.5
Zn (0.05N HCl)	0.45	0.53	0.48	<1.0

AAAC - Acid ammonium acetate; EDTA - Ethylene diamine tetra acetic acid; * Adapted from Tanaka and Yoshida, 1970

Both acid ammonium acetate - EDTA extractable and 0.05 N HCl extractable Zn in soils were low for rice crop growth (table 2).

Available Zn in soil and tissue Zn at maximum tillering stage of the crop

Soils and plant samples analyzed at maximum tillering stage of the crop showed that available Zn in soils and tissue Zn in plants of control plot were in deficient ranges for healthy growth of rice (table 3).

Application of 2.5 kg Zn/ha in the form of $ZnSO_4$ $7H_2O$ increased the available Zn in soil to a sufficient level range from 0.98 to 1.08 mg/kg and also increased the tissue Zn to a level range from 14.5 to 16 mg/kg (table 3). But application of 2.5 kg Zn/ha in the form of ZnO increased the available Zn in soil to a range of 0.8 to 0.88 mg/kg while it increased the tissue Zn to a level range from 1[illegible].5 to 12.6 mg/kg (table 3). Further increase of Zn in both forms increased the available Zn in soil as well as tissue Zn. It shows that the addition of Zn in both forms increased the available Zn in soil and addition of 2.5 kg Zn/ha is appeared to be sufficient to supply the zinc requirement for the rice crop grown in this soil (table 3). If soil application of Zn is concerned, zinc sulfate is better than ZnO. Both varieties responded similarly to zinc application in these soils. Table 3 also showed that major part of the zinc compound applied to the soil has been fixed by soil. But application of 2.5 kg Zn/ha is sufficient to supply zinc requirement and increased the tissue zinc concentration to a level more than critical level for crop growth. However further addition of Zn what is more than 2.5 kg Zn/ha to the soil increased the soil available zinc as well as tissue zinc.

Growth, yield components and grain yield

Application of zinc increased the dry matter production of rice when compared with the control treatment (table 4). Addition of 2.5 kg Zn/ha increased the dry matter production by 27%, plant height by 9.4%, number of tillers/m^2 by 21% over control treatment with an average of 3 seasons at maximum tillering stage of the crop. Further addition of zinc more than 2.5 kg/ha did not significantly increased all these growth parameters of rice grown in this soil (table 4). Table 4 also showed that application of Zn at higher rates like 10 kg Zn/ha has negative effect on these growth parameters. Two sources of zinc were equally effect on the growth parameters of rice except in 1999/2000 *maha* season crop (table 4). However better source seems to be the zinc sulfate as increments of all growth parameters, yield components and grain yield were always higher when compared it with ZnO (table 4). Table 5 shows that both zinc sources equally effected on increasing yield components namely number of panicles/m^2 culm length and panicle length of rice grown on these soils. Application of 2.5 kg Zn/ha increased the number of panicles per square meter by 24%, culm length by 5% panicle length by 7% over the control with an average of 3 seasons (table 5).

Similar trends were obtained for the thousand-grain weight and number of filled grains per panicle of rice (table 6). It also showed that application of 2.5 kg Zn/ha increased the thousand-grain weight by 3.6% and number of filled grains per panicle by 17% over control (table 6). Both compounds were equally effective on these growth parameters, but better source was zinc sulfate as it increased more compared with ZnO (table 6). Application of Zn at the rate of 2.5 kg Zn/ha increased the grain yield by 16.5% with a average of 3 seasons (table 6). Further addition of Zn increased the grain yield but it is not significantly different from the grain yield at 2.5 kg Zn/ha. Zinc sulfate produced higher grain yield compared it with ZnO in all 3 seasons, but yields were not significantly different (table 6).

Results of all 3 sites over 3 seasons showed that application of Zn significantly increased the grain yield and yield components and sufficient Zn fertilizer dose was 2.5 kg Zn/ha and this amount increased the sufficient amount of available Zn in soil as well as in plant tissues.

Residual effect of applied zinc

Yield data recorded from the trial conducted on same plots in second season using the same variety showed the residual effects of zinc on second crop of rice (table 7). Application of 2.5 kg Zn/ha increased the number of panicles/m^2, thousand-grain weight, number of filled grains per panicle and grain yield of second crop of rice respectively by 5.6%, 3.3%, 3.4% and 5.3% over control treatment. But only thousand grain weight was significantly increased (table 7) However application of 5 kg Zn/ha increased the number of panicles/m^2, thousand grain weight, number of filled grains per panicle and grain yield of the second crop of rice respectively by 11.6% 4.8%, 4.2% and 12% over control treatment but only increments of TGW and GY were significant (table 7). Further addition of Zn even at higher rates also significantly increased the all yield components and grain yield of second crop of rice showing residual effect in second season (table 7). Both sources of Zn showed the residual effects on growth of second crop of rice in second season and both were equally affected on grain yield but zinc sulfate always has the higher effect compared with ZnO (table 7).

Table 3. Effect of applied zinc on available Zn in soil and zinc contents in plant tissues at maximum tillering stage of the rice crop grown in LHG soils of LCIZ.

Treatment	*Rate of Zn (Kg/ha)*	*Season*					
		Maha1998/99		*Yala 1999*		*Maha 1999/2000*	
		Soil (mg/kg)	*Tissue (mg/kg)*	*Soil (mg/kg)*	*Tissue (mg/kg)*	*Soil (mg/kg)*	*Tissue (mg/kg)*
$ZnSO_4 7H_2O$	0.0	0.50	8.2	0.45	7.6	0.52	8.0
	2.5	1.08	14.5	0.98	15.3	1.06	16.0
	5.0	1.25	20.2	1.32	22.8	1.42	25.0
	7.5	1.86	26.6	1.75	28.5	1.90	27.0
	10.0	2.10	28.0	2.20	28.0	2.45	27.2
ZnO	0.0	0.52	7.6	0.46	8.2	0.44	8.5
	2.5	0.80	12.3	0.85	11.5	0.88	12.6
	5.0	1.05	18.5	1.12	17.0	1.25	19.0
	7.5	1.40	20.6	1.36	24.8	1.45	23.0
	10.0	1.78	24.5	1.85	26.2	1.92	23.5

Table 4. Effects of applied zinc on dry matter production (DMP-g/2 tiller), plant height (PH-cm) and number of tiller per square meter (NTM) at maximum tillering stage of the rice crop grown in LHG soils in LCIZ.

Treatment		*Season*								
		Maha 1998/99			*Yala 1999*			*Maha 1999/2000*		
		DMP	*PH*	*NTM*	*DMP*	*PH*	*NTM*	*DMP*	*PH*	*NTM*
Zinc source	$ZnSO_4 7H_2O$	25.5a	63.5a	336a	36.1a	70.8a	314a	19.9a	52.5a	347a
	ZnO	23.2a	60.5a	329a	34.1a	70.4a	299a	17.4b	51.0a	339a
	LSD (0.05)	2.9	3.5	10.0	2.8	1.4	16	1.7	1.6	29
Zinc level	0.0	22.3b	55.3a	290b	28.1b	67.9b	282c	15.8c	51.2ab	298c
	2.5	28.5a	66.8b	352a	38.3a	71.1a	326a	20.5ab	52.9ab	375a
	5.0	29.5a	67.2b	355a	40.6a	72.4a	324ab	21.2a	53.4a	371ab
	7.5	28.2a	66.4b	322a	37.1a	70.9a	299bc	18.1bc	50.6b	346ab
	10.0	28.6a	66.8b	326a	36.8a	70.8a	301abc	17.9bc	50.6b	326bc
LSD (0.05)		3.2	8.5	35	4.5	2.1	26	2.7	2.4	46
CV%		8.7	6.9	12.4	9.7	6.2	6.4	11	4.5	10.1

LSD - Least significant difference at 5% level; CV- Coefficient of variation

Table 5. Effects of applied zinc on number of panicles per m^2 (NPM) culm length (CL) (cm) and panicle length (PL) (cm) at harvesting stage of the rice crop grown in LHG soils of LCIZ.

Treatment		*Season*								
		Maha 1998/99			*Yala 1999*			*Maha 1999/2000*		
		NPM	*CL*	*PL*	*NPM*	*CL*	*PL*	*NPM*	*CL*	*PL*
Zinc source	$ZnSO_4 7H_2O$	248a	60.5a	26.5a	267a	62.9a	27.5a	265a	54.5a	21.6a
	ZnO	244a	59.2a	26.3a	253a	61.5b	27.4a	258a	53.8a	21.4a
	LSD (0.05)	12	1.8	0.6	15	1.2	0.7	13.0	1.7	0.5
Zinc level	0.0	234b	56.0b	24.2b	237b	60.1c	26.4b	246c	53.0a	20.8b
	2.5	257a	59.1a	26.7a	267a	63.2a	28.2a	269ab	55.1a	21.6a
	5.0	252a	58.9a	27.2a	273a	63.4a	27.6a	276a	55.7a	22.0a
	7.5	251a	58.5a	27.1a	272a	62.5ab	27.6a	257bc	53.9a	21.5a
	10.0	248a	58.4a	27.3a	251ab	62.0b	27.5a	257bc	53.2a	21.9a
LSD (0.05)		18	2.3	2.4	23	1.1	1.1	20	2.8	0.8
CV%		6.4	8.6	7.3	7.0	6.2	4.5	6.6	4.1	4.8

LSD - Least significant difference at 5% level; CV - Coefficient of variation

Table 6. Effects of applied zinc on 1000 grain weight (TGW) (g), number of filled grains per panicles (NFG) and grain yield (t/ha) (GY) of rice grown in LHG soils of LCIZ.

Treatment		*Season*								
		Maha 1998/99			*Yala 1999*			*Maha 1999/2000*		
		TGW	*NFG*	*GY*	*TGW*	*NFG*	*GY*	*TGW*	*NFG*	*GY*
Zinc source	$ZnSO_4 7H_2O$	22.6a	109a	4.15a	24.6a	129a	6.08a	25.5a	102a	4.07a
	ZnO	22.5a	107a	3.95a	24.2a	126a	5.84a	25.4a	100a	3.93a
	LSD (0.05)	0.3	8.0	0.23	0.3	8	0.27	0.4	3	0.46
Zinc level	0.0	21.9a	88b	3.61b	23.8a	113b	5.40b	24.9b	96b	3.47b
	2.5	22.9b	116a	4.36a	24.5ab	131a	6.07a	25.7a	102a	4.08a
	5.0	22.9b	117a	4.31a	24.8a	137a	6.23a	25.8a	105a	4.37a
	7.5	22.6b	115a	4.14a	24.7a	134a	6.22a	25.5ab	102a	4.07a
	10.0	22.7b	115a	4.06a	24.3b	132a	6.01a	25.5ab	102a	3.97ab
LSD (0.05)		0.5	12	0.37	0.4	14	0.38	0.7	5.0	0.58
CV%		8.8	10.6	9.0	6.2	8.2	6.8	4.6	8.5	11.9

LSD - Least significant difference at 5% level CV - Coefficient of variation

Table 7. Residual effect of applied zinc on number of panicles per m² (NPM), thousand grain weight (TGW) (g), number of filled grains per panicles (NFG) and grain yield (GY-t/ha) of 2nd crop rice grown on LHG soils of LCIZ.

Treatment		*Yala 2000*			
		NPM	*TGW*	*NFG*	*GY*
Zinc source	$ZnSO_4 7H_2O$	340a	27.58a	93.0a	3.962a
	ZnO	317a	27.18a	90.3a	3.834a
	LSD (0.05)	27	0.44	4.0	0.157
Zinc level	0.0	300b	26.55b	88.0b	3.629c
	2.5	317ab	27.43a	91.0b	3.823bc
	5.0	335ab	27.83a	91.7ab	4.068ab
	7.5	342ab	27.90a	97.8a	4.132a
	10.0	347a	27.93a	95.5a	4.089a
LSD (0.05)		43	0.69	6.1	0.249
CV%		9.9	8.9	7.7	4.8

LSD - Least significant difference   CV - Coefficient of variation

CONCLUSION

Low Humic Gley soils which occur as lower members of the drainage catena in association with red yellow podzolic soils contains comparatively less than critical level of available zinc for rice crop growth. This is further confirmed by the tissue zinc content. Application of zinc at the rate of 2.5 kg Zn/ha significantly increased the growth and grain yield of rice grown in this soil. Further addition of zinc increased the grain yield but it is not significantly different from the yield at 2.5 kg Zn/ha. However experiment shows that 2.5 kg Zn/ha is not sufficient for second crop of rice and it does not show the residual effect in second season. But zinc rate higher than 2.5 kg/ha significantly increased the yield components and grain yield of the second crop of rice showing its residual effect. Both sources of zinc can be used to supplement the Zn to the rice, but better one seems to be zinc sulfate in comparison to the zinc oxide.

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