Available Zn Distribution, Response and Uptake of Rice (O*riza sativa*) to Applied Zn Along a Toposequence of Lake Gerio Fadama Soils at Yola, North-eastern Nigeria.

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Abstract: A screen house pot experiment was conducted at FAO/TCP farm of the Adamawa State University, Mubi north-eastern Nigeria, to study the response of rice to Zn fertilizer application and the distribution of Zn along toposequence of the Lake Gerio Fadama soils of North-eastern Nigeria which was used for the study. The experiment consisted of four Zn rates of 0, 5, 7.5 and 10 kg Zn ha^{-1} as $ZnSO_4.7H_2O$. The effect of treatment on Zn concentration and dry matter yields response were determined. The 0.1N HCl and DTPA extractable Zn ranged from 8.5 to 9.5 mg kg^{-1} soil, 2.2 to 2.7 mg kg^{-1} soil with mean values of 9.08 and 2.35 mg kg^{-1} soil respectively. Available Zn soil status is therefore assessed as medium. Dry matter yields and Zn uptake were optimum at 5 kg ha^{-1} with corresponding values of 2.04 and 11.86 mg kg^{-1} respectively.

[H. E. Shehu and G. Y. Jamala. Available Zn Distribution, Response and Uptake of Rice (O*riza sativa*) to Applied Zn Along a Toposequence of Lake Gerio Fadama Soils at Yola, North-eastern Nigeria. Journal of American Science 2010;6(11):1013-1016]. (ISSN: 1545-1003). (http://www.americanscience.org)

Key words: Zinc uptake; Toposequence; Fadama soils; Rice

Introduction

The need to increase food production becomes a major concern considering the rate at which population is increasing. This resulted in intensive use of land with the consequence of depleting the macro and micro nutrients faster than they can be restored. Attention has been given to the supply of macronutrients only forgetting the micronutrients.

In Nigeria and even in many developing countries, study on soil micronutrients was neglected in both soil science and crop production. Most work on soil in Nigeria has been on soils developed on crystalline basement complex, sedimentary and metamorphic rocks (Kparmwang *et al* 1995) and most savanna soils are reported to have low clay contents, organic matter and cation exchange capacities (Lombin, 1983). Zn deficiency was first diagnosed in rice on the calcareous soils of northern India (Nene, 1966). It was subsequently found to be a wide spread phenomenon in lowland rice areas of Asia, and next to N and P deficiencies.

Zn deficiency is now considered the most widespread disorder in lowland rice (Neue and Lantin, 1994). Quijano-Guerta *et al*, 2002) reported that Zn is the major cause of low rice yields in the major rice producing areas as Zn deficiency is one of the prevalent chemical stresses that is linked to coastal hydrology. With the initiation of several irrigation schemes in north-eastern Nigeria particularly the Lake Gerio Irrigation project, Gerio basin has become agriculturally important. The area covers about 850 ha and only 320 ha are currently under cultivation and rice is the main irrigated crop.

Information on the micronutrient fertility status of these soils particularly Zn is not documented in the literature though deficiency has been noted in other crops.

Therefore, this investigation was carried out to study and determine the available Zn distribution along toposequence and responses of rice to applied Zn under pot culture conditions.

Materials and Methods

A pot experiment was conducted in screen house in the FAO/TCP farm of the Adamawa State University, Mubi (10^o 16” N and 13^o 17” E) to determine the distribution of available Zn along the toposequence of lake Gerio fadama soils in Yola, north-eastern Nigeria and to asses the response and uptake of rice (*Oriza sativa*) to applied Zn from 11th August to 27th September 2008. Soil samples were collected from points using Geo-reference system satellite receiver (GPS, 2002 – GARMIN 12). The sampling points were divided into upper, middle and down slopes. The upper slope ranged between 156.4 to 159.3 m above sea level. The middle slope ranged from 153.4 to 159.0 m above sea level while the down slope ranged from 155.7 to 156.6 m above sea level. These primarily represent the soils of Lake Gerio Fadama irrigation projects of the lower Benue trough of north-eastern Nigeria. The soil samples were sieved using 2 mm sieve and analyzed for particle size, pH, electrical conductivity, organic carbon, available P, total N, K, Ca, Na and available Zn.

Available Zn was extracted by 0.1N HCl and DPTA. Soil solution ratio was 1:10 and 1:2 for HCl and DPTA respectively. This was shaked for 2 hours and the filtrate analyzed for Zn on atomic absorption spectrophotometer (Buck Scientific model – 210 VG). To determine the response of rice to applied Zn, composite surface soil samples, 0-15 cm were used. The treatments include 0. 5, 7.5 and 10 kg Zn ha^{-1} replicated three times in a complete randomized design. Rice seeds (IITA 2-1-2 Cv.) were sawn in pots and filled with 4 kg soil and was grown for seven weeks. Deionized water was used for irrigation. Shoots were harvested and oven dried at 70 ^{o}C and dry matter yields were determined. Data was subjected to statistical analysis using SAS software (1999).

Results and Discussion

Particle size and Zn distribution are presented in Table 1. The texture of the soil ranged from silt clay to silt clay loam. The Zn content ranged from 8.5 to 9.5 mg kg^{-1} with mean value of 9.1 mg kg^{-1}. Critical limits for Zn suggested by Nelson *et al* (1959), Trerweiler and Landsay, (1969) and latter confirmed by Shukla and Kwari (1990) were 0 to 4.5, 3.5 to 4.0, 4.5 and 4.5 mg kg^{-1} HCl extractable Zn respectively. Considering these reports, all HCl extractable Zn of Lake Gerio irrigation project were higher than the 4.5 mg kg^{-1} critical levels for Zn and thus could be classified as medium. Medium Level has also been reported in some lowland areas of Nigeria such as Sokoto, Zamfara, Kebbi, Bayelsa, Rivers and part of Niger state (FAO, 2005). There were no marked differences in the distribution of available Zn along toposequence which agrees with the findings of Voncir *et al*, (2008).

The DPTA critical limits reported by Lindsay and Norvel, (1978) and Landon, (1984) to be 0.6 to 0.8 and 0.5 to 1.0 mg kg^{-1} soil DPTA extractable Zn respectively were lower than the values obtained at Lake Gerio fadama soils with mean value of 2.4 mg kg^{-1}.This also could be classified as moderate confirming the HCl extractable Zn status.

Some chemical properties of the experimental soil are presented in Table 2. Soil pH ranged from 6.4 to 6.8. Organic matter content was also low (ranged from 1.7 to 2.1%). The distribution of available P ranged from 3.2 to 10.9 mg kg^{-1} while N lower and upper values were 0.03 and 0.08% respectively. The ECEC ranged from 20.1 to 22.5 meq 100 g^{-1} as EC ranged from 0.22 to 0.46 ms cm^{-1}.

Table 1: Particle size and Zn distribution of the experimental soil.

Toposequence	Particle size (%)			Textural	DPTA	0.1N HCl	Zn
	Sand	Silt	Clay	class	(mg kg^{-1})	(mg kg^{-1})	status
Upper slope	72.0	11.0	17.0	SL	2.4	9.5	medium
Middle slope	69.0	12.0	19.0	SCL	2.7	9.2	medium
Down slope	66.0	10.0	24.0	SCL	2.2	8.5	medium
Composite	68.0	12.0	20.0	SCL	2.4	9.1	medium
Mean	69.0	11.0	20.0	SCL	2.35	9.08	medium

SL= Silt Loam; SCL=Silty Clay Loam

Table 2: Distribution of DPTA/HCl extractable Zn and other soil properties along toposequence of Lake Gerio irrigation Project, Yola, North- eastern Nigeria.

Toposequence	pH 1:2.5 (H_2O)	Organic C (%)	%N	Bray P (mg kg^{-1})	ECEC (meq kg^{-1})	EC (ms cm^{-1})
Upper slope	6.6	1.7	0.08	10.9	20.1	0.26
Middle slope	6.4	2.1	0.03	1.5	20.1	0.22
Down slope	6.8	2.1	0.03	3.2	22.5	0.46
Composite	6.6	2.0	0.05	5.0	20.2	0.31
Mean	6.6	2.0	0.05	5.15	20.7	0.313

Table 3: Zn uptake and dry matter responses of rice plant to applied Zn.

Zn (kg ha^{-1})	Dry matter (g pot^{-1})		Zn uptake (mg pot^{-1})	
	Mean	SE	Mean	SE
0	0.83^{b}	±0.21	5.79^{b}	±1.45
5	2.04^{a}	±0.29	11.86^{ab}	±2.90
7.5	1.77^{a}	±0.23	14.54^{a}	±2.79
10	2.50^{a}	±0.24	15.72^{a}	±2.07

Means with the same letter are not significantly different using Duncan's Multiple Range Test at 5% level of significance.

Table 4: Correlation coefficient between dry matter and Zn, N, P and K uptake by rice.

	Zn	Dry matter	Zn uptake	N uptake	P uptake
Zn	1.000				
Dry matter	0.755**	1.000			
Zn uptake	0.712**	0.700**	1.000		
N uptake	0.414	0.720**	0.709**	1.000	
P uptake	0.511	0.799**	0.493	0.786**	1.000
K uptake	0.702**	0.987**	0.678*	0.713**	0.783**

* = Significant at 5% level of probability
** = Significant at 1% level of probability

The response of dry matter to applied Zn is shown in Table 2. Though the soils showed a moderate Zn content, increase in dry matter yield was recorded. Optimum dry matter yield was obtained at 5 kg ha^{-1} Zn application which gave a corresponding dry matter yield of 2.04 g pot^{-1} while the highest dry matter yield was recorded at 10 kg Zn ha^{-1} rate of 2.50 g pot^{-1}. This is confirmed in the positive correlation (Table 4) that exists between Zn and dry matter yield (r = 0.755). Lack of significant response between the Zn rates could be attributed to the soil Zn status and thus the demand for the crop could be met at 5 kg ha^{-1}. Other factors that might have contributed to no marked response of dry matter to Zn application could be attributed to low organic matter content and Mg:Ca ratio as also noted by Neue and Landin, (1994).

Zn uptake response by rice plant to applied Zn (Table 3) was significant at P = 0.05. The application at 5, 7.5 and 10 kg Zn ha^{-1} had uptake advantage of 105,151 and 172% respectively over soils that did not receive Zn application. Optimum Zn uptake was obtained at 5 kg ha^{-1} Zn application. This shows that uptake of Zn in plants is a function of the amount of Zn applied. This is shown in the significant correlation between applied Zn and Zn uptake of r = 0.712. In assessing the uptake of Zn, the previous work of Dobernmann and Fairhurst (2000) who also observed that ratio of P:Zn in the shoot are good indicators of Zn deficiency where values are not to exceed 20 to 60:1. The application of Zn has contributed to the positive correlation between N and P uptake (r = 0.786) and N and K uptake (r = 0.713).

Nutrient utilization efficiency (NUE) of Zn indicated that the rate of increase in uptake from 5 to 7.5 kg ha^{-1} Zn rate is greater than the rate of increase from 7.5 to 10 kg^{-1}. This shows that decline in NUE starts at 7.5 kg ha^{-1} rate. The low utilization of this element may not be unconnected with the medium level soil status of Zn since the element is required in small quantity.

Conclusion

The inferences drawn from the response of rice to Zn application confirms the results of soil analysis where most of the soil along the toposequence are at medium level and will require low level of Zn application of 5 kg Zn ha^{-1} for optimum yields in the Lake Gerio irrigation projects.

Acknowledgement:

We are grateful to Adamawa State University, Mubi for providing facilities for the research.

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20/7/2010