Oryza Vol. 49. No. 4, 2012 (292-295)

Zinc utilization efficiency in different genotypes of rice

T K Nagarathna, A G Shankar, V R Ramakrishna Parama, M T Sanjay and M Udayakumar
University of Agricultural Sciences, GKVK, Bangalore 560 065

ABSTRACT

Zinc utilization efficiency (ZUE) and effect of total leaf zinc (Zn) on productivity were examined in 22 genotypes of rice. The results revealed that there was a significant genetic variability within high and low leaf Zn types with regards to ZUE. The genotypes with low leaf Zn showed relatively high ZUE. A positive significant relationship was seen between total leaf Zn and grain yield, and also with total dry matter. Increasing Zn acquisition may have a positive effect on growth, development and productivity in rice genotypes.

Key words: *rice, genotypes, zinc utilization efficiency, zinc acquisition*

Zinc utilization efficiency (ZUE), the ability of a plant to grow and yield well under zinc-deficient conditions, varies among cereal species (Graham and Rengel, 1993 and Erenoglu *et al*, 2001). Genotypic differences for zinc use efficiency have been reported for several crops species (Rengel and Graham, 1995 and Cakmak *et al*, 1994). Physiological mechanism(s) conferring ZUE and their relative significance on low Zn soil/ solution culture have been investigated by several workers (Erenoglu *et al*, 2001, Rengel and Romheld, 2000, Hacisalihoglu and Kochian, 2003). Genotypic differences in Zn efficiency have been related to various mechanisms operative in the rhizosphere and within a plant system. Considerable progress has been made over the past few years to identify mechanisms that the plant species and genotypes possess for efficient acquisition of Zn from soils low in Zn availability (Rengel and Romheld, 2000 and Marschner *et al*, 1986). These include, higher uptake of zinc by roots, protection against superoxide free radicles, i.e. efficient antioxidative defence mechanism, efficient utilization and (re)-translocation of Zn (Hart *et al*, 1998 and Rengel and Romheld, 2000). Cakmak *et al.* (1996) showed that Zn efficiency of cereals is mainly related to difference in acquisition of Zn by the roots.

Zinc level in the plant is not often directly related to Zn mediated metabolic reactions. One of the reasons could be the compartmentalisation of Zn into metabolic and non metabolic pools and other reason could be due to quantitative and qualitative differences in synthesis and activity of Zn related proteins in the plant. Therefore, the plants which maintain high metabolic activity per unit Zn are desirable. Therefore, the present study was undertaken to estimate the ZUE of selected rice genotypes and whether Zn influences growth and yield.

MATERIALS AND METHODS

Twenty two germplasm lines of rice were selected including some of the released varieties like BPT-5204, IR-64, Thanu and IR-20 and sown during wet season 2006-07 at V.C. Farm, Mandya, Karnatak. Recommended NPK at the rate of 100:50:50 kg ha^{-1} was applied. Complete dose of nitrogen and phosphorus were applied at the time of transplanting and potassium was applied at two stages, 50% at the time of transplanting, and remaining 50% was applied at anthesis. Twenty four days old seedlings were transplanted in the field at spacing of 20x10cm.

Zinc was estimated in the grains and leaf sample using Polarized Zeeman Atomic Absorption Spectrophotometer (AAS-2-6100) (Piper 1966).

Plant Zn utilization efficiency was calculated using the following formula:

$$\text{ZUE} = \frac{\text{Amount of biomass produced}}{\text{Total amount of Zn in the leaves}}$$

Table 1. Zinc utilization efficiency of selected genotypes from four different groups

Sl. No.	Groups	Genotypes	Zinc Utilization Efficiency (g mg^{-1} Zn)	
			Total dry matter	Grain
1	HLHS	C 4938-B-B-1-1	0.0171	0.0145
2		IR 73898-71-2-6-3	0.0212	0.0081
3		NWGR-33	0.0191	0.0132
4		Samrat	0.0206	0.0118
5		GMR 14	0.0177	0.0076
6		BPT-5204	0.0264	0.0119
7		IR 20	0.0293	0.0127
		Mean	0.0217	0.0114
		SEm+	0.001	0.0014
		CV%	10.49	21.36
8	HLLS	JING-XIAN-89	0.0197	0.0120
9		IR 64	0.0110	0.0107
10		HKR-01-121	0.0218	0.0109
11		TOX 3749-34-3-1	0.0155	0.0130
		Mean	0.0170	0.0116
		SEm+	0.0012	0.0007
		CV%	15.40	13.39
12	LLHS	RPHR 203-8-2	0.0383	0.0160
13		IR 50	0.0257	0.0150
14		PK-3161	0.0292	0.0121
15		ADRON-111	0.0322	0.0141
16		PR 25953-2-1	0.0211	0.0078
		Mean	0.0293	0.0130
		SEm+	0.0019	0.0013
		CV%	14.30	21.75
17	LLLS	CR749-20-20-2-18-15	0.0257	0.0158
18		Thanu	0.0350	0.0149
19		WAT310-WAS-B-28-8-3-3	0.0264	0.0123
20		IET 8116	0.0391	0.0165
21		KR-1	0.0218	0.0110
22		IR 596556-5K-2	0.0420	0.0262
		Mean	0.0317	0.0161
		SEm+	0.0027	0.0019
		CV%	18.99	26.04

HLHS- high leaf high seed, LLHS - low leaf high seed, LLLS - low leaf low seed, HLLS - high leaf low seed

All the genotypes were classified into four groups to identify contrasting genotypes differing in acquisition of Zn and transportation to seed. Based on distribution of Zn in the leaf and seed, the genotypes were classified as high leaf high seed Zn types (HLHS), low leaf high seed Zn types (LLHS), low leaf low seed Zn types (LLLS) and high leaf low seed Zn types (HLLS).

In all the selected genotypes, ZUE which reflects the amount of biomass produced per unit amount of Zn taken by plants was calculated to check the genetic variability across the genotypes. To examine this aspect the genotypes were classified into two different groups, high leaf Zn and low leaf Zn types irrespective of their seed Zn levels and assessed their mean productivity in terms of total dry matter (TDM) and yield. All the 22 selected genotypes were also classified based on total Zn content of the plant into high and low types to study the effect of Zn on productivity. The Zn levels of this group and also productivity and biomass yields were computed to see whether high total leaf Zn influences the growth rates and also grain yield.

RESULTS AND DISCUSSION

In general the genotypes with low leaf Zn showed relatively high ZUE. For example, mean ZUE with

Table 2. Total leaf zinc content and TDM of low zinc and high zinc types

GT	Total leaf Zn (µg/total LA)	TDM (g $plant^{-1}$)	Grain yield (g $plant^{-1}$)
Low zinc types			
IR 59656-5K-2	772.20	23.46	13.07
KR-1	725.44	18.96	9.06
IR 50	740.19	18.34	8.77
RPHR-203-8-2	778.43	27.56	14.17
WAT 310-WAS-B-28-8-3-3-3	788.07	19.31	10.59
CR 749-20-2-18-15	788.79	27.82	12.09
Thanu	823.90	26.35	11.56
PK-3161	842.47	23.79	10.62
ADRON 111	850.82	25.31	12.45
High zinc types			
IET 8116	911.61	26.01	12.74
IR 20	916.35	27.47	15.09
JING-XIAN-89	972.89	22.11	12.10
C 4938-B-B-1-1	976.16	23.29	12.52
Samrat	982.87	25.31	13.68
HKR-01-121	983.22	21.89	11.98
NWGR-33	1068.83	23.87	13.14
R 1223-616-629-1	1087.65	25.04	11.75
BPT-5204	1102.98	27.21	16.52
IR 64	1120.26	26.04	12.26
PR-25953-2-1	1155.14	23.61	18.68
IR 73898-71-2-6-3	1244.83	22.95	11.31
TOX 3749-34-3-1	1280.72	30.21	16.23

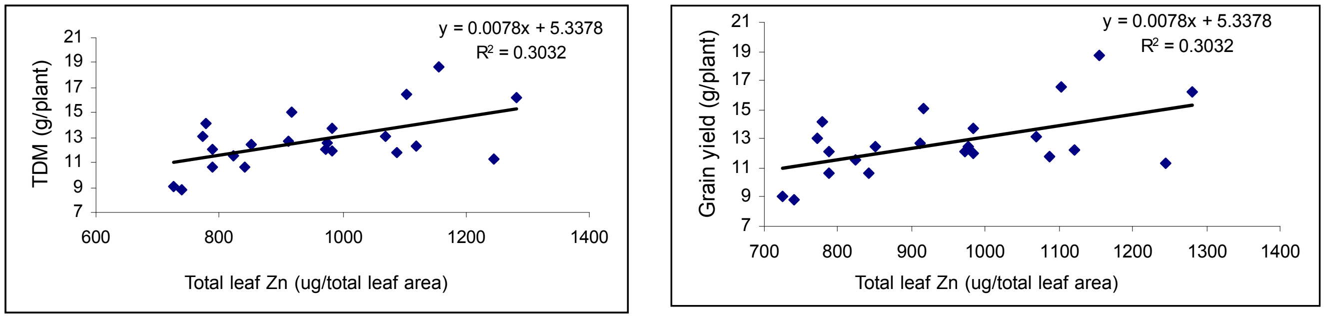

Fig. 1. Relationship between total leaf Zn and productivity in low and high Zn types

regards to TDM is 0.0217 for high Zn types as against 0.0317 in low Zn types. Zinc utilization efficiency for grain yield in high Zn types was 0.0114 and it was 0.0161 for low Zn types. It is evident from these results that the genotypes with relatively low leaf Zn showed higher ZUE. However, there is a significant genetic variability within high and low leaf Zn types with regards to utilization efficiency. It is desirable to identify high Zn types with relatively high ZUE. For example, BPT-5204 and IR 20 fall into such category (Table 1).

Genotypes were classified into two different groups, high leaf Zn and low leaf Zn types irrespective of their seed Zn levels and assessed their mean productivity in terms of TDM and yield. All the 22 selected genotypes were also classified based on total leaf Zn content of the plant into high and low types. The Zn levels of this group and also productivity and biomass yields were computed (Table 2). In both the groups there is a significant variability in total leaf Zn content, however, the mean total leaf Zn content in high types was 34% higher. The objective of the analysis is to see whether high total leaf Zn influences the growth rates and also grain yield. In spite of genetic variability in TDM and grain yield within the group a positive significant relationship is seen between leaf Zn and grain yield and also with TDM (Fig 1). In fact the mean grain yield of low Zn types is 11.37 g against 13.69 g in high Zn category, indicating 16.9% of the higher productivity. Similarly mean TDM was also high in high Zn types.

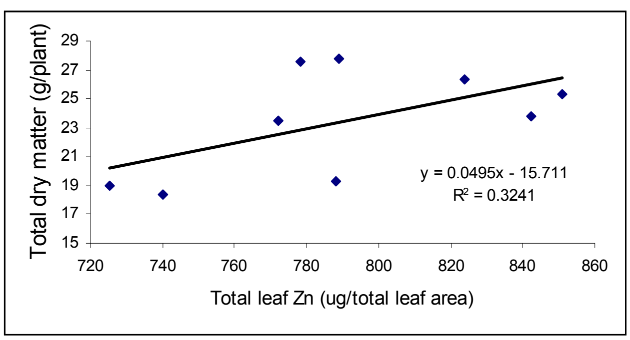

Fig. 2. Relationship between total leaf Zn and total dry matter in low Zn types

From the foregoing analysis with the selected genotypes, it is evident that higher Zn acquisition (total leaf Zn) results in higher growth rates and also grain yield. The genotypes were classified as low and high Zn types. There is variability in Zn levels within a group. The relationship between Zn acquisition and TDM were analysed within a group. It was revealed that TDM had a increasing trend with increase of total leaf Zn (Fig. 2). From these results it can be inferred that increasing Zn acquisition may have a positive effect on growth, development and productivity in rice genotypes.

REFERENCES

Cakmak IK, Gülüt, H, Marschner and Graham RD 1994. Effect of zinc and iron deficiency on phytosiderophore, J. Plant. Nutr, 17:1-17.

Cakmak I, Yilmaz A, Ekiz H, Torun B, Erenoglu B and Braun HJ 1996. Zinc deficiency as a critical nutritional problem in wheat production in Central Anatolia. Plant Soil, 180: 165–172.

Erenoglu B, Römheld V and Cakmak I 2001. Retranslocation of zinc from older leaves to younger leaves and roots in wheat cultivars differing in zinc efficiency. In: Plant nutrition: Food security and sustainability of agro-ecosystems through basic and applied research, Developments in Plant and Soil Sciences, Springer, The Netherlands, pp. 224-225.

Graham RD and Rengel DZ 1993. Genotypic variation in Zn uptake and utilization by plants. In: Ed. A D Robson, Zinc in soils and plants. Kluwer Academic Publishers, Dordrecht, The Netherlands, 107-114.

Hacisalihoglu G and Kochian LV 2003. How do some plants tolerate low levels of soil zinc? Mechanisms of zinc efficiency in crop plants. New Phytologist, 159: 341-350.

Hart JJ, Norvell WA, Welch RM, Sullivan LA and Kochian LV 1998. Characterization of zinc uptake, binding, and translocation of bread and durum wheat cultivars. Plant. Physiol., 118, 219–226.

Piper CS 1966. Soil and Plant Analysis. Hans Publishers, Bombay.

Rengel Z and Graham RD 1995.Wheat genotypes differ in Zn efficiency when grown in chelate-buffered nutrient solution: II. Nutrient uptake. Plant Soil, 176: 317–324.

Rengel Z and Romheld V 2000. Root exudation and Fe uptake and transport in wheat genotypes differing in tolerance to Zn deficiency. Plant Soil, 222**:** 25–34.