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Influence of Zinc Deficiency on Shoot / Root Dry Weight Ratio of Rice Genotypes

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Abstract: Shoot/ root dry weight is the most sensitive parameter in evaluation of genotypes for their tolerance to zinc stress. A green house experiment was conducted at Tamil Nadu Agricultural University, Coimbatore to screen rice genotypes for zinc efficiency employing solution culture technique with modified Hoagland's solution as the nutrient medium. The experiment was laid out in factorial completely randomized design. Fifty six rice genotypes were raised with five zinc treatments (Zn 0.0, 0.025, 0.05, 0.10 and 0.20 ppm), replicated thrice and maintained for 30 days. Plants were scored at ten days interval and the shoot / root dry weight ratio was computed at 10 days interval. The data were subjected to Systat multivariate analysis and the genotypes were classified as efficient (a), moderately efficient (b) and inefficient (c) at each level of deficient and excessive zinc supply.

Key words: *Solution culture, shoot/root dry weight, zinc efficiency, screening, rice genotypes*

INTRODUCTION

Rice and wheat, the world's two most important cereal crops are affected by zinc deficiency. At least 70 % of the rice crop is produced in flooded soils in the paddy system. Unfortunately, flooding of the soil reduces the availability of zinc to the crop and increases the concentrations of phosphorus and bicarbonate ions which can exacerbate zinc deficiency problems. It has been estimated that possibly 50 % of paddy soils are affected by zinc deficiency. This could involve up to 35 m ha in Asia alone. It has been estimated from soil test samples that, on an average, 49% of soils from all the main agricultural areas in India are deficient in zinc. India, with a cultivated land area of 166.2 m ha, could possibly have upto 83 m ha of zinc deficient soils [1]. Though fertilizer recommendations exist, correction of zinc deficiency via fertilization does not always remain a successful strategy due to top soil drying, subsoil constraints, disease interactions and high cost of fertilizers in the developing countries [8]. A long term sustainable solution to zinc deficiency limitation is the development of rice genotypes with superior zinc efficiency, which can grow and yield under low soil Zn conditions. Zinc has several functions in plants as carbohydrate metabolism, protein metabolism, auxin metabolism, pollen formation, maintenance of the integrity of biological membranes and resistance of pest and disease infestation. The cause for deficiency of a particular nutrient is half soil and half genotype, which solidly augments genotypic diversity in nutrient efficiency and paves way for breeding genotypes with enhanced efficiency. Shoot /root dry weight is the most sensitive parameter in evaluation of genotypes for their susceptibility to zinc deficiency [6]. Hence the present investigation was framed to screen rice genotypes for their tolerance to zinc stress employing the ratio of shoot dry weight and root dry weight as a tool by solution culture technique.

MATERIALS AND METHODS

The experimental set up consisted of plastic plates with depressions bottom severed with nylon mesh. The plates were countersunk into plastic trays containing modified Hoagland solution [9] as the nutrient medium. Pregerminated rice seedlings (five days old) of 56 rice genotypes were raised in the trays with one seedling in each depression. The seeds were held above the nylon mesh and only the roots were let into the nutrient solution. The solution was aerated by fabricated aerators. Five levels of zinc (Zn 0.0, 0.025, 0.05, 0.10 and 0.20 ppm as $ZnSO_4$) were imposed. The seedlings were screened at ten days interval adopting Standard Evaluation System of Rice [10], comprising of grades from 1 to 8.

1: Growth and tillering nearly normal; healthy
2: Growth and tillering nearly normal; basal leaves slightly discoloured.
3: Stunting slight, tillering decreased, some basal leaves brown or yellow
5: Growth and tillering severely retarded, about half

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of all leaves brown or yellow
7: Growth and tillering ceases, most leaves brown or yellow
8: Almost all plants dead or dying

The shoot and root dry weights were recorded at 10 days interval and the ratio between the two computed. The rice genotypes were grouped as a,b,c adopting Systat Multivariate Grouping[18], where ‘a’ represented highly zinc efficient, ‘b’, moderately zinc efficient and ‘c’, zinc inefficient based on the shoot/ root dry weight ratio of the genotypes.

RESULTS AND DISCUSSIONS

At Zn 0.0 mg L^{-1}, those genotypes with the ratio ranging from 0.98 to 1.69 fell under the score 'a', from 1.85 to 2.33 represented 'b' and from 2.45 to 2.89 were grouped as 'c'. At Zn 0.025 mg L^{-1}, the genotypes with the ratio from 1.21 to 1.82 were grouped as 'a', from 1.93 to 2.59 as 'b' and from 2.71 to 3.28 as 'c'. At Zn 0.05 mg L^{-1} those genotypes with the ratio from 1.34 to 2.18 belonged to the score 'a', from 2.21 to 2.93 to the score 'b' and from 3.24 to 3.49 to the score 'c'. At Zn 0.10 mg L^{-1}, those genotypes with the ratio ranging between 1.41 and 2.36 were ranked as 'a', between 2.44 and 3.08 as 'b' and between 3.11 and 3.84 as 'c'. At Zn 0.20 mg L^{-1}, group 'a' comprised of the genotypes with the ratio ranging from 1.68 to 2.45, group 'b' with the ratio ranging from 2.61 to 3.01 and group 'c' with the ratio ranging from 3.11 to 3.67 (Table 1).

At Zn 0.0 mg L^{-1}, the genotypes ADT 12, ASD 16, TRY 1, TKM 9, Pusa Vikas, Poornima, Norungan and Pokkali exhibited their superiority by registering higher shoot dry weight / root dry weight while a reverse trend was noted for the genotypes IR 8, IR 36, ADT 2, ADT 3, ADT 14, ADT 15, ADT 17, ADT 19, ADT 38, ADT 39, ASD 19, PMK 3, TKM 10, TKM 11, CSR 10, MDU 4, MDU 5, CO 43 and ADTRH 1.

Table 1: Shoot dry weight / root dry weight ratio as influenced by genotypic divergence

S.No.	Genotypes Zn (mg L^{-1})	IR 8	IR36	IR 64	IR 72	ADT1	ADT2	ADT3	ADT7	ADT11	ADT12	ADT14	ADT15	ADT17	ADT19
a.	Zn 0.0	1.56 ^{a}	1.64 ^{a}	2.21 ^{b}	1.87 ^{b}	1.85 ^{b}	1.10 ^{a}	0.98 ^{a}	1.97 ^{b}	2.16 ^{b}	2.48 ^{c}	1.54 ^{a}	1.69 ^{a}	1.19 ^{a}	1.26 ^{a}
b.	Zn 0.025	1.72 ^{a}	2.17 ^{b}	3.28 ^{c}	1.94 ^{b}	1.93 ^{b}	1.45 ^{a}	1.21 ^{a}	2.06 ^{b}	2.24 ^{b}	2.82 ^{c}	1.73 ^{a}	1.82 ^{a}	1.75 ^{a}	1.35 ^{a}
c.	Zn 0.05	1.99 ^{a}	2.28 ^{b}	3.41 ^{c}	2.15 ^{a}	2.18 ^{a}	1.64 ^{a}	1.98 ^{a}	2.21 ^{b}	2.49 ^{b}	2.93 ^{b}	1.86 ^{a}	1.97 ^{a}	2.14 ^{a}	1.48 ^{a}
d.	Zn 0.10	2.10 ^{a}	2.44 ^{b}	3.55 ^{c}	2.36 ^{a}	2.56 ^{b}	2.29 ^{a}	2.24 ^{a}	2.44 ^{b}	2.65 ^{b}	3.05 ^{b}	2.27 ^{a}	2.15 ^{a}	2.19 ^{a}	1.86 ^{a}
e.	Zn 0.20	2.15 ^{a}	2.98 ^{b}	3.62 ^{c}	3.01 ^{b}	2.67 ^{b}	2.32 ^{a}	2.64 ^{b}	3.26 ^{b}	2.66 ^{b}	3.28 ^{c}	2.42 ^{a}	2.19 ^{a}	2.21 ^{a}	2.19 ^{a}

S. No.	Genotypes Zn (mg L^{-1})	ADT36	ADT37	ADT38	ADT39	ADT41	ADT43	ADT44	ADT45	ADT46	ASD16	ASD18	ASD19	ASD20	PMK1
a.	Zn 0.0	2.11 ^{b}	2.02 ^{b}	1.11 ^{a}	1.35 ^{a}	2.12 ^{b}	2.33 ^{b}	1.97 ^{b}	2.02 ^{b}	2.14 ^{b}	2.56 ^{c}	2.15 ^{b}	1.16 ^{a}	2.09 ^{b}	2.11 ^{b}
b.	Zn 0.025	2.26 ^{b}	2.15 ^{b}	1.69 ^{a}	1.44 ^{a}	2.26 ^{b}	2.71 ^{c}	2.32 ^{b}	2.14 ^{b}	2.55 ^{b}	2.78 ^{c}	2.32 ^{b}	1.78 ^{a}	2.28 ^{b}	2.39 ^{b}
c.	Zn 0.05	2.32 ^{b}	2.28 ^{b}	1.82 ^{a}	1.66 ^{a}	2.54 ^{b}	2.84 ^{b}	2.44 ^{b}	2.78 ^{b}	2.82 ^{b}	3.24 ^{c}	2.84 ^{b}	1.94 ^{a}	2.32 ^{b}	2.45 ^{b}
d.	Zn 0.10	2.82 ^{b}	2.47 ^{b}	1.97 ^{a}	1.82 ^{a}	2.86 ^{b}	2.91 ^{b}	2.76 ^{b}	3.14 ^{b}	3.26 ^{c}	3.30 ^{c}	3.35 ^{c}	2.04 ^{a}	2.48 ^{b}	2.99 ^{b}
e.	Zn 0.20	2.89 ^{b}	2.45 ^{a}	2.04 ^{a}	2.17 ^{a}	2.91 ^{b}	2.97 ^{b}	2.73 ^{b}	2.99 ^{b}	2.93 ^{b}	2.7 0 ^{b}	2.84 ^{b}	2.14 ^{a}	2.34 ^{a}	3.29 ^{c}

S. No.	Genotypes Zn (mg L^{-1})	PMK2	PMK3	TRY1	TRY2	TKM9	TKM10	TKM11	CSR10	CSR13	P.Vikas	MDU4	MDU5	CO43	CO45
a.	Zn 0.0	2.19 ^{b}	1.09 ^{a}	2.61 ^{c}	2.21 ^{b}	2.45 ^{c}	1.32 ^{a}	1.22 ^{a}	1.13 ^{a}	2.06 ^{b}	2.69 ^{c}	1.29 ^{a}	1.25 ^{a}	1.12 ^{a}	2.24 ^{b}
b.	Zn 0.025	2.41 ^{b}	1.22 ^{a}	2.80 ^{c}	2.34 ^{b}	2.55 ^{b}	1.54 ^{a}	1.46 ^{a}	1.27 ^{a}	2.17 ^{b}	2.98 ^{c}	1.35 ^{a}	1.44 ^{a}	1.26 ^{a}	2.41 ^{b}
c.	Zn 0.05	2.69 ^{b}	1.49 ^{a}	3.24 ^{c}	2.65 ^{b}	2.71 ^{b}	1.63 ^{a}	1.58 ^{a}	1.34 ^{a}	2.36 ^{b}	3.24 ^{c}	1.48 ^{a}	1.74 ^{a}	1.48 ^{a}	2.62 ^{b}
d.	Zn 0.10	3.23 ^{c}	1.85 ^{a}	3.84 ^{c}	2.97 ^{b}	2.89 ^{b}	1.78 ^{a}	1.67 ^{a}	1.41 ^{a}	2.64 ^{b}	3.46 ^{c}	1.55 ^{a}	1.92 ^{a}	1.69 ^{a}	2.87 ^{b}
e.	Zn 0.20	2.90 ^{b}	2.01 ^{a}	3.67 ^{c}	2.84 ^{b}	2.80 ^{b}	1.84 ^{a}	1.94 ^{a}	1.68 ^{a}	2.71 ^{b}	3.20 ^{c}	1.84 ^{a}	2.02 ^{a}	1.75 ^{a}	2.76 ^{b}

S. No.	Genotypes Zn (mg L^{-1})	CO47	W.Ponni	Poornima	Norungan	Pokkali	Triveni	Mozikaruppu	Karuvali	Rasakudam	Purpleputtu	BTS24	AS98024	CORH2	ADTRH1
a.	Zn 0.0	2.15 ^{b}	2.32 ^{b}	2.46 ^{c}	2.89 ^{c}	2.76 ^{c}	2.18 ^{b}	2.09 ^{b}	2.21 ^{b}	2.32 ^{b}	2.09 ^{b}	2.19 ^{b}	2.28 ^{b}	2.18 ^{b}	1.21 ^{a}
b.	Zn 0.025	2.38 ^{b}	2.46 ^{b}	2.56 ^{b}	3.11 ^{c}	2.92 ^{c}	2.45 ^{b}	2.20 ^{b}	2.46 ^{b}	2.59 ^{b}	2.28 ^{b}	2.36 ^{b}	2.42 b	2.46 ^{b}	1.38 ^{a}
c.	Zn 0.05	2.65 ^{b}	2.69 ^{b}	2.89 ^{b}	3.49 ^{c}	3.42 ^{c}	3.28 ^{c}	2.88 ^{b}	2.79 ^{b}	2.84 ^{b}	2.46 ^{b}	2.64 ^{b}	2.59 ^{b}	2.63 ^{b}	1.89 ^{a}
d.	Zn 0.10	2.88 ^{b}	2.74 ^{b}	3.01 ^{b}	3.64 ^{c}	3.59 ^{c}	3.36 ^{c}	3.08 ^{b}	2.99 ^{b}	2.91 ^{b}	2.59 ^{b}	2.87 ^{b}	3.11 ^{c}	2.84 ^{b}	2.11 ^{a}
e.	Zn 0.20	2.96 ^{b}	2.69 ^{b}	2.98 ^{b}	3.42 ^{c}	3.18 ^{c}	3.40 ^{c}	3.15 ^{c}	3.14 ^{c}	3.11 ^{c}	2.61 ^{b}	2.92 ^{b}	2.84 ^{b}	2.88 ^{b}	2.23 ^{a}

a: Zinc inefficient; b - Moderately zinc efficient; c - Highly zinc efficient

At Zn 0.20 mg L^{-1}, the ratio was appreciably higher in IR 64, ADT 7, ADT 12, PMK 1, TRY 1, Pusa Vikas, Norungan, Pokkali, Triveni, Mozikaruppu, Karuvali and Rasakudam while IR 8, ADT 2, ADT 14, ADT 15, ADT 17, ADT 19, ADT 37, ADT 38, ADT 39, ASD 19, ASD 20, PMK 3, TKM 10, TKM 11, CSR 10, MDU 4, MDU 5, CO 43 and ADTRH 1 registered a conspicuously lower ratio. At all the other intermediate levels, the genotypes ASD 16, TRY 1, Pusa Vikas, Norungan and Pokkali putforth a spectacular increase in the ratio while IR 8, ADT 2, ADT 3, ADT 14, ADT 15, ADT 17, ADT 19, ADT 38, ADT 39, PMK 3, TKM 10, TKM 11, CSR 10, MDU 4, MDU 5, CO 43 and ADTRH 1 gave out a markedly lower shoot / root ratio. The other genotypes had ratios between the higher and lower values and some genotypes had lower ratio at Zn 0 and Zn 0.025 mg L^{-1} but it shot up tremendously with elevated levels of zinc supply.

Several workers opined that shoot dry weight is depressed to a greater extent than root dry weight under Zn stress [12, 16, 17]. In line with the above findings, the inefficient genotypes exhibited spectacular reduction (50 % and more) in shoot and root dry weight at deficient zinc supply than at the sufficiency levels. At the elevated level (Zn 0.2 mg L^{-1}), shoot growth and root growth were depressed in several genotypes. This finding corroborates with the view of paivoke [14], who noted toxic Zn levels to affect the shoot growth more than the root growth resulting in a decreased shoot / root ratio in some plant species as *Pisum sativum*.

Zinc deficiency is a powerful determinant of the shoot / root ratio. Higher sensitivity of the genotypes is associated with higher root growth at the expense of shoot growth. Lower shoot / root dry weight ratio is a well known phenomenon in P-deficient plants [5] and is considered as an adaptive response of plants for more efficient P acquisition from soils [2]. Zinc deficiency induced enhancement of root growth cannot be interpreted as an adaptive mechanism for Zn acquisition in Zn – deficient genotypes.

When Zn deficient and Zn sufficient plants were compared, much larger reduction in the shoot / root ratio characterized Zn inefficient genotypes. Zinc efficient genotypes can sustain a relatively larger shoot growth per unit of root when subjected to Zn deficiency. Lower shoot / root dry weight ratio under Zn deficiency, in sensitive genotypes in particular might be a reflection of Zn deficiency induced photo oxidative damage in shoots leading to lower shoot growth [6]. Impairment in shoot growth of Zn deficient genotypes was more distinct. Roots of those genotypes should have been more competitive for photosynthates than the shoots leading to lower shoot / root dry weight ratios. The dramatic decline in shoot / root ratio in Zn inefficient genotypes when compared to the efficient ones as witnessed in the present study is consistent with other studies using nutrient solution cultures where Zn deficiency reduced the shoot / root ratio in wheat [7] and *Phaseolus vulgaris* [4] although no change in the shoot / root ratio was recorded for *Lycopersicum esculentum* and *Gossypium hirsutum* [3]. Barley plants grown in chelate buffered nutrient solution showed a tendency to increase root weight while having shoot growth severely reduced with a decrease in solution Zn activities [13].

According to Jackson [11], the shoot / root ratio is controlled by a mineral supply without apparent involvement of a hormonal regulation. A shortage of a nutrient in the outside medium causes reduction in the amount transported to shoots, which then experiences nutrient deficiency and reduced growth. This reduced growth causes changes in assimilate partitioning viz., greater amounts being available for transport to roots. A decrease in the shoot / root ratio under Zn deficiency observed here may be a compensatory mechanism geared towards acquisition of a scarce resource from the environment by maintaining or increasing root growth at the expense of shoot growth. Such compensatory mechanism was less obvious for Zn – efficient genotypes which are either better capable of extracting Zn from deficient environments or more efficient in utilizing Zn taken up, thus reducing or even obviating a need for increased root growth at the expense of shoot growth [15].

Though Zn inefficient genotypes showed the largest decrease in shoot / root ratio, Zn efficient genotypes maintained almost the same ratio which corresponded to a gradual depletion of seed Zn reserves and building up of a sufficient mass of roots required to support growth of a unit shoot [15]. Zinc efficient genotypes were apparently faster in adapting to environments with low Zn activity. Changes in shoot / root ratio manifested the genotype x Zn interaction.

REFERENCES

1. Alloway, B.J., 2003. In Zinc in soils and crop nutrition. International Zinc Association. Belgium.
2. Anghinoni, I. and S.A. Barber, 1980. Phosphorus influx and growth characteristics of corn roots as influenced by phosphorus supply. Agronomy Journal, 172: 655-668.
3. Cakmak, I. and H. Marschner, 1988. Enhanced superoxide radical production in roots of zinc deficient plants. Journal of Experimental Botany, 39: 1449-1460.

4. Cakmak, I., H. Marschner and F. Bangerth, 1989. Effect of Zn nutritional status on growth, protein metabolism and levels of indole – 3 – acetic acid and other phytohormones in bean (*Phaseolus vulgaris*). Journal of Experimental Botany, 40: 405-412.
5. Cakmak, I., K.Y. Guluk, H. Marschner and R.D. Graham, 1994. Effect of zinc and iron deficiency on phytosiderophore release in wheat genotypes differing in zinc efficiency. Journal of Plant Nutrition, 17: 1-17.
6. Cakmak, I., N. Sari, H. Marschner, H. Ekiz, A. Kalayci, A. Yilmaz and H.J. Braun, 1996. Phytosiderophore release in bread and durum wheat genotypes differing in zinc efficiency. Plant and Soil, 180: 183-189.
7. Cakmak, I., N. Sari., H. Marschner, M. Kalayci, A. Yilmaz, S. Eker and K.Y. Gulut, 1996. Dry matter production and distribution of zinc in bread and durum wheat genotypes differing in zinc efficiency. Plant and Soil, 180: 173-181.
8. Graham, R.D. and Z. Rengel, 1993. Genotypic variation in Zn uptake and utilization by plants *In*: A.D. Robson, (*Ed*). Zinc in Soils and Plants. Kluwer Academic Publishers, Dordrecht, The Netherlands. pp: 107-114.
9. Hoagland D.R. and D.J. Arnon, 1950. The water-culture method for growing plants without soil. Circ. 347. Univ. of Calif. Agric. Exp. Station, Berkley.
10. IRRI, 1980. The International Rice Research Institute, Standard Evaluation System for Rice. P.O. Box 933, Manila, Philippines, pp: 36-37.
11. Jackson, M.B., 1993. Are plant hormones involved in root to shoot communication? Advances in Botanical Research, 42: 509-513.
12. Natesan, A. and Senthil Kumar, 2001. Studies on zinc use efficiency in wheat genotypes. Division of Plant Physiology, IARI, New Delhi.
13. Norvell, W.A. and R.M. Welch, 1993. Growth and nutrient uptake by barley (*Hordeum vulgare* L. cv. Herta): Studies using an N – (2-hydroxyethyl) ethylene dinitriloacetic acid buffered nutrients solution technique. 1. Zinc ion requirements. Plant Physiology, 101: 619-625.
14. Paivoke, A., 1983. The long term effect of zinc on growth and development, chlorophyll content and nitrogen fixation in the garden pea. Annuals of Botanical Fenn., 20: 205-213.
15. Rengel, Z. and R.D. Graham, 1995. Wheat genotypes differ in zinc efficiency when grown in the chelate buffered nutrient solution. I. Growth. Plant and Soil, 176: 307-316.
16. Rengel, A. and V. Romheld, 2000. Root exudation and Fe uptake and transport in wheat genotypes differing in tolerance to Zn deficiency. Plant and Soil, 222: 25-34.
17. Rengel, Z., V. Romheld and H. Marschner, 1998. Uptake of zinc and iron by wheat genotypes differing in tolerance to zinc deficiency. Journal of. Plant Physiology, 152: 433-438.

Systat, 2003. www.spss.com/software/science/systat