Journal of the Arkansas Academy of Science

Volume 28 Article 14

1974

Zinc Nutrition of Rice Plants as Influenced by Seed Germinated in Zinc Solutions

Narsimaha R. Kasireddy
University of Arkansas, Fayetteville

Lyell F. Thompson
University of Arkansas, Fayetteville

Zinc Nutrition of Rice Plants as Influenced by Seed Germinated in Zinc Solutions

NARSIMAHA R. KASIREDDY and LYELL F. THOMPSON
Department of Agronomy, University of Arkansas, Fayetteville, Arkansas 72701

ABSTRACT

In recent years a physiological disorder of rice (*Oryza sativa* L.) seedlings growing in soils high in exchangeable calcium has been diagnosed as zinc deficiency. Calculations show that less than 30 g of zinc is needed to satisfy the nutrition of a hectare of 6-8-wk-old rice plants. Rice seed was soaked and germinated in dilute solutions of zinc ethylenediamine tetraacetate, zinc sulfate and zinc lignosulfonate prior to planting in greenhouse pots containing a zinc-deficient soil. The rice plants grown from the zinc-treated seed produced more growth and sorbed more zinc than rice plants grown from untreated seed.

INTRODUCTION AND REVIEW OF LITERATURE

Rice (*Oryza sativa* L.) grown on soils high in exchangeable calcium in the southern U.S. rice belt has been plagued with chlorosis for several years. According to Place (1969), in a typical chlorosis situation, rice seeded on these soils germinates and grows normally until the initial flood is applied, then within two to seven days after flooding the rice seedlings begin to lose their turgidity, become chlorotic and may die. Tanaka and Yoshida (1970) and Westfall et al. (1971) described these symptoms in rice and attributed them to either zinc deficiency or lime-induced iron deficiency. Place (1969) indicated that iron chelates had no effect on the chlorosis of these rice plants.

In 1966 Zn deficiency was reported for the first time under field conditions at the International Rice Research Institute (1970). Since that time IRRI (1971), Westfall et al. (1971), Wells et al. (1973) and Thompson and Wells (1974) have reported on the response of rice to Zn. These reports all indicated that Zn deficiency is most likely to occur in rice growing on alkaline (or calcareous) soils under flooded conditions. These researchers recommend additions of approximately 8-12 kg of Zn (elemental) per hectare as inorganic Zn for normal rice production on such soils. However, the writers' calculations show that less than 30 g of Zn is needed to satisfy the nutrition of a hectare of 6-8-wk-old rice plants; chlorotic rice seedlings that live through the 6-8-wk period usually recover and produce nearly normal yields (Wells et al., 1973). If this quantity of zinc could be sorbed into the 120 kg of seed normally planted per hectare the need for soil applications of Zn could be reduced and the risk of excessive accumulation of soil Zn from continuous Zn applications to the soil would be eliminated.

It was reasoned that the organic solvent dimethyl sulfoxide (DMSO) might facilitate the sorption of Zn compounds into the seed. Jacob et al. (1964) described the unique quality of DMSO in penetrating organic membranes. Estes (1969), Garren (1967), Leonard (1967) and Schmid (1968) also showed that DMSO can serve as a carrier in transporting dissolved chemicals into living tissue.

The objective of this experiment was to determine whether rice seed germinated in Zn solutions would absorb enough Zn to satisfy the requirements of rice seedlings grown on a Zn-deficient soil.

Published with the approval of the Director of the Arkansas Agricultural Experiment Station.

MATERIALS AND METHODS

Surface soil from a Zn-responsive Crowley silt loam near the Rice Branch Experiment Station at Stuttgart, Arkansas, was used at the test soil. The soil had a pH of 7.9 and a neutral N NH_4OAc extractable calcium level of 1,488 ppm. After being dried, crushed and uniformly mixed it was placed in 15-cm plastic pots at 2.5 kg per pot. Nine different Zn seed treatments were prepared; there were four replications. Five grams of "Bluebelle" cultivar rice seed was sprouted in a germinator in each of the nine different Zn solutions, each containing 1% DMSO, prepared with three different concentrations of Zn ethylenediamine tetraacetate, $ZnSO_4$ and Zn lignosulfonate. The seed was germinated in just the quantity of solution that would be absorbed entirely by the germinating rice.

The rates of Zn sorbed by the germinating seed were equivalent to 2.17, 11.25 and 45 g of Zn/ha at rice seeding rates of 120 kg seed/ha. After soaking for 48 hr, 12 germinated seeds were transplanted into each pot. A comparison treatment which contained 7.5 ppm of Zn as $ZnSO_4$ mixed with the soil was also included. Urea N, and K as K_2SO_4, were applied to the soil at a rate of 25 ppm 40 days after seeding. The plants were harvested 69 days after planting, dried, ground in a stainless steel Wiley mill, wet digested and analyzed for Zn, Fe and Mn by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Plants grown from Zn-treated seed were visually taller and greener than those in the non-Zn check treatment group. Typical chlorotic Zn deficiency symptoms appeared on the check plants about 4 wk after seeding. Fewer plants survived in the check treatment group, and the highest rate of Zn lignosulfonate had a marked effect on survival (Table I). Dry weight yields (Table II) show a significant response to zinc, with increasing rates of zinc generally increasing yields. There were no differences from Zn sources. Both Zn concentration (Table III) and in Zn uptake per pot (Table IV) were increased significantly by the Zn treatments, with $ZnSO_4$ and Zn lignosulfonate being superior to Zn EDTA. Data in Table III show that the low rate of Zn tended to increase Fe concentration in the tissue, but higher rates of Zn tended to progressively decrease Fe concentration; however, this effect was not significant. Zn had no effect on Mn content of the rice tissue.

More recent investigations by the junior author indicate that the very dilute DMSO concentration was not necessary or helpful in increasing Zn sorption into the rice seed.

These data show that very small quantities of Zn sorbed into the germinating rice seed reduce Zn-deficiency chlorosis and increase seedling survival, plant growth and Zn concentration and uptake. This method of Zn fertilization needs additional investigation under both greenhouse and field conditions.

Table I. Effect of Rates and Sources of Zn Absorbed into Rice Seed on Number of Rice Plants Harvested per Pot

Zn treatment (g)		Av. No. Plants/Pot*		
Per kg Seed	Per 10^6 kg Soil	Zn EDTA	Zn SO_4	Zn Lignosulfonate
0	0		4.70e	
0.025	1.263	8.25b	7.25bc	6.50cd
0.100	5.050	5.00ef	7.00bc	7.00bc
0.400	20.20	6.25cde	5.50def	10.25a
	7500.0 Zn mixed with soil 7.25bc			

*Means followed by the same letters are not significantly different at the 0.05 probability level.

Table II. Effect of Rates and Sources of Zn Absorbed into Rice Seed on Dry Matter Yield of Rice Plants

Zn Sorbed (g) Per kg Seed	Dry Matter Yield (g/pot)*		
	Zn EDTA	Zn SO_4	Zn Lignosulfonate
0		2.89c	
0.025	3.46b	3.40b	3.96a
0.100	3.88a	3.84a	2.62cd
0.400	3.89a	3.97a	3.28b
7.5 ppm Zn mixed with soil	4.02a		

*Means followed by the same letter are not significantly different from at the 0.05 probability level.

Table III. Effect of Rates and Sources of Zn Absorbed into Rice Seed on Zinc, Iron and Manganese in Rice Tissue

Source	Zn Sorbed (g) Per kg Seed	Parts Per Million* Zn	Fe	Mn
Check	0	6.25cd	30.00	244.67
Zn EDTA	0.025	5.25d	56.25	294.50
	0.100	7.75bcd	39.50	309.50
	0.400	7.50bcd	33.00	237.15
$ZnSO_4$	0.025	5.25d	42.00	159.00
	0.100	7.00bcd	33.00	159.00
	0.400	10.50abc	32.00	201.25
7.5 ppm Zn mixed with soil		13.25a	28.50	208.50
Zn Lignosulfonate	0.025	8.25bcd	35.00	199.00
	0.100	11.25ab	32.25	199.50
	0.400	11.50ab	29.00	288.75

*Means followed by the same letter are not significantly different at the 0.05 probability level.

Table IV. Effect of Rates and Sources of Zn Absorbed into Rice Seed on Zn Uptake by Rice Plants

Zn Sorbed (g) Per kg Seed	Zn Uptake (mg/pot)*		
	Zn EDTA	$ZnSO_4$	Zn Lignosulfonate
0		0.017e	
0.025	0.018de	0.024cde	0.032bcd
0.100	0.032bcde	0.021de	0.029bcde
0.400	0.029bcde	0.041a	0.037abc
7.5 ppm Zn as $ZnSO_4$ mixed with soil		0.052a	

*Means followed by the same letters are not significantly different at the 0.05 probability level.

LITERATURE CITED

ESTES, G.O. 1969. The influence of dimethyl sulfonide (DMSO) on growth and uptake of nutritive elements in *Phaslolus vulgaris* L. and *Solanum tuberasum* L. Thesis, Oregon State Univ.

GARREN, RALPH. 1967. Uptake and distribution of labeled dimethyl sulfonide and its influence on nutritive element transport in plants. Ann. N.Y. Acad. Sci. 141.

INTERNATIONAL RICE RESEARCH INSTITUTE. 1970. Annual Report for 1969. IRRI, Los Banos, The Philippines. p. 155-161.

INTERNATIONAL RICE RESEARCH INSTITUTE. 1971. Annual Report for 1970. IRRI, Los Banos, The Philippines. p. 31-40, 102-106.

JACOB, S.W., M.G. BISCHEL and R.J. HERSCHLER. 1964. Sulfonide (DMSO): a new concept in pharmacotherapy. Current Therap. Res. 6(2). 134-135.

LEONARD, C.D. 1967. Use of dimethyl sulfonide as a carrier for iron in nutritional foliar sprays applied to citrus. Ann. N.Y. Acad. Sci. 141.

PLACE, G.A. 1969. Relationship of iron, manganese, and bicarbonate to chlorosis of rice grown in calcareous soil. Ark. Agr. Exp. Sta. Rept. Series 175.

SCHMID, W.E. 1968. On effects of DMSO in cation transport by excised barley roots. Am. J. Botany 55:757-61.

TANAKA, A., and S. YOSHIDA. 1970. Nutritional disorders of the rice plant in Asia. Int. Rice Res. Ins. Tech. Bull. 10.

THOMPSON, LYELL, and B.R. WELLS. 1974. Zinc fertilization of rice on some Arkansas soils. Ark. Farm Research 23(2).

WELLS, B.R., LYELL THOMPSON, G.A. PLACE and P.A. SHOCKLEY. 1973. Effect of zinc on chlorosis and yield of rice grown on alkaline soil. Ark. Agr. Exp. Sta. Rept. Series 208.

WESTFALL, D.G., W.B. ANDERSON and R.J. HODGES. 1971. Iron and zinc response of chlorotic rice grown on calcareous soils. Agron. J. 63:702-705.