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THE RELATIVE EFFICIENCY OF ZINC CARRIERS ON GROWTH AND ZINC NUTRITION OF CORN

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KEY WORDS

Corn Diffusion coefficient Organic manure Zn–DTPA Zn–EDTA Zn-fulvate

SUMMARY

A comparison of different zinc carriers showed that application of Zn–DTPA, Zn–EDTA, Zn-fulvate and $ZnSO_4$ significantly increased the dry matter yield and zinc uptake by corn over the control treatment where no zinc was applied. The chelates in particular enhanced to a greater extent the uptake of both native and applied sources than that observed with $ZnSO_4$ as the zinc carrier. Both the dry matter yield and zinc uptake by corn showed a positive and significant relationship with self-diffusion coefficient of zinc showing thereby that diffusion contributed mainly the supply of Zn from the ambient soil matrix to plant roots. The effectiveness of the chelates varied depending on their capacity to retain Zn in a soluble form in the soil solution.

It is evident that zinc nutrition of plants in alkaline and calcareous soils can be more effectively regulated by both synthetic and natural chelates or organic manures which contain substantial amount of complexed zinc.

INTRODUCTION

Both synthetic and natural chelates augment the availability of micronutrient cations to plants from the soil by enhancing both diffusive and convective flow of nutrients to surface of plant roots[2,4,7,9,10].

Anderson reported[1] the relative effectiveness of different zinc carriers in augmenting crop growth to vary in the order: Zn–DTPA > Zn–EDTA > Zn–EDDHA > $ZnSO_4$ > Zn-Rayplex (polyflavonoid). The slight superiority of Zn–DTPA over Zn–EDTA in a calcareous soil near pH 8.0 is predicted from chelate-stability-diagram[4].

The objectives of this study were (i) to investigate the relative efficiency of both

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natural and synthetic zinc chelates in augmenting the growth and zinc nutrition of corn (ii) to determine the contribution of the diffusive transport of Zn from the bulk of soil mass to plant root surface which in turn affects the dry matter production and zinc uptake by the corn crop.

EXPERIMENTAL

Greenhouse study

A pot culture experiment was conducted to compare the relative efficiency of different zinc chelates in augmenting the growth and zinc nutrition of corn (*Zea mays* L.). The characteristics of the soil used are presented in Table 1. DTPA extractable micronutrients were determined according to method described by Lindsay and Norvell[5].

The treatments included five different sources such as Zn–DTPA, Zn–EDTA, Zn-citrate, Zn-fulvate and $ZnSO_4$; each supplying three levels of zinc (1.25, 2.5, and 5 ppm). All the sources were tagged with the ^{65}Zn isotope (20 μci/mg Zn) to determine the relative contribution of the applied and native sources of Zn to plant growth. Zn-fulvate was prepared by adding AR grade $ZnSO_4$ tagged with ^{65}Zn in equimolar quantities. The molecular weight of fulvic acid was 906 whereas ratio Zn/fulvic acid was 1:1.

Plastic buckets were filled with 3 kg of processed soil. A basal dose of 45 mg N, 45 mg P_2O_5 and 45 mg K_2O per pot from AR grade inorganic salts, urea, KH_2PO_4 and KCl respectively were added in solution form and thoroughly mixed with soil. Six healthy seeds of corn were sown in each pot at proper moisture conditions. After germination; plants were thinned to three eliminating week plants. One more dose of nitrogen @ 45 mg N/pot was applied after 30 days of crop growth.

The crop was harvested after 45 days growth. The plants were washed in 0.1 *N* HCl followed by washing with deionized water. Samples were dried in an oven at 65°C for 48 hours, weighed and ground in a stainless steel blender. Representative samples were digested in the tri-acid mixture (HNO_3:$NClO_4$:H_2SO_4 = 10:3:1) and total zinc determined on atomic absorption spectrophotometer. An aliquot (2 ml) of the plant extracts and the zinc carriers was analysed for radioactive zinc on a well type scintillation head on a gamma ray spectrometer and the following calculations were made:

(i) Percent Zn derived from the applied source =

$$= \frac{\text{Sp. act. of samples at zero hour} \times 100}{\text{Sp. act. of the added source at Zero hour}}$$

(ii) Percent utilization of the applied source =

$$= \frac{\text{mg Zn in plant from applied/pot} \times 100}{\text{mg Zn in added to soil/pot}}$$

The data obtained from the greenhouse study were processed and analysed statistically[8].

Table 1. Chemical characteristics of alkaline soil

Mechanical composition (%)			Textural class	C.R.C. (meq/100 g)	pH	O.C.	DTPA-extractable micronutrients (ppm)			
Sand	Silt	Clay					Fe	Cu	Zn	Mn
80.6	8.6	9.4	Loamy sand	6.2	8.4	0.18	5.6	0.28	0.48	8.1

Self-diffusion coefficient of zinc

The self-diffusion coefficient of zinc in soil was determined by combination of the methods described by Elgawhary *et al.*[2] and Melton *et al.*[6]

RESULTS AND DISCUSSION

The experimental results on the evaluation of the relative efficiency of Zn–DTPA, Zn–EDTA, Zn-citrate, Zn-fulvate and $ZnSO_4$ in augmenting the dry matter yield and zinc uptake by corn crop in a zinc deficient alkaline soil are presented in Table 2 and Fig. 1. It is evident that application of $ZnSO_4$ and Zn-chelates significantly enhanced the yield of dry matter. Application of varying levels of the

Table 2. Relative efficiency of Zn-chelates and $ZnSO_4$ on dry matter yield (g/pot) of corn

Sources	Zinc levels (ppm)			Mean
	1.25	2.50	5.00	
$ZnSO_4$	22.14 (169)	22.78 (177)	24.05 (192)	22.99 (179)
Zn-CIT	26.77 (225)	29.35 (256)	27.18 (230)	27.77 (237)
Zn–FA	26.55 (222)	30.36 (268)	29.61 (259)	28.84 (250)
Zn–EDTA	26.20 (218)	28.19 (242)	29.85 (262)	28.08 (241)
Zn–DTPA	29.19 (254)	32.61 (296)	38.17 (363)	33.32 (304)
Mean	26.17 (218)	28.54 (248)	29.77 (261)	
Control yield	8.24			

F-test for significance	+ S.E.M.	C.D. (0.05)	C.D. (0.01)
Control *vs* treatments	2.033**	4.15	5.57
For sources	0.994**	1.93	2.60
For levels	1.406	2.87	3.87
For interaction	0.703	N.S.	N.S.

** Highly significant; N.S. – non significant.
Bracketed figures indicate percent increase over control.

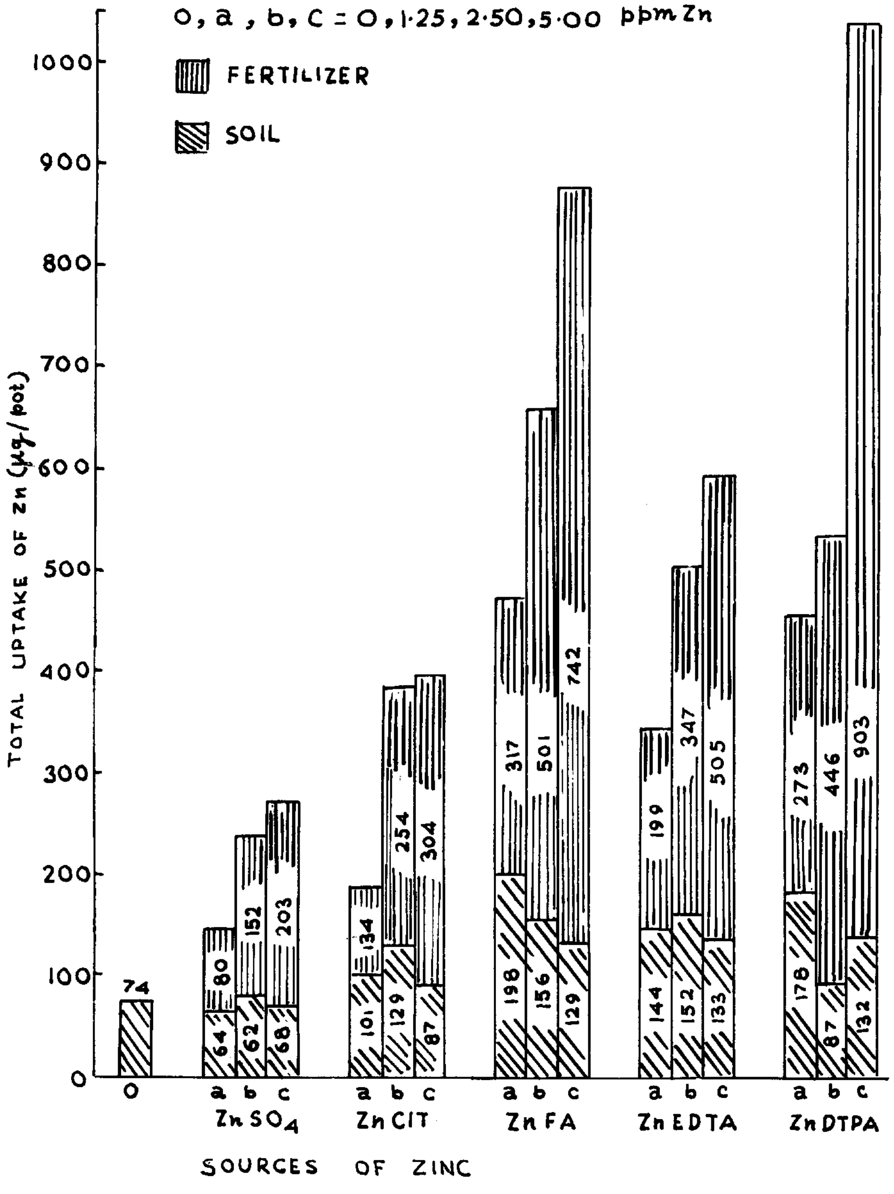

Fig. 1. Effect of natural and synthetic Zn-chelates on the uptake of zinc from soil and ^{65}Zn-labelled sources.

different zinc sources increased the yield ranging between 169 to 363 per cent over the yield in the control treatment. In case of zinc supplied as different sources, yield increase ranged between 254 to 363 per cent with Zn-DTPA, 222 to 268 per cent with Zn-fulvate, 218 to 262 per cent with Zn–EDTA, 225 to 256 per cent with Zn-citrate and 169 to 179 per cent with $ZnSO_4$. The increase in dry matter yield was highly with successive doses of Zn-citrate and Zn-fulvate up to 2.5 ppm and with Zn–EDTA and Zn–DTPA upto 5.00 ppm. The yield declined beyond the 5.0 ppm level of zinc application of the sources.

A quadratic equation defining the relationship between dry matter yield and doses of applied zinc was computed.

$$y = 99.83 + 79.58x - 11.88x^2 \; (r = +0.777)$$

Thus parallel to the increase in yield, significant enhancement of the total uptake of zinc was noted after the application of different Zn-chelates and $ZnSO_4$. The results indicate that the increase in total removal of zinc was highly significant

Table 3. Percent zinc in plants and percent utilization from ^{65}Zn-labelled sources

Zn-levels (ppm)	Per cent zinc derived from applied					
	Zn–DTPA	Zn–EDTA	Zn–FA	Zn–CIT	$ZnSO_4$	Mean
1.25	58 (7.3)	58 (5.3)	61 (8.4)	57 (3.6)	55 (2.1)	58 (5.3)
2.50	84 (5.9)	69 (4.6)	77 (6.7)	66 (3.4)	65 (2.0)	72 (4.5)
5.00	87 (6.0)	79 (3.4)	88 (6.0)	78 (3.0)	75 (1.8)	81 (4.0)
Mean	76 (6.4)	69 (4.4)	75 (7.0)	67 (3.3)	65 (2.0)	

F-test for significance	± S.E.M.	C.D. (0.05)	C.D. (0.01)
For sources	2.6** (0.34**)	7.6 (0.73)	10.2 (0.99)
For levels	3.7** (0.51**)	5.4 (1.04)	7.2 (1.39)
For interaction	1.9 (0.25)	3.8 N.S. (0.52) N.S.	5.1 N.S. (0.67) N.S.

** Highly significant; N.S. – non significant.
Bracketed figures indicate percent utilization of applied zinc.

with Zn–DTPA, Zn–EDTA and Zn-fulvate as the sources of zinc. The two carriers Zn-citrate and $ZnSO_4$ gave significant increases at 1.25 and 2.5 ppm levels only.

The data pertaining to the effect of different sources at varying levels of application on the per cent zinc in plants derived from the applied sources and the per cent utilization of applied zinc are presented in Table 3.

The results suggest that the relative uptake of applied zinc increased with increase in the level of applied zinc for all sources. A significant difference of different sources and levels of zinc was noted for per cent uptake of zinc from the applied sources. The extent to which isotopic exchange takes place between the labelled zinc chelates and soil is an important factor affecting the efficiency of the zinc sources. It varies depending on the amounts of labile from of native Zn and that of the Zn-chelates.

It seems reasonable to assume that with any particular chelate the rate of isotopic exchange will depend largely on the concentration of soluble zinc in the soil solution in equilibrium with diverse organic and inorganic native solid phases. The data showed that both Zn-DTPA and Zn–FA were subject to relatively higher degree of isotopic dilution in the root environment of the corn crop than other Zn carriers used in this investigation.

The data in Table 3 also indicate that the utilization of the applied zinc differed

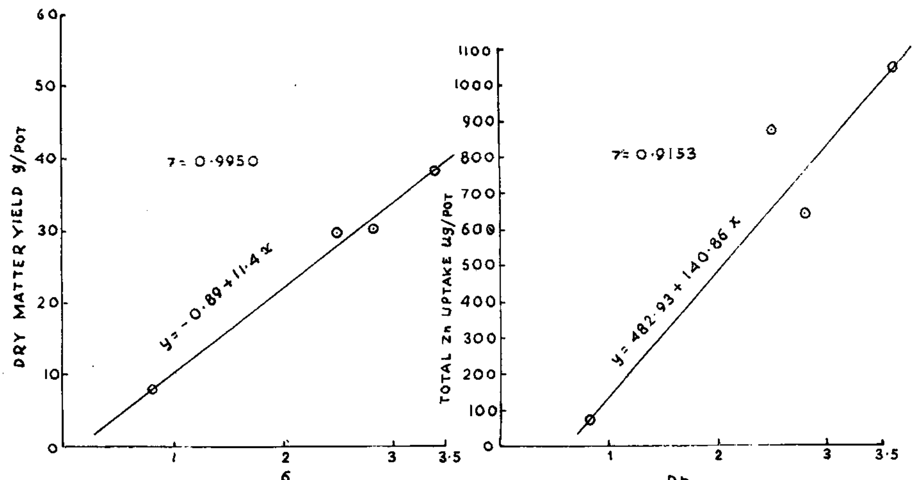

Fig. 2. The relationship between self-diffusion coefficient of Zn and dry matter yield and uptake of Zn by corn crop.

highly significantly between the sources and it also differed highly significantly between the levels of zinc. At all graded levels of applied zinc, the values for both per cent zinc in plants derived from the fertilizers and per cent utilization of the native zinc are higher with Zn–DTPA, and Zn–FA in comparison to that with the rest of the sources used.

The relationship between the self-diffusion coefficient of Zn and dry matter yield and uptake of zinc by the corn crop are depicted in Fig. 2. The dry matter yield and zinc uptake showed a linear relationship. A positive and highly significant correlation ($r = +0.995$) was obtained between the self diffusion coefficient of Zn and the dry matter yield of corn. The uptake of zinc and the self-diffusion coefficient of Zn also showed positive and significant correlation ($r = +0.915$).

This suggests that diffusion is the main mechanism contributes to the zinc nutrition of crops in alkaline and calcareous soils which quite frequently suffer from zinc deficiency. The added Zn-chelates evidently increased the concentration gradient of zinc towards the corn roots. The calculated equilibrium concentration of soluble Zn in soil solution with Zn–DTPA, Zn–FA, Zn–EDTA and free Zn^{2+} with the application of 5 ppm of the different carriers of zinc in this soil (pH 8.4) ranged from 1125 to 1.03 ppb respectively. This supports the contention that application of chelated Zn sources enhances the diffusive flow and the uptake of zinc by the roots of crops.

The relative efficiency of the different zinc sources in affecting yield, total Zn uptake, per cent derived from applied sources and per cent utilization of the native Zn varied in the following order: Zn–DTPA > Zn–FA > Zn-EDTA > Zn-citrate > $ZnSO_4$.

These results further show that the zinc nutrition of plants in alkaline and calcareous-zinc-deficient soils can be effectively regulated by using natural or synthetic zinc chelates. However, the economics of the two kinds of sources remains to be determined by conducting field experiments with zinc sensitive crops.

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