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CHELATION IN NUTRITION

Chelates and the Trace Element Nutrition of Corn

LEON CHESNIN

Department of Agronomy,
University of Nebraska,
Lincoln, Neb.

THERE has been a growing recognition of the need for micronutrients for crop production. In a survey conducted by the Micronutrient Committee of the American Council on Fertilization Application (*1*), research investigators reported the existence of zinc deficiency of corn in 20 states in the U. S., while iron deficiency of corn was observed in three states. The need for supplying iron for crop production in Nebraska was recognized in the early 1930's. However, the existence of zinc deficiency of crops in Nebraska was diagnosed by the author as recent as 1954. Since that time, zinc deficiency of corn has been found in every area of Nebraska where the crop is grown (*2*). This problem is associated mainly with the loss of soil organic matter by erosion, or by land grading for irrigation or terrace construction. Iron deficiency is generally found in soils with pH values above 7.0 under conditions of high moisture and poor aeration. This situation is generally associated with bottomland fields that have a high water table in the spring. Poor soil drainage tends to result in iron deficiency. In upland and bottomland fields, the presence of calcium carbonate reduces the availability of iron in the soil.

A number of materials have appeared on the market for use in correcting deficiences of iron and zinc. These materials are both inorganic and organic in nature. Iron chelates have been used successfully to correct iron deficiency of fruit and ornamentals as well as soybeans (*7*). Viets (*6*) has indicated that any zinc compound that will dissolve in dilute hydrochloric acid is satisfactory as a fertilizer for soil application. There has been little information on the comparative effectiveness of iron and zinc chelates on the growth of corn. This report concerns information obtained at the University of Nebraska on the utilization of iron and zinc chelates by corn grown in a greenhouse environment. The results of these studies may be influenced by the fact that chelating agents may have stimulating effects upon the growth of plants (*5, 7*) and that interrelationships of micronutrients have been shown to

Corn was grown in solution culture media in the greenhouse and supplied iron in the form of EDTA, DTPA, HEDTA, and EDDHA. Maximum weight of corn tops decreased with the addition of iron in the following sequence and at the optimum concentration for each: HEDTA, EDTA, DTPA, and EDDHA. The proportion of iron taken up by the plants that was translocated from the roots to the tops varied with the form and concentration of the iron supplied to the plants. In another study, corn grown in a zinc-deficient soil in the greenhouse was supplied zinc in organic and inorganic forms. Corn plants supplied zinc in organic form produced more vegetative yield and contained more zinc than plants supplied the same amount of zinc in the sulfate form. There were differences in the effectiveness of the organic sources of zinc.

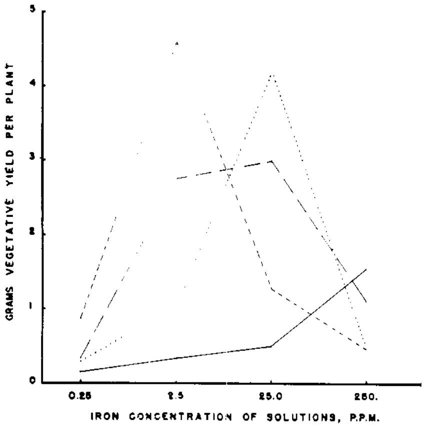

Figure 1. Dry matter production of Wf9 × Hy corn plants supplied varying concentrations of iron in chelated forms in nutrient solutions

—— EDDHA; — — DTPA; - - - HEDTA; . . . . EDTA

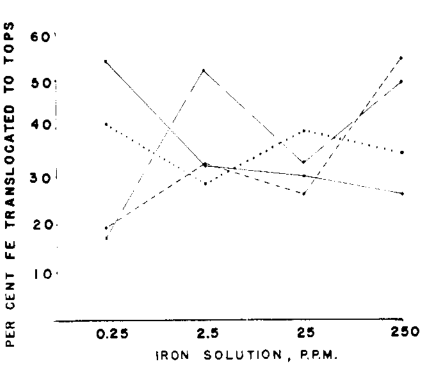

Figure 2. Percentages of the total amount of chelated forms of iron taken up by Wf9 × Hy corn from nutrient solutions that was translocated to the tops

—— EDDHA; — — DTPA; - - - HEDTA; . . . . EDTA

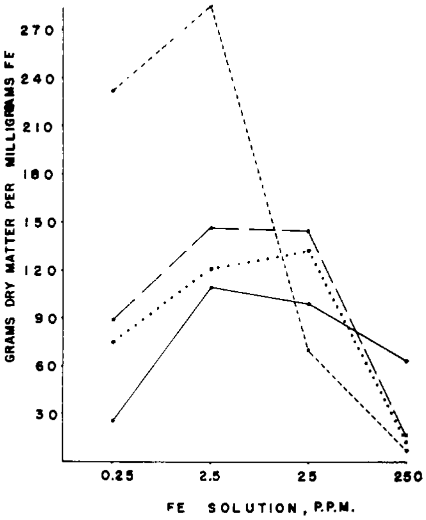

Figure 3. Dry matter production of Wf9 × Hy corn tops in grams per milligram of iron in the tops

—— EDDHA; — — DTPA; - - - HEDTA; . . . . EDTA

be important in the growth of corn in a sand culture media (*3*).

Chelated Iron Nutrition of Corn

Utilization of chelated forms of iron by single-cross corn was studied using solution culture media. Plants were supplied a Hoagland and Arnon (*4*) No. 1 nutrient solution. Iron was supplied to the nutrient solutions in the form of EDTA, DTPA, HEDTA, and EDDHA. The amount of iron supplied was in a logarithmic concentration scale of 0.25, 2.5, 25, and 250 p.p.m. to cover the range of deficiency to excess. Wf9 × Hy corn seedlings were grown in the aerated nutrient solutions for 4 weeks. At harvest, the roots and tops were washed in dilute HCL solution to remove surface contamination with iron. The plant material was then washed in detergent solution and rinsed in distilled water. The plant material was dried in an oven at 70° C.

At harvest, chlorosis was evident in all plants supplied the lowest concentration of chelated iron. At the highest concentration of iron in the solutions as EDTA, HEDTA, and DTPA, plants showed strong toxic effects in the form of necrotic tissue. Iron supplied in EDDHA form resulted in slight evidence of toxicity at the highest concentration in the nutrient solutions.

Dry matter production of the tops of the corn plants was measured (Figure 1). Maximum production of dry matter by the corn plants was obtained at the 2.5 p.p.m. of iron concentration in the HEDTA form. When iron was supplied in the EDTA or DTPA forms, maximum dry matter production was obtained at the 25 p.p.m. concentration of iron. Dry matter production increased with increasing concentration of iron as EDDHA in the nutrient solutions. Maximum dry matter production of the corn plants decreased with the addition of iron in the following sequence of chelated forms: HEDTA, EDTA, DTPA, and EDDHA at the optimum concentration for each.

The iron contents of the plant roots and toys were determined. The percentage of the total amount of iron taken up by the plants that was translocated from the roots to the tops of the corn plants was calculated (Figure 2). An increase in the concentration of iron as EDTA in the nutrient solution had little effect on the percentages of the iron taken up by the plants and then translocated to the tops. There was a tendency for a greater proportion of the iron supplied in the form of HEDTA to be translocated to the tops of the corn plants with increasing concentration in the nutrient solutions. With the DTPA form of iron, there was a tendency also for increased translocation of iron to the tops with concentrations of iron in the nutrient solutions above the lowest level. However, the percentage of iron translocated to the tops tended to decrease with increasing concentration of iron as EDDHA in the nutrient solutions.

Trace elements supplied to plants deficient in these nutrients generally have a marked effect in stimulating the growth of the plants (*7*). While micronutrients generally function in plant enzyme systems that are involved in metabolic processes, the mere presence of the nutrient does not necessarily assure the end result of growth. Plants showing extreme symptoms of iron

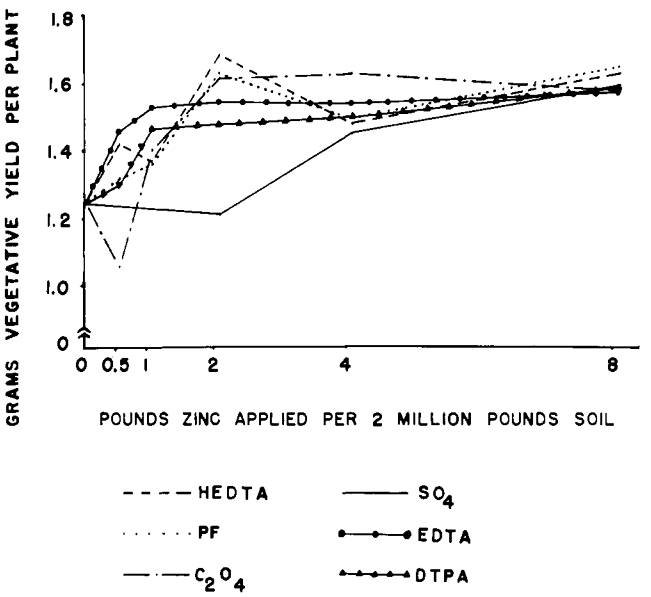

Figure 4. Vegetative yield of corn in grams

Mean values for two single-cross corn hybrids, Wf9 X Hy and N6 X N15, as influenced by soil applications of organic and inorganic zinc carriers

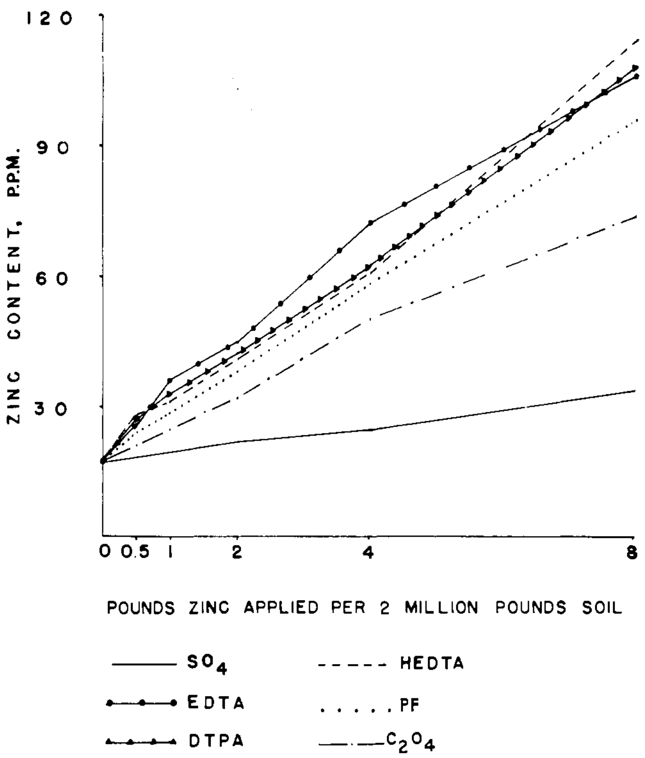

Figure 5. Zinc content of corn tops in p.p.m.

Mean values for two single-cross corn hybrids, Wf9 X Hy and N6 X N15 as influenced by soil applications or organic and inorganic zinc carriers

deficiency may have a higher iron content than normal-appearing plants. It has been interpreted that the deficient-appearing plant cannot utilize the form of iron it contains in metabolic activity.

Micronutrients are generally supplied to plants by foliage and soil applications to obtain optimum growth in terms of vegetative dry matter or seed production. The effectiveness of the trace element source in stimulating growth is evaluated in terms of the amount applied. However, in the case of soil applications, only a portion of the nutrient is taken up by the plant, and only a fraction of this may actually function to correct the nutritional needs of the plant.

The effectiveness of iron used in plant growth was evaluated by determining the grams of top growth of corn produced per milligram of iron translocated to the tops of the plants (Figure 3). In general, the greatest amount of top growth per unit of iron translocated by the plants was obtained at the medium concentrations of iron supplied in the nutrient solutions. Dry matter production per milligram of iron supplied in the DTPA, EDDHA, and EDTA forms tended to be greatest at the 2.5 and 25 p.p.m. concentrations of iron in solution. The HEDTA form of iron was the most effective source for promoting corn growth at the two lowest iron concentrations in this study. However, there was a marked decrease in dry matter production per milligram of iron in the form of HEDTA at the higher concentrations in the solutions. This is related to the fact that at the higher concentrations of HEDTA iron in the solution, the concentration of iron in the tops tended to increase (Figure 2), while dry matter production tended to decrease due to the physiological effects of this concentration of iron in the plants. In general, the effectiveness of the utilization of translocated iron for the growth of corn in this study decreased when iron was supplied to the nutrient solutions in the following forms of chelates: HEDTA, DTPA, EDTA, and EDDHA.

It would appear from this study that Wf9 X Hy corn is not able to utilize iron chelates equally in its metabolic processes.

Chelated Zinc Nutrition of Corn

Corn was grown in the greenhouse for 7 weeks in zinc-deficient soil from western Nebraska. The variables in this investigation were the form and rate of zinc applied as a band below the seed. Zinc was applied to the soil in organic and inorganic forms. The organic forms applied in this investigation included EDTA, DTPA, HEDTA, C_2O_4 (oxalate), and Rayplex Zn (a modified polyflavonoid complex designated as PF). Organic forms of zinc were applied at a rate 0.5, 1, 2, 4, and 8 pounds of zinc per 2 million pounds of soil. Zinc sulfate (designated as SO_4) was used as a standard in this investigation because of its long history in zinc nutrition studies. Zinc was applied in the sulfate form at rates of 2, 4, and 8 pounds of zinc per 2 million pounds of soil. Two single-cross corn hybrids were grown in the pots (Wf9 X Hy and N6 X N15).

In general, the average vegetative yield of corn tended to increase with the application of zinc in both inorganic and organic forms (Figure 4). In the case of organic forms of zinc, dry matter production tended to reach a maximum with application rates of 1 to 2 pounds of zinc per 2 million pounds of soil. The application of zinc in the sulfate form resulted in increased dry matter production up to the rate of 8 pounds per 2 million pounds of soil. These increases in dry matter production due to the application of zinc were highly significant statistically. The corn plants tended to respond in dry matter production to the application of 0.5 pound of zinc in the organic form. However, a growth response was not obtained with the application of 2 pounds of zinc in the sulfate form, but was obtained at the 4 pound rate of application. For dry matter production, the organic carriers were more effective than zinc sulfate as sources of zinc applied to the soil for the growth of corn in zinc-deficient soil in this study.

The zinc content of the corn plants (Figure 5) was determined in p.p.m. by x-ray spectrography. The zinc content of corn increased markedly with increasing rate of application of zinc

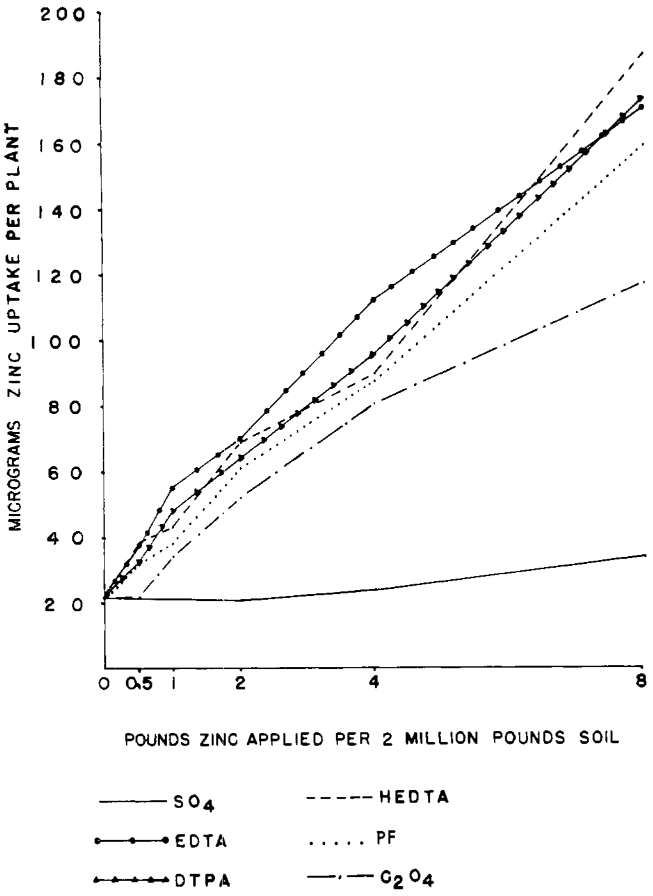

Figure 6. Total uptake of zinc in micrograms per plant in corn tops

Mean values for two single-cross corn hybrids, Wf9 × Hy and N6 × N15, as influenced by soil applications of organic and inorganic zinc carriers

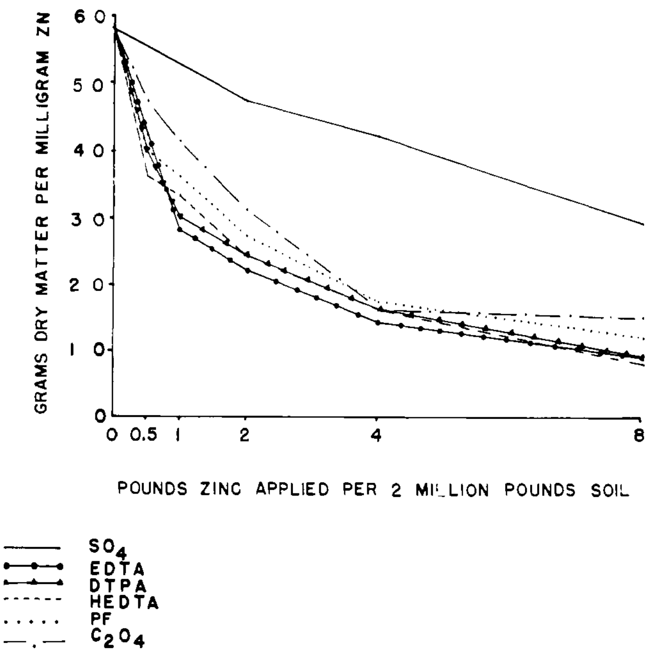

Figure 7. Dry matter production of corn tops in grams per milligram of zinc in the tops

Mean values for two single-cross corn hybrids, Wf9 × Hy and N6 × N15

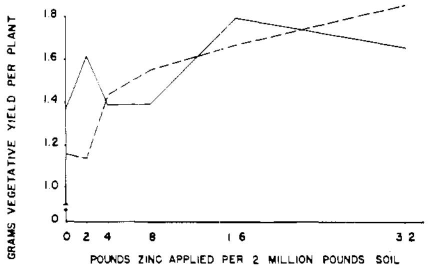

Figure 8. Dry matter production in grams of two single-cross corn hybrids, Wf9 × Hy (- -) and N6 × N15 (——), as influenced by soil applications of zinc sulfate

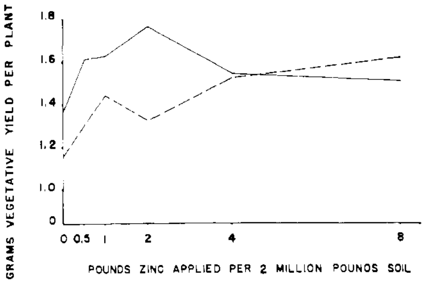

Figure 9. Dry matter production in grams of two single-cross corn hybrids Wf9 × Hy (- -) and N6 × N15 (——), as influenced by soil applications of zinc EDTA

in the organic forms. However, the application of zinc in the sulfate form had very little effect on the zinc content of the plants until more than 4 pounds of zinc were applied per 2 million pounds of soil. There were considerable differences in the composition of corn plants supplied the various sources of zinc as indicated by the slopes of the curves for zinc content of the corn tops. The zinc content of corn plants was influenced more by the EDTA, DTPA, HEDTA, PF, and C_2O_4 sources of this nutrient than by the SO_4 source.

The total amount of zinc taken up by the corn plants and translocated to the tops was calculated from the data on yield and zinc content (Figure 6). Zinc uptake by corn supplied the various carriers used in this investigation plotted as a family of curves that were very similar to the curves obtained for zinc content of the plants (Figure 5) in p.p.m. The total amount of zinc taken up by the plants increased with increasing rate of zinc application of the organic materials. In the case of zinc supplied as the sulfate form, there was no appreciable increase in zinc uptake by corn until the application rate exceeded 4 pounds of zinc per 2 million pounds of soil. Zinc uptake was greatest with the application of the EDTA, DTPA, HEDTA, PF, and C_2O_4 forms of this nutrient, as compared to the application of SO_4 form.

The effectiveness of zinc used in plant growth was evaluated by determining the grams of top growth produced per milligram of zinc translocated to the tops of the corn plants (Figure 7). In general, there was a tendency for the dry matter production per milligram of zinc in the tops to decrease with increasing rate of application of the organic and inorganic source of zinc. With the application of organic sources of zinc to the soil, a family of curves was obtained from the values for dry matter produced per milligram of translocated zinc which appeared to be reciprocal values of normal growth curves. The highest values were obtained from the unfertilized plants. Apparently, when zinc content limited plant growth, the stunted plants still had a large proportion of dry matter in comparison to their low zinc content. With the application of zinc to the soil, there was a marked increase in plant growth (Figure 4). However, this was associated with a proportionately greater increase in zinc content of the plants (Figure 5). With further increases in the rate of application of zinc to the soil, there was a decline in the rate of dry matter production, but the zinc content of the plants tended to increase directly with the rate of application. This suggested that there was an excess of zinc taken up by the plants which did not function in growth processes. Applications of zinc in the sulfate form resulted in higher values for dry matter per milligram of zinc in the tops than obtained with the application of zinc in the organic forms. Dry matter production of corn tops was nearly the same at the highest rate of application of all sources of zinc (Figure 4). Nevertheless, the zinc content of the plants fertilized with zinc sulfate at the highest rate of application was much lower than the zinc content of the plants fertilized with the organic materials at the same rate of application. This suggests that while plants take up much less zinc sulfate that is applied to the soil than zinc chelates, the sulfate form is utilized more effectively by the plant in its metabolic processes than the chelate form. However, considering the effectiveness of the total zinc applied to the soil for correcting the nutrient requirements of corn for growth, the organic sources were more effective than zinc sulfate (Figure 4). The organic sources of zinc were not equally effective in this investigation.

A comparison was made of the response of two single-cross corn hybrids (Wf9 × Hy and N6 × N15) to soil applications of SO_4 (Figure 8) and EDTA (Figure 9) forms of zinc. The results indicated that genetic factors are important in the trace element nutrition of this crop. With both carriers, at application rates of 0 to 2 pounds of zinc per 2 million pounds of soil, N6 × N15 produced significantly more growth than Wf9 × Hy. At higher rates of application of zinc, growth differences were not significant.

While a great deal has been learned about the chelate and trace element nutrition of corn, the complexities of the relationships that have been revealed indicate clearly that a complete understanding of the subject is still in the distant future. Many more investigations are needed in which the physical and chemical environment, and genetic factors are controlled.

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