MAINTENANCE OF IRON SUPPLY IN NUTRIENT SOLUTIONS BY A SINGLE ADDITION OF FERRIC POTASSIUM ETHYLENEDIAMINE TETRA-ACETATE

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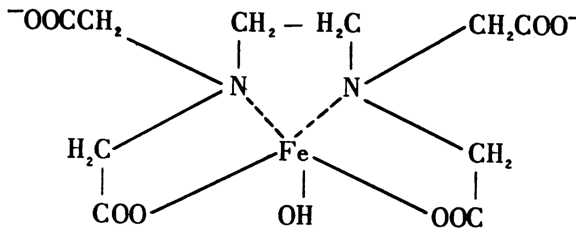
When plants are grown in nutrient solution, invariably special attention must be paid to the problem of providing an adequate supply of available iron. Since iron is readily precipitated by high pH or phosphate, it is customary to add either organic or inorganic salts of iron to the nutrient solution at frequent intervals. HORNER, BURK, and HOOVER (1) developed a synthetic humate capable of holding iron in solution at moderately high pH and phosphate concentrations. Unfortunately, the humate is difficult to prepare and of indeterminate composition. EDGERTON (2) showed that by substituting metaphosphate for the usual orthophosphate in the nutrient solution, the resulting iron metaphosphate complex did not precipitate and was a satisfactory source of iron for plants. However, it may not always be desirable to use the meta instead of the orthophosphate and metaphosphoric acid as generally available contains large amounts of sodium.

Recently ethylenediamine tetra-acetic acid has become commercially available for use as a sequestrant. This substance forms chelated complexes especially with di- and tri-valent ions. SCHWARZENBACH and BIEDERMANN (3) represent the iron complex as:



This complex was examined as a source of iron for plants. Stock solutions were prepared by dissolving the free acid (Sequestrene AA—Alrose Chemical Co., Providence, Rhode Island) in KOH solution in the ratio of one molecule of acid (mol. wt. = 292 gm.) to two molecules of KOH. Iron, as ferrous sulphate, was added in the appropriate amounts to give varying molar ratios of iron to the complexing agent. The solution became quite acid on addition of the iron salt and was adjusted to pH 5.5 with KOH. In the presence of the complexing agent, ferrous iron is oxidized to the ferric form by atmospheric oxygen in a short time. In some cases, the complex was prepared by adding equi-molar ratios of the free acid and KOH to a suspension of freshly prepared excess $Fe(OH)_3$ in water. This was shaken for several days until, after filtration, iron and nitrogen analyses indicated an equi-molar ratio of iron to the ethylenediamine tetra-acetate. The pH was 5.5.

The stability of the complex was tested by adding 5 p.p.m. iron, as the complex, to nutrient Hoagland solution at various pH values. The solutions were allowed to stand three months (no plants present) in the dark, and then the amount of iron left in the solution determined. No loss of iron occurred below pH 6. At pH 7, 18% of the iron had precipitated and at pH 8, 30% had come down. Even at pH 9, precipitation was not complete, about 10% remaining in the solution.

Tomato, sunflower, corn, and barley plants were grown in Hoagland solution (15 liters per five plants) in which the molar ratio of iron to the ethylenediamine tetra-acetate was varied, maintaining the iron constant at 3 p.p.m. The iron complex was added a day or two after the plants were transferred to the nutrient solutions and this was the only addition of iron throughout the experiment. The pH was not controlled and rose from an initial value of 5.5 to a final value of 7.5 or 8. The growth period was approximately six to eight weeks. The yield data are given in table I.

TABLE I

EFFECT OF RATIO OF IRON TO ETHYLENEDIAMINE TETRA-ACETATE ON THE GROWTH OF PLANTS. IRON CONTENT KEPT CONSTANT AT 3 P.P.M.

Molar ratio of iron to complex	Dry weight of plants (gm.)			
	Tomato	Sunflower	Corn	Barley
1:0.1	61.8	59.8	55.9	50.5
1:0.5	58.5	75.9	62.6	55.2
1:1	52.8	75.8	64.2	62.8
1:1.5	52.2	77.5	1.7	33.5
1:2	57.3	78.0	1.9	27.1
1:4	8.6	39.0	1.2	4.1

For general use, an equi-molar ratio of iron to complexing agent seems the most satisfactory. Below this ratio, iron will precipitate out of solution and the plants tend to become chlorotic. Above this ratio, such plants as corn and barley do not grow well.

In another series of experiments, the level of iron was varied, but the ratio of iron to complexing agent was maintained constant at equi-molar proportions. The experiment was carried out as before with plants in 15 liters of Hoagland solution and only one addition of iron. The growth period was approximately five weeks. The yield data are given in table II.

There was some chlorosis in the corn and barley plants grown in solutions containing less than 5 p.p.m. iron. Tomato and sunflower displayed chlorosis only at levels less than 1 p.p.m. Tomato and corn were also grown in solutions which contained from 5 to 100 p.p.m. iron in the form of ferric ethylenediamine tetra-acetate. At 100 p.p.m. iron, both plants were injured,

TABLE II

EFFECT OF CONCENTRATION OF IRON ETHYLENEDIAMINE TETRA-ACETATE ON GROWTH OF PLANTS. IRON AND COMPLEXING AGENT PRESENT IN EQUI-MOLAR PROPORTIONS.

P.p.m. iron as the complex	Dry weight of plants (gm.)			
	Tomato	Sunflower	Corn	Barley
0.01	11.1	28.2	11.3	4.9
0.10	69.6	74.2	26.8	18.4
1.0	76.7	74.5	64.1	24.1
3.0	74.5	77.1	64.0	23.5
5.0	77.7	77.8	62.3	30.6
10.0	82.7	76.2	63.0	33.3

especially in the early growth stages. At 50 p.p.m., some injury was apparent; at 25 p.p.m. or less, the plants grew well and were deep green.

It therefore appears that perhaps 5 or 10 p.p.m. iron as the ethylenediamine tetra-acetate complex provides adequate iron to the plant, is non-toxic and need be added only once.

It is convenient to prepare the complex by dissolving 26.1 gm. ethylenediamine tetra-acetic acid in 268 ml. of 1.0 N KOH, then adding 24.9 gm. $FeSO_4 \cdot 7\,H_2O$ and diluting to one liter. After aerating overnight to produce the stable ferric complex, the pH should be about 5.5. One ml. of this solution provides 5 p.p.m. to one liter of nutrient solution.

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