Certain Aspects of the Nutrition of Tomato Seedlings in Sand Culture

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The present work is a study of the effect on tomato seedlings of the interrelations of the cations and anions present in a three-salt nutrient solution. This was done by means of two triangle systems which have recently been described (2) (4), whereby the anions or cations of a three-salt nutrient solution can be varied and yet have the rest of the nutrient solution constant as desired without the addition of other elements than the original ones. In Triangle I the anions were varied and the cations held constant; in Triangle II the cations were varied and the anions were kept constant.

All of the salts used in the experiment with the exception of the calcium salts were 0.0045 molar concentration; the calcium salts were 0.006 molar. For Triangle I three stock solutions, N, S, and P were prepared. Solution N consisted of potassium nitrate, magnesium nitrate, and calcium nitrate. Solution S consisted of potassium sulfate, magnesium sulfate, and calcium sulfate. Solution P contained monobasic calcium phosphate, potassium dihydrogen phosphate, and monobasic magnesium phosphate.

Plants at one corner of Triangle I were watered with a solution containing only the various nitrate salts; at a second corner with a solution containing only the sulfate salts; and at the third with the solution containing only the phosphate salts, as noted in Figure 1. All intermediate points were watered with solutions made by mixing together various amounts of these three stock solutions so that each point on the triangle varied by 1/6 from every other point.

In Triangle II, three stock solutions, M, K, and C were used. M consisted of magnesium nitrate, magnesium sulfate, and monobasic magnesium phosphate. K contained potassium nitrate, potassium sulfate, and potassium dihydrogen phosphate. C consisted of calcium nitrate, monobasic calcium phosphate, and calcium sulfate. Plants of Triangle II were watered with M, K and C as shown in Figure 2 in a fashion similar to that of the first triangle. Since detailed work with the 28 different nutrient solutions of the two triangles had been done using bean (2) and barley (4), only certain points of the triangles were used in the present work, as noted in the accompanying figures.

Tomato seeds of the Marglobe variety were germinated in pure quartz sand and were fed with a complete nutrient solution until they were twenty-one days old, at which time they were transplanted into glazed 4 x 8 inch self-draining crocks. They were placed on the experimental treatments at this time and were fed every other day, being watered with distilled water on alternate days. Altogether about 700 plants were used. The experiment performed first in the early summer was repeated again during the late summer and fall. All plants were harvested when 49 days old. Since the results obtained were similar to those previously reported (4) only the data for the dry weights of the tops are recorded here in Figures 1 and 2.

It was noted that the potassium deficiency symptoms appeared sooner in Triangle II than they did in another experiment on potassium nutrition being carried on at the same time. In the latter experiment a sodium salt had been substituted for a potassium salt. Therefore it was decided to set up an experiment to see if sodium was causing this effect, and if so, to determine how much sodium could substitute for potassium in the metabolism of tomato seedlings. In most work dealing with potassium deficiency a sodium salt has been substituted for the potassium salt (3) (5) (6).

Individual pots of half of a large group of tomato seedlings were supplied with nutrient solutions containing the following parts per million of potassium: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 100, 140, and 180. The nutrient solution was complete in every other respect. The other half of the group was given nutrient solutions which contained, in addition to the above-mentioned amounts of potassium, enough sodium to bring to 180 p.p.m. the total amount of potassium plus sodium given to any one plant. The potassium and sodium varied in inverse amounts. Thus, a plant in this group receiving 10 p.p.m. of potassium received in addition 170 p.p.m. of sodium, while a plant receiving 100 p.p.m. of potassium received also 80 p.p.m. of sodium. The basic minus-potassium solution contained 0.006 molar calcium nitrate, 0.00225 molar magnesium sulfate and 0.00225 molar monobasic magnesium phosphate. Potassium and sodium were added in the form of chlorides. The stock solutions of these were made up in such concentrations that 1 cc. of either one contained 5 p.p.m. Sufficient quantities of these were added to the basic minus-potassium solution to give the desired amounts of potassium and sodium. The complete nutrient solution used as a control contained 180 p.p.m. of potassium, as a modified Shive's three salt solution usually contains about that concentration. The complete solution was made by adding enough potassium chloride to the base solution to make 180 p.p.m. of potassium. This was used rather than a three-salt solution so as to determine whether the chloride ion was responsible for any of the results.

Results and Discussion

Dry weights of the tops of the plants given each treatment of the triangles are shown in Figures 1 and 2.

Plants of Triangle I were as a group slightly better than plants of Triangle II. The usual deficiency symptoms of the six ions involved were noted as described in the literature, and for the most part the interrelations of the various ions produced results similar to those previously noted for barley (4). Certain noteworthy manifestations are described below.

Triangle I. NO_3, SO_4, PO_4 varied; Mg, K, and Ca constant.

Deficiency symptoms began to appear after several days. Plants without nitrogen began to become hard and to appear stunted and yellow. Those plants given a high phosphate concentration in the total absence of nitrates, or with the nitrates very low in amount, became stunted as a result of phosphorus toxicity. Even a little nitrogen was able to alleviate this phosphorus toxicity since plants fed with N⅓ SO P⅔ remained in fairly good condition, while the plants given NO

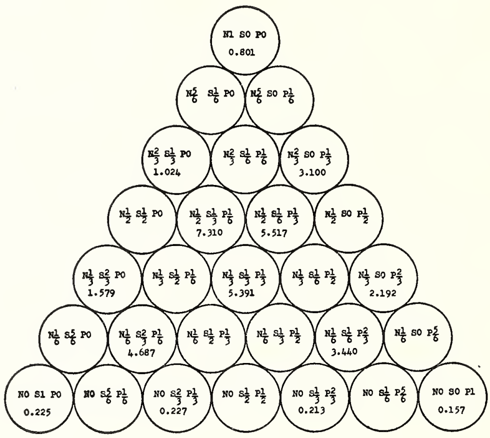

Fig. 1. Triangle I. Fractions denote amounts of solutions N, S, and P mixed together to make the nutrient solution used for watering that point of the triangle. Numbers below refer to average dry weight in grams for four seedlings. Only key points of the triangle were used.

SO P1 were almost dead. Phosphorus deficiency became apparent very early in the growth responses of the seedlings, in fact, sometimes appearing faster than the nitrogen deficiency. It was manifested by stunting and a purplish color starting along the veins on the under sides of the leaves which remained a dark green. Sulfur deficiency caused a slight stunting and a chlorotic mottling of the leaves.

Results of treatments in the central regions of the triangle showed such slight variations as not to be significant.

Triangle II. Mg, K, Ca varied; NO_3, SO_4, PO_4 constant.

Here the first deficiency symptoms, those caused by lack of potassium, appeared soon and were manifested by severe stunting and the curling downward of leaves, rather than by a die-back from the tips as occurs, e.g., in barley.

Calcium deficiency resulted in a severe stunting and in the death of the terminal meristem.

There were no clear-cut symptoms produced by lack of magnesium excepting a slight stunting. A calcium-magnesium relationship was not found in this experiment with tomato seedlings. When plants were

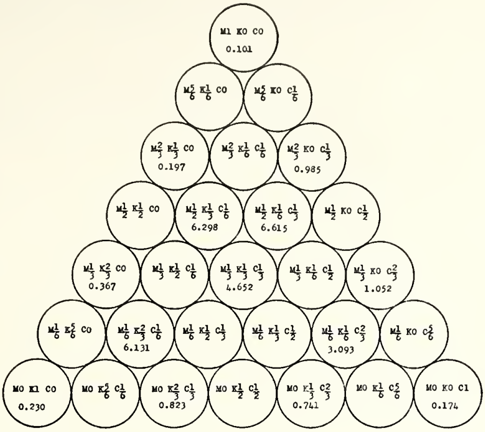

Fig. 2. Triangle II. Fractions denote amounts of solutions M, K, and C mixed together to make the nutrient solution used for watering that point of the triangle. Numbers below refer to average dry weight in grams for four seedlings. Only key points of the triangle were used.

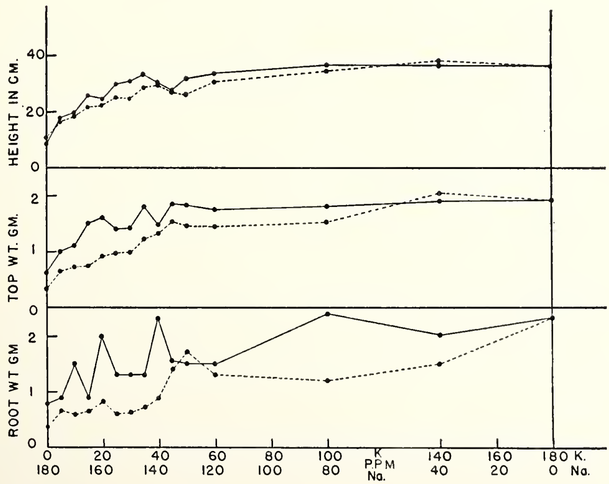

Fig. 3. Dotted lines represent data referring to plants fed with complete solutions, which contained various amounts of potassium. Solid lines represent plants fed with complete solutions, containing various amounts of sodium in addition to the potassium. The three graphs represent average heights at time of harvest, and average dry weights of the tops and roots, respectively, of groups of four seedlings.

grown in the absence of potassium, a relatively high concentration of magnesium as compared with calcium produced results not different from a high concentration of calcium and a low concentration of magnesium.

Results of the experiment on the interrelation of potassium and sodium are shown in the accompanying graphs, in which are recorded the average dry weights of tops and roots and the average heights of the plants in each treatment.

Sodium can greatly retard and modify the appearance of potassium deficiency symptoms. Plants given sodium only and no potassium were less poor than plants given neither sodium nor potassium; they had larger leaves and were enabled to make some growth and to persist for some length of time. Plants given neither sodium nor potassium were severely stunted and their leaves were smaller and deformed. This superiority of the plants given sodium in addition to potassium was particularly manifested in dry weights of the plants up to the level of about 100 p.p.m. However, in outward appearance one could hardly detect differences between them after the level of 40 p.p.m. of potassium. The most dry weight was synthesized by plants which had 180 p.p.m. of potassium plus 90 p.p.m. of sodium. Plants given sodium in addition to potassium were taller and more vigorous. Plants given sodium when potassium was present in small amounts (5-25 p.p.m.) had thicker stems and larger leaves than plants given potassium only.

Conclusion

1. When plants were given a high phosphate concentration in the total absence of nitrates, or with the nitrates very low in amount, they became severely stunted as a result of phosphorus toxicity.

2. When plants were grown in the absence of potassium, a relatively high concentration of magnesium as compared with calcium produced results not different from a high concentration of calcium and a low concentration of magnesium.

3. Phosphorus deficiency became apparent very early in the growth responses of the seedlings, in fact, sometimes appearing faster than nitrogen deficiency symptoms.

4. The usual potassium deficiency symptoms appeared faster and seemed more severe in those plants given neither potassium nor sodium than in those plants that had a sodium salt substituted for a potassium salt.

5. It was found that sodium can greatly retard and modify the appearance of potassium deficiency symptoms. Plants given sodium but no potassium had larger leaves than those given neither sodium nor potassium. Plants given sodium when potassium was present in small amounts (5-25 p.p.m.) had thicker stems and larger leaves than plants given potassium only. The presence of sodium in addition to even as much as 100 p.p.m. of potassium was definitely stimulating to the plant in that more organic matter was synthesized as shown by the dry weights; however, in outward appearance one could hardly detect

differences in those plants receiving the sodium in addition to the potassium above the level of 40 p.p.m. of potassium.

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