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Micronutrient Deficiencies of Cantaloupes as Related to the Proximity and Profile of the Subsoil Level.

By S. S. IVANOFF

Deficiency diseases caused by lack of micronutrients are common and worldwide (7). They have been encountered in Mississippi for some time (1, 4, 5, 6). Their symptoms may be very characteristic and striking in some cases, but they also may be inconspicuous and common in character, showing only as stunting or lack of vigor. It may be said that as a general rule each crop responds differently to different micronutrient deficiencies. For instance, boron deficiency on cotton is expressed by a group of symptoms which are quite different from those exhibited on apples, on beets, or on pines. We no doubt have micronutrient troubles which have not yet been identified as such and are probably attributed to other or unknown causes.

Sometimes difficulties have been experienced in correcting the troubles even after they have been clearly identified. More definite knowledge is needed as to which micronutrient is lacking in any particular soil, and in what region of the soil, which crops are more affected than others under given conditions, what are the symptoms of each element deficiency on each crop, and most of all, what is the most effective and economical way to correct the condition. Failures to correct the trouble by spraying micronutrient solutions on the foliage of some valuable ornamental plants have been encountered. These may be attributed to various factors such as the low absorptive qualities of the tissues, the age of the plant, unfavorable atmospheric conditions, thickness of the cuticle and other morphological structures, and perhaps to other causes. In some instances adding micronutrients to the soil has not corrected the trouble. Since some of these trace elements are toxic in nature, an oversupply of them would be dangerous.

The bulletin describes a chlorotic condition of the cantaloupe crop as it develops in the field, its causes, and the means by which it was completely corrected. In addition a relation between the incidence of this trouble and the subsoil profile was studied, and in this connection, a theory is proposed to explain the curious manner of development of this micronutrient disease in the field, the eventual complete and natural recovery of some plants and not of others, and the basis on which the incidence of this and perhaps other micronutrient diseases may be sometime explained.

This abnormal and injurious condition of cantaloupe vines has been observed for a long time in Mississippi. It has often caused considerable losses to the crop, some annoyance to growers and much puzzlement about its cause. The nutritional disease is expressed from the beginning by yellowing of the foliage, slow growth, and stunting of the vines. In severe cases, which are quite frequent, the leaf color is straw yellow to sulphur yellow with some burning along the edges. In some cases, the stunted plants wither and die before any fruit is set. In other instances, with less severe chlorosis, the vines show a very gradual greening up followed by a remarkably quick growth and recovery. In most cases, however, the crop will be considerably delayed.

Not all the vines in a given plot area are uniformly affected. Some are very discolored and severely stunted, others are noticeably chlorotic but show some slow growth, while still others may be healthy, vigorous, and normal in every way. The trouble has been seen in most localities in Mississippi where cantaloupes are grown and particularly on light sandy soils which are really the best for cantaloupe growing, all other conditions being favorable. It has been observed on many commercial varieties grown, but not on certain hybrids, thus indicating that perhaps some kind of resistance to it is available. The condition has been closely observed on Experiment Station plots at State College, on a number of private farms and in gardens of the county. Complaints by growers have been frequent and many unsuccessful attempts have been made to correct the trouble by application of commercial fertilizers.

In the spring of 1963 this chlorotic condition appeared on a valuable planting of cantaloupes made for a special purpose in an isolated private garden near Mississippi State University. The plot comprised about ten thousand square feet, was well fertilized with 5-10-5 commercial fertilizer and was planted in the usual manner with one variety each of cantaloupes and watermelons. Abundant rains fell after planting. The topsoil was Shubuta fine sandy loam deep alluvial surface phase, with pH 5.7. The trouble was noticed on a great many cantaloupe plants soon after emergence. As usual some of them were severely affected, others less so, and still others looked normal. The most severely chlorotic plants were on soil of lighter color, and the best looking plants were on a section of the plot with darker soil. All the watermelon vines looked normal and produced a heavy early crop.

Assuming this time that a deficiency of one or more microelements in the tissue or in the soil, perhaps brought about by leaching or by chemical inactivation, might be the cause of the failure of the cantaloupe plants to grow normally, a foliage spray experiment was undertaken whereby each vine was supplied with one only of the following micronutrients: boron, copper, iron, magnesium, manganese, molybdenum and zinc. All of the compounds were of the highest available purity. Also included were calcium nitrate and a mixture of nitrogen, phosphorus and potassium salts.

Sixty-five of the most severely chlorotic vines were selected for the test, most of which did not measure more than 14 inches across. Partly chlorotic vines were omitted from the test. Each microelement was applied on 5 different vines scattered at random throughout the experimental block, each vine constituting a replication. For checks, ten vines were sprayed with distilled water, and ten other vines not sprayed. Additional checks were provided by applying commercial fertilizer, 5-10-5, as dust around some of the vines.

Two spray applications were made, using a 100 cc capacity hand sprayer, the first application when the plants were seven weeks old, the second about a week later. Each vine was sprayed uniformly and carefully, in an effort to avoid drifts, and received approximately 10 cc of the solution each time, some of which dripped to the ground. After spraying five plants with one solution, the sprayer was thoroughly washed before using it again with another solution in order to avoid any mixing of chemical elements. Records on recovery from chlorosis and amount of growth of the vines were taken two weeks after the first spray application. A heavy rain and then light intermittent showers preceeded the first spray application and more showers fell between the two applications.

Table 1 shows the results of the trials. They may be summarized as follows: The best recovery from chlorosis was effected by sodium molybdate and zinc sulphate. The results were striking. All the replications showed a dark green color, many buds and sprouts, and the vines had increased in size many times in the short interval between first spray applications and record taking. The vines commenced to set fruit and eventually produced a fairly good harvest of good

Table 1. Results showing degree of recovery from severe non-infectious chlorosis of cantaloupe vines following spray applications with different microelements. Two spray applications were made at one-week interval, seven weeks after planting. Each plant received about 10cc of the spray material at each application.

Solution sprayed on plants	Order of application	Concentration %	Rating[1]
Sodium molybdate	7	0.1	4.0
Zinc sulphate	8	0.1	4.0
Boric acid	2	0.1	3.2
Calcium nitrate	9	0.5	2.6
Manganese sulphate	6	0.1	0.6
N-P-K	10	1.5	0.6
Copper sulphate	3	0.1	0.4
Magnesium sulphate	5	0.1	0.2
Distilled water	1	0.0	0.1
Iron sulphate	4	0.1	0.0
None	—	—	0.0

[1]Legend—Extent of green matter on leaves (recorded two weeks after first spray application) was accompanied by a corresponding growth of vines and was recorded as follows:

0—Plants completely chlorotic with some necrosis (burning) along the leaf edges. No recovery or fresh growth noted.

1—Slight greening of leaves and some growth noticable.

2—Plants show some growth but also show signs of chlorosis.

3—Plants almost normal green and showing considerable growth.

4—Vines very green, color normal. Increase of growth several times the original size.

quality cantaloupes. There was good recovery from chlorosis by the application of boric acid, also, the effects resembling closely those of molybdenum and zinc, the vines becoming green and very enlarged (see legend under Table 1). The other elements, such as copper, iron, magnesium and manganese, produced either no change or only insignificant beneficial effects, except calcium nitrate, which induced a recovery below that of boric acid. It is interesting to note that the chlorotic plants were unable to utilize potassium, phosphorus, and nitrogen when applied to the surface of foliage, under the conditions of the trials. Nor were beneficial effects noted from applying the commercial fertilizer mixed with the soil. The plants remained unresponsive as did all the untreated checks.

In addition to the spray experiments described above, some investigations were made on the contour of the subsoil in regard to the position of chlorotic and non-chlorotic plants above it. In previous studies made elsewhere concerning abnormal stunted growth of crops like lettuce, beets, carrots, and flax grown under irrigation, a high positive correlation was found between the size of the plants and their nearness to the clay subsoil. The very stunted plants were situated from about 20 to 36 inches away from the subsoil below, while the largest and tallest plants, growing nearby in the same row, were only 5 to 8 inches above the clay subsoil level. The undulating line of the crop seemed to parallel the undulating profile of the subsoil. The roots of the largest plants seemed to have reached the subsoil quickly, being nearest to it, and were in close touch with it, while the roots of the stunted plants were still within the sandy topsoil area, some distance from the clay area. Adding various combinations of commercial N, P and K fertilizers did not correct the situation and the problem was left unsolved. It did not occur to this investigator then that the trouble may have been that of minor element deficiency, and consequently no such nutrients were tried.

In the case of the present problem with cantaloupes, borings were made with a soil auger directly under the chlorotic plants and under those other plants in the same area which had shown normal green color from the very start. It was found that the subsoil under the normal plants was nearer to them than was the subsoil under the chlorotic plants. In borings under eight non-chlorotic plants, the clay subsoil stood at a distance from the sandy surface of about 12 to 14 inches, while under the chlorotic plants on the other hand, in eight other borings, the clay was located deeper, some 21 to 24 inches below the topsoil surface. It seemed from these tests that the subsoil layer did not have a regular horizontal surface but represented more or less an undulated profile, some points of which were closer to the emerging plants than others.

Chemical analyses were made of the topsoil and subsoil some time after harvest. The topsoil contained 184 lbs. of P_2O_5 per acre, while the subsoil had 150 lbs. per acre. The exchangeable potassium was 256 and 291 lbs., respectively. Calcium was sufficient and magnesium high in all samples.

Organic matter was low in both soil layers, varying from 1.45% for the topsoil to 1.01% for the subsoil. There were not great differences in the major nutrients or in organic matter content between the lighter sandy soil where most of the chlorotic plants grew and the darker colored sandy soil where many of the healthy plants were found. The difference in color probably was due to the larger amount of clay in the darker soil.

All the above circumstances may be considered in formulating an answer to some puzzling questions. The following questions may be asked:

Why in the same field do some plants develop chlorosis while their neighbors remain healthy? Why did zinc alone produce complete recovery of the chlorotic plants without the aid of molybdenum or of any other essential elements? And the reverse question may also be asked, why did molybdenum alone produce the same satisfactory results as zinc without the aid of the other elements, zinc and boron, which likewise, each alone, induced marked color changes and growth of the sprayed plants?

These questions may be examined within the context of a simple theory. First, it may be assumed that none of the essential elements are available in sufficient amounts in the topsoil, having been leached out, or tied up by phosphorus, or inactivated by certain physical conditions, waterlogging, etc. Second, it may also be assumed that all of the needed essential microelements are present and available in sufficient quantities in the subsoil, perhaps in the upper transition layers, which may serve as depository for these vital nutrients. To these two assumptions should be added the fact alreadv demonstrated, that the subsoil profile or contour is undulating in outline and not level or smoothly inclined. In other words, the clayish subsoil surface, even though not closely delineated, represents numerous small "craters," "hills," and "valleys" of different heights and depths.

Because of the above circumstance, real or plausible, the roots of some plants whether sprayed or not, will reach the subsoil surface more quickly than others, which will enable them to continue to live and develop by absorbing the various microelements needed, perhaps all of which are lodged in or in the neighborhood of the subsoil. Such plants will have a normal growth and will quicklv spread their roots in all directions.

On the other hand, other plants whose roots happened to be as far away from the sustaining subsoil as 20 or more inches may seem to have exhausted their life energy before reaching the level of the essential microelements. But if such plants, before they actually die are supplied with one single micronutrient, which will act as a stimulus, then they will continue their growth, albeit slowly, until their roots reach the neighborhood of the subsoil where they are likely to encounter a very favorable nutrient environment, including the rest of the micronutrients and also the accumulated N, P and K, after rains had leached them down through the sandy topsoil. The result would be a burgeoning of growth of the plants as observed.

This interpretation points to parts of the subsoil and to the transitional soil zone as important sources of micronutrients. It has been observed by workers in California (2) that deep cultivation, 21 inches or more, has lessened the severity of deficiency symptoms in cotton, and suggested that this resulted from better root development. In addition, it may now be suggested that deep cultivation or plowing will tend to break up the undulating profile of the subsoil and also bring up more clay particles containing micronutrients into the topsoil.

The role of phosphorus in the ability to bind zinc should not be overlooked in interpreting microelement deficiency problems, particularly in cases where this mineral had been applied to the soil in large quantities (3).

This work needs to be continued, in order to find the most effective, economic ways of applying the microelements to this crop. It is well known that with some crops, molybdenum may be applied as a seed treatment.

The subject of micronutrients as catalysts or reaction regulators offers a very interesting and rewarding field for basic research which should be exploited with intensity and alacrity. New deficiency diseases are being discovered continually, a fact testifying perhaps to the incomprehensive knowledge existing about them. In contributing to the normal growth of plants, micronutrients also contribute to the better and greater utilization of the major elements, N, P, and K. We are yet to assess properly the potential magnitude and prominence the minor elements may assume by reducing the per-acre cost of production of many crops in this country, and by increasing general agricultural prosperity throughout the world.

Summary

A micronutritional disease on cantaloupe vines, frequently encountered in Mississippi, is described. The vines turn yellow from the start; some die; others eventually may recover. Fertilizing such vines with commercial fertilizers containing N, P, and K has been of no help. On the other hand, the trouble was completely corrected by spraying the chlorotic vines with 0.1 percent solution of zinc sulphate, or of sodium molybdate, or of boric acid. Each of these compounds, applied alone, induced a quick recovery of the green color of the foliage and stimulated an unusually rapid growth of the vines.

In the field some plants develop the chlorosis, while their neighbors remain healthy. This is associated with the fact that the subsoil, which probably contains all the micronutrients necessary for normal plant growth, is undulating in outline. Thus plants growing over deep topsoil, lacking available micronutrients, fail to reach the subsoil and consequently develop the chlorosis, while those plants situated closer to the subsoil make the vital contact and develop normally.

The above circumstances may also help to explain why this micronutrient deficiency trouble may be corrected by any of the three elments—zinc, molybdenum, or boron—and why recovering plants eventually burst forth in vigorous growth. When one needed micronutrient is applied to the foliage of a dying chlorotic plant, this acts as a stimulus, enabling the roots to reach down to the pockets and the recesses of the sustaining subsoil, where the other needed mi-

cronutrients are assumed to be found, together with the accumulated N, P, and K. After this a burgeoning begins, resulting in a very green and vigorous plant.

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