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IMPORTANCE OF INORGANIC ELEMENTS IN THE GROWTH OF AVOCADO TREES

A. R. C. Haas
Plant Physiologist, University of California,
Citrus Experiment Station, Riverside.

SUMMARY

Topa Topa avocado seedlings differed greatly in their growth in pure silica sand as compared with soil even when the Hoagland's nutrient solution, in the case of the sand cultures only, contained five minor elements: aluminum, boron, iron, manganese, and zinc. Increased and healthier-appearing growth occurred in comparable soil than in sand cultures even with the minor-element additions being made to the sand cultures only. When copper was added to the list of minor elements supplied to the nutrient of the sand cultures their seedling growth was appreciably improved.

The growth of Topa Topa avocado seedlings in sand and in soil cultures grown as above but receiving various concentrations of copper was shown to improve as the copper content of the nutrient solution was increased within a certain range of copper concentration. Excessive copper was found to be undesirable and especially so in the sand cultures. The addition of copper to the nutrient solutions reduced considerably the differences in growth between sand and soil cultures at comparable copper concentrations in the nutrient solutions, although growth still was generally slightly the better in the comparable soil cultures.

Ferrous sulfate of c. p. grade requires still further purification (with H_2S at a suitable pH) in order to eliminate the many elements that may occur as impurities. This has led to a study of vanadium, nickel, and other inorganic elements as to their effect on the growth of avocado plants, both vanadium and nickel appearing to offer promise.

The vegetative growth of Topa Topa avocado seedlings in soil cultures responded to variations in the concentrations of the nutrient solution. Improvement in top growth was near a maximum when the culture solution was one and one-half times the strength of Hoagland's solution, whereas the root system approached a maximum at one times the strength of Hoagland's solution.

Leaf size and green-color intensity increased as the concentration of Hoagland's nutrient solution was increased.

In avocado culture the nutrient concentration should be relatively high even when the solution is supplied in large volume.

The percentage of K was greatest in the dry matter of mature leaves in the soil culture that received the most dilute nutrient solution, which probably indicates that some other element was a limiting factor in growth. Sodium tended to increase in the dry matter of the

fine rootlets as the sodium concentration in the nutrient solution was increased.

Increasing the nutrient concentration in soil cultures may not increase the percentages of certain elements in the leaves but may increase the production of leaves having a relatively stable composition. The avocado plant appears to have a rather high nutrient requirement.

Recently an experiment using three-gallon-capacity crocks was conducted with Topa Topa avocado seedlings in which in one case soil was diluted with plaster sand (to promote good drainage) and in the second case pure silica sand was used. The soil cultures received Hoagland's nutrient solution: Ca 159, Mg 54, Na 7, K 185, NO_3 718, Cl 10, SO_4 216, and PO_4 105 ppm, plus sodium nitrate and varied in such a manner that each of the cultures received the same concentration of nitrogen and different ratios of sodium to potassium. The sand cultures received the same solutions as the soil cultures plus certain minor elements: iron, manganese, zinc, boron, aluminum, and after a period of time copper also. The inorganic salts employed in preparing the nutrient solutions were all of chemically pure grade and the ferrous sulfate used as the source of iron was further purified.

Fig. 1. *Topa Topa avocado seedlings, right to left: 1. sand, 2. soil. Their nutrient solution contains the highest K and no Na: 1. contains trace elements, 2. contains no trace elements. Rack pair of cultures to the left are sand and then soil, respectively, the nutrient for each pair successively containing increasing concentrations of Na and lower K. Note that in every pair of cultures the soil culture is far superior to the sand culture.*

Fig. 2. *Continuation of the Topa Topa avocado cultures shown in figure 1. Left to right: 16, soil; 15, sand. The nutrient solution for cultures 16 and 15 contains no K and the highest Na. Each pair of cultures to the right are soil and then sand, respectively, the nutrient solution for each pair successively containing increasing K and decreasing Na until 2 and 1 in figure 1 are reached. Note in every pair of cultures that despite the use of trace elements in the sand culture nutrients and not in the soil culture nutrients, growth was always superior in the soil cultures.*

The growth made by these sand and soil cultures from January 24, 1952, to September 17, 1952, is shown in figures 1 and 2 where in every case considerably more and healthier-appearing growth was made in the soil than in the sand cultures despite the addition of certain trace elements to the sand and not to the soil nutrient solutions.

The first impression would he that perhaps the cultures were not given their nutrient solution frequently enough. However, increasing the nutrient supply to four liters of freshly prepared solution per week for each three-1 gallon-capacity container failed to alter the growth differences. We shall return later to the question of the effect of dilute or of more concentrated nutrient solutions on the growth of avocado seedlings.

It was mentioned that of the trace elements used in the sand cultures, copper was used a short period after the experiment was begun and an improvement was soon evident in the growth of the sand cultures. This pointed to the possible need not only of copper as a minor element but also gave an indication that possibly the addition of other trace elements to sand cultures was warranted and that the so-called minor-element program commonly used in sand or soil cultures may not be adequate.

To further investigate this matter, a set of soil cultures (containing some plaster sand) and a comparable set of pure silica sand cultures were prepared in which the need of avocado plants for copper was the primary concern. A Topa Topa avocado seedling was planted on January 29, 1952, in each three-gallon-capacity container. Each culture received Hoagland's nutrient solution with only the sand cultures receiving aluminum, boron, iron, manganese, and zinc. The soil and the sand cultures received comparable concentrations of copper (as the sulfate) in their nutrient solutions: 0, .1, .25, .50, .75, 1.0, 2.5, and 5 ppm of copper.

In figure 3 is shown the poor growth made in culture no. 1 where the sand culture received no copper whereas the original soil in culture no. 2 contained some copper. In the other pairs of sand and soil cultures in which the nutrient of a given pair contains the same concentration of copper that increases with each successive pair of cultures (left to right), the growth in the sand cultures more nearly equals that in the comparable soil cultures. As the copper in the nutrient solutions increases there is a tendency toward better and greater plant growth. In the sand cultures on September 17, 1952, the trunk heights for the five cultures shown in figure 3 were: 26.5, 46.8, 51.8, 42.5, 58.8 and for the soil cultures, 46.8, 52.5, 53.3, 54.5, 51.5 inches, respectively. At the 1, 2.5 and 5 ppm concentration of copper in the sand cultures, growth decreased to 39, 43.8, and 47.5 inches, respectively, whereas at 1 ppm copper the soil culture growth was 55 inches, which dropped to 45.8 inches at the 2.5 ppm copper level. Although the seedling growth tended to increase as the concentration of copper was increased up to certain limits, apparently an excessive concentration of copper is not desirable. Citrus trees in contrast to avocado trees receive considerable copper as a result of spraying the lower portion of the tree for brown rot control.

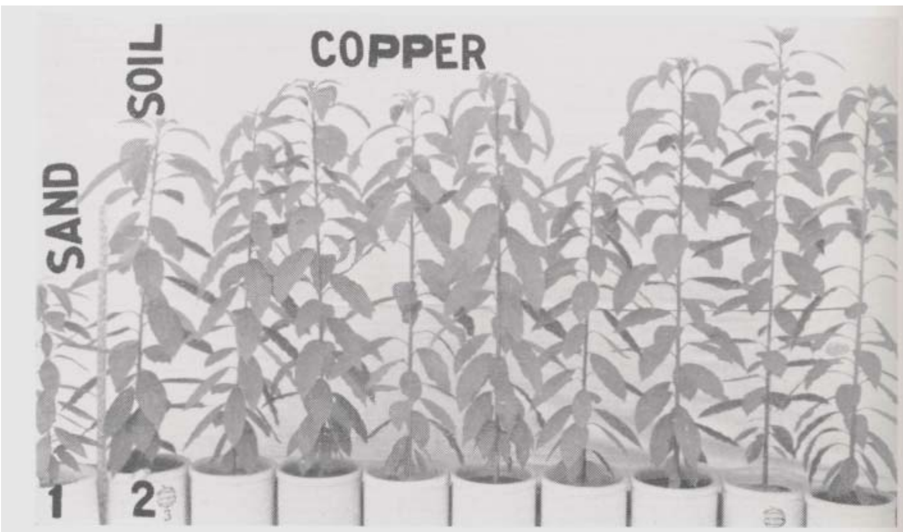

Fig. 3. *Growth of Topa Topa avocado seedlings in silica sand and in soil cultures. Each pair of cultures (sand and soil cultures, respectively) received Hoagland's nutrient solution: 1. sand culture with five trace elements (aluminum, boron, iron, manganese, and zinc); 2. soil culture with none of these five trace elements. Each pair of sand and soil cultures successively, left to right, have included in their nutrient solution: 0, .1, .25, .50, and .75 ppm, respectively, of copper. The sand cultures, after the first culture .on the left that received no copper, approach quite favorably the growth made in comparable soil cultures that also receive copper.*

The re-purification of the so-called chemically pure ferrous sulfate used as the source of iron in these experiments eliminates a large number of elements some of which may be useful in the growth of the avocado plant as was found in the case of copper. Some additional studies already have indicated that vanadium and nickel are probably useful in promoting better growth in avocado plants.

In preliminary tests with vanadium, sand and soil cultures were conducted as in the experiment with various concentrations of copper. The trunk height of the Topa Topa avocado seedlings planted in soil cultures on January 29, 1952, measured (on October 24, 1952) : 53.5, 52.8, 60.0, 62.8, 61, 66.5 and 47.8 inches, respectively, when the nutrient solution contained 0, .01, .02, .03, .04, .05, .06, and .07 ppm, respectively, of vanadium as ammonium vanadate. In sand cultures the acidity of the nutrient tended to interfere and is being greatly reduced in later experiments. Here trunk heights at the end of the same period as the soil cultures were: 44, 57.3, 38, 32.5 and 30.8 inches, respectively, at comparable concentrations of vanadium. The soil receiving no added vanadium, if assumed to contain vanadium, would account for the lower trunk height in the sand culture receiving no vanadium.

Likewise the use of nickel in soil cultures appears to benefit the appearance and growth of the avocado plants. As a consequence of these preliminary results further tests of a parallel nature will be undertaken.

Vigorous, healthy, growth of avocado trees is one thing whereas fruit production is another. Both phases of avocado growth:—vegetative and reproductive and their relationship—should be better understood. It is often said that avocado trees require the same fertilizers and perhaps to a less degree than do citrus trees. About citrus trees it is frequently claimed that weak nutrients if supplied often enough or in large enough volume in nutrient solutions is adequate in order to obtain the better tree growth.

Returning therefore now to the question raised earlier, we may investigate the effect of the concentration of the nutrient solution upon the vegetative growth of Topa Topa seedlings. On January 24, 1952, an experiment was begun in the glasshouse, making use of the three-gallon-capacity soil cultures containing plaster sand. Every Monday, until the plants were harvested (September 17, 1952), each culture received four liters of nutrient solution that resulted in considerable drainage water. Distilled water also was added to the cultures according to their needs during the heat of summer. Copper (0.25 ppm) was added to the nutrient solution of each culture shortly after the start of the experiment.

Hoagland's solution previously mentioned and without minor elements added (except equal copper in each culture) was the basis of the nutrient applied. Table 1 gives the concentration of the ions in the nutrient solution applied to cultures no. 1 to 8, inclusive.

When the experiment was concluded it was observed (Fig. 4) that an increased concentration of the culture solution up to approximately one and one-half times the strength of Hoagland's solution (culture no. 7, right to left in figure 4) resulted in increased plant growth. The fresh weight of all the leaves of each of the cultures nos. 1-8, inclusive, were: 62, 82, 132, 183, 175, 196, 220, and 177 grams, respectively, with the best appearing leaves occurring at the one and one-half strength of Hoagland's nutrient solution. The largest width of each mature leaf was determined and the average largest width for the eight cultures were: 2.58, 2.29, 2.85, 3.30, 3.35, 3.62, 3.66, and 3.74 inches, respectively. These results indicate that the leaf size increased as the concentration of the nutrient solution increased. A typical mature leaf was taken from the tree in each culture and a narrow section of the leaf was cut near the region of greatest width. These transverse sections were placed in a row as shown in figure 5. With increasing concentration of the culture solution not only was the width of the leaves increased but the green color of the leaves also was intensified. In harvesting the leaves, those touching the nutrient and those immature were excluded from the samples used for chemical analysis.

Table 1

Concentration of elements (ppm) in nutrient solution applied to soil cultures

Culture No.	Nutrient strength in terms of Hoagland's solution	K	Na	Ca	Mg	NO_3	SO_4	Cl	PO_4
1	⅛	23.1	0.9	19.9	6.8	89.8	27.0	1.3	13.1
2	¼	46.3	1.8	39.8	13.5	179.5	54.0	2.5	26.3
3	½	92.5	3.5	79.5	27.0	359.0	108.0	5.0	52.5
4	¾	138.8	5.3	119.3	40.5	538.5	162.0	7.5	78.8
5	1	185.0	7.0	159.0	54.0	718.0	216.0	10.0	105.0
6	1¼	231.3	8.8	198.8	67.5	897.5	270.0	12.5	131.3
7	1½	277.5	10.5	238.5	81.0	1077.0	324.0	15.0	157.5
8	2	370.0	14.0	318.0	108.0	1436.0	432.0	20.0	210.0

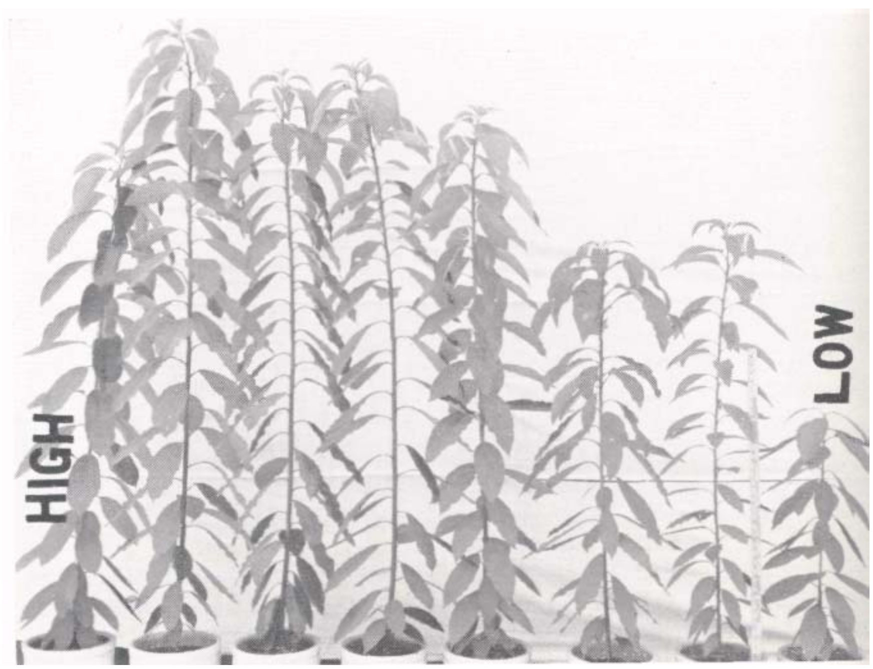

Fig. 4. *Right to left: growth of Topa Topa avocado seedlings in three-gallon-capacity (soil-plaster sand mixture) cultures that received a nutrient solution* ⅛ ,¼, ½, ¾, 1, 1¼, 1½, *and* 2 *times the strength of Hoagland's solution (see Table 1). Equal concentrations of copper (0.25 ppm) were added to each culture solution; no other minor elements were used.*

The trunks measured: 31, 53, 49, 66.5, 72.5, 71.5, 78.5, and 63 inches, in height, respectively, and their fresh weights were: 33, 66, 94, 163, 198, 194, 243, and 171 grams, respectively. The dry weights of the entire root systems (cotyledons discarded) were:

24.7, 29.4, 27.0, 34.4, 44.2, 29.4, 33.8, and 23.7 grams, respectively, for cultures nos. 1-8. The largest root system was made at the nutrient strength of one times that of Hoagland's solution whereas the greatest leaf production was at one and one-half the strength of Hoagland's solution.

Figure 4 appears to show that the nutrient should be of a sufficiently high concentration even when in large volume supply in order to obtain excellent avocado growth. Possibly when nutrient solutions are very dilute, a limiting factor the more readily may be encountered.

Samples of the leaves and fine rootlets of the avocado plants in cultures nos. 1-8. inclusive, were prepared for chemical analysis and the averages of closely agreeing duplicate determinations are given in Table 2. The content of K in the dry matter of the mature leaves was greatest in the culture (no. 1) in which K was the lowest in the eight nutrients applied. It would appear that growth here was limited not by a lack of K but by a lack of a sufficiency of some other element, possibly nitrogen. In previous results Haas (1) has shown that avocado leaves respond very appreciably in their fresh weight and nitrogen and phosphorus content after the concentration of nitrate-nitrogen applied in the nutrient solution to soil cultures exceeds 125 to 150 ppm.

The dry matter of the fine rootlets shows a marked increase in calcium in cultures 6, 7, and 8. As sodium in the culture solution was increased, the tendency for sodium to increase in the rootlets became more evident whereas an accumulation of sodium was not apparent in the leaves. From table 2 it is evident that increasing the concentration of nutrient elements when limiting factors are overcome, may not increase the concentration of the elements added but instead may increase the production of more leaves of a relatively stable composition in respect to certain elements. For excellent growth the avocado plant has a rather high nutrient requirement.

Table 2

Percentages of calcium, magnesium, potassium, and sodium in the leaves and fine rootlets of avocado seedlings grown in soil cultures with similar nutrients but of different concentrations

Culture No.	Nutrient strength in terms of Hoagland's solution	Per cent in dry matter of leaves				Per cent in dry matter of fine rootlets			
		Ca	Mg	K	Na	Ca	Mg	K	Na
1	⅛	1.559	.617	1.489	.059	.344	.631	1.096	.092
2	¼	1.831	.640	1.079	.049	.316	.577	0.999	.197
3	½	1.591	.597	1.052	.039	.366	.542	0.799	.223
4	¾	2.002	.684	0.605	.034	.340	.390	0.854	.207
5	1	2.025	.648	0.737	.083	.377	.504	0.738	.197
6	1¼	1.969	.675	0.605	.045	.515	.548	0.897	.253
7	1½	1.973	.614	0.725	.031	.613	.634	0.850	.289
8	2	2.056	.701	0.856	.046	.565	.464	1.000	.263

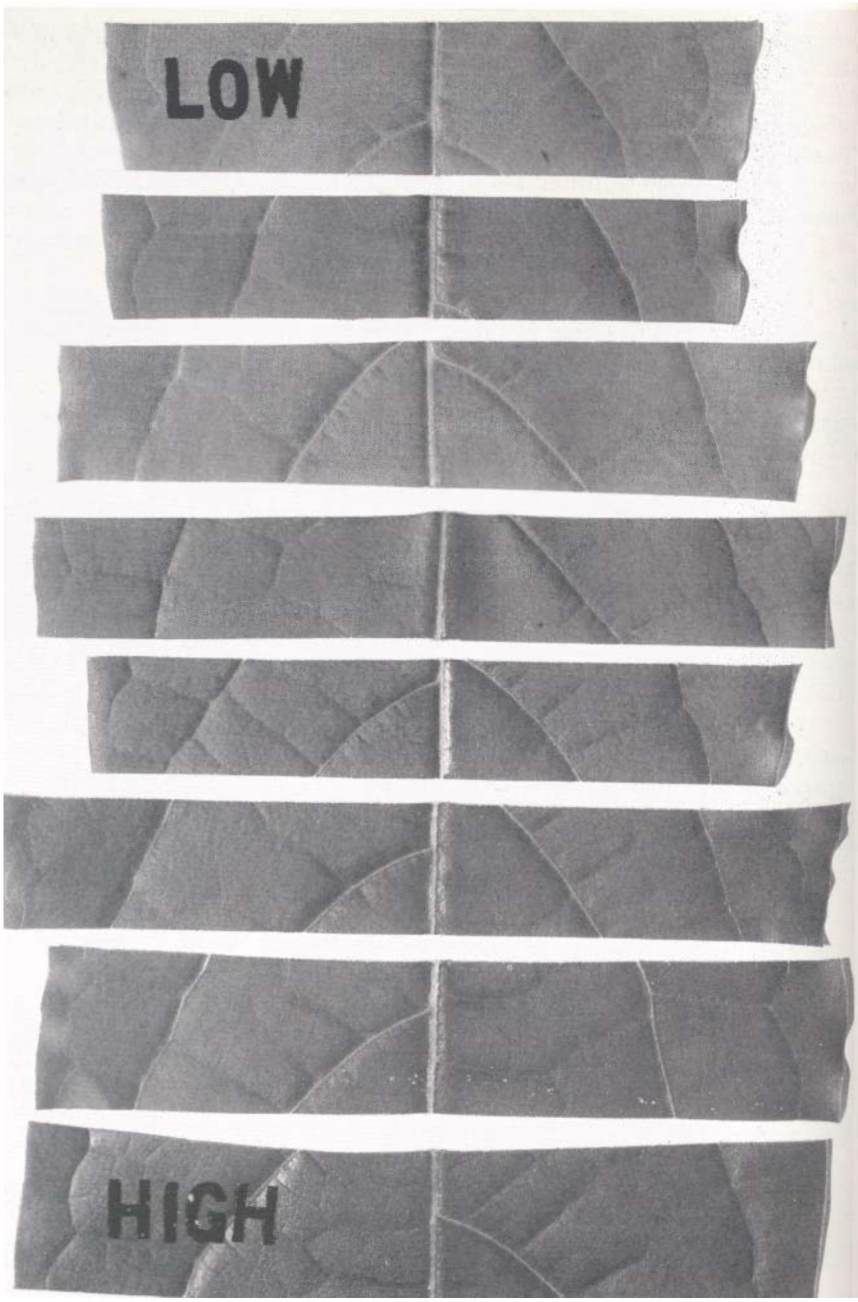

Fig. 5. *Increasing width and intensity of the green color in transverse sections cut across the midrib near the widest portion of the leaf. The strengths of the nutrient solution used top to bottom were:* $\frac{1}{8}$,$\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, 1¼, 1½, *and* 2 *times that of Hoagland's solution (see Table 1)*

LITERATURE CITED

Haas, A. R. C. Nitrogen effects on avocado seedlings in soil cultures, Calif. Avocado Soc. Yearbook 1947: 51-54.