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GROWTH AND COMPOSITION OF AVOCADO SEEDLINGS IN SOIL CULTURES AS AFFECTED BY THE RELATION OF CALCIUM TO MAGNESIUM IN THE APPLIED SOLUTION

A. R. C. HAAS
University of California, Citrus Experiment Station, Riverside, California

INTRODUCTORY

The nitrogen used in the fertilization of avocado orchards frequently is in the form of urea, gas ammonia, ammonium nitrate, ammonium sulfate, etc., with ammonia initially available and gradually transformed into the nitrate form. Nitrate salts or ammonium compounds when directly added to the soil or irrigation water are usually in a very pure state and it is therefore ordinarily in the irrigation water that calcium and magnesium finds its way into avocado orchards. Some irrigation waters may contain very low concentrations of calcium and magnesium whereas others may contain high concentrations.

Largely as a result of improvement in a number of citrus orchards by increasing the available magnesium supply, interest has been shown in the question as to whether avocado trees might be benefited if the calcium and/or the magnesium available to the trees were to be increased. In this study, experimental cultures were employed under glasshouse conditions and leaves have been collected from the field, but it is not intended that the results obtained should advocate any immediate changes in field practice.

THE INORGANIC STATUS OF FUERTE AVOCADO LEAVES

First of all, it is necessary that we have some concept of the differences that exist in mature avocado and citrus leaves in the field and then evaluation may be much easier. From Table I it is seen that the percentage of calcium in the dry matter of mature Fuerte avocado leaves obtained from the field ranged from 0.86 to 3.70, whereas in healthy, mature citrus leaves the range extends from about 5 to 7 per cent. In these same avocado leaves the magnesium content ranged from 0.36 to 1.10 per cent whereas in healthy, mature citrus leaves the content is approximately 0.30 per cent. In Table I the potassium content is shown to range from 0.20 to 2.12 per cent whereas in healthy citrus leaves the range is usually between 0.5 and 1.0 per cent. With citrus leaves the content of these elements may depend in large measure (as seen when soil conditions are similar) upon the nature of the rootstock variety.

The extremities of the ranges shown in Table I in many cases indicate an unhealthy condition. For example the sample no. 18 is extremely high in calcium as a result of an extremely low potassium content, or vice versa. Samples no. 19 and 26 contain low amounts of calcium whereas the potassium content is very high. Samples no. 3, 7, and 22 contain a low content of magnesium. The highest sodium values were accompanied

by injury in the leaf. There is much reason to believe that sodium and chlorine may account for much of the leaf troubles in certain areas especially during the years of low rainfall.

TABLE 1
Composition of Mature Fuerte Avocado Leaves Collected in Various Orchards

No.	Location of Orchard	Per Cent in dry matter Ca	Mg	K	Na	Remarks
1	Santa Paula*	1.91	0.61	0.88		Healthy
2	Santa Paula	2.64	0.68	0.87		Healthy
3	CES Riverside	1.66	0.49	1.28	0.24	Healthy
4	Pala	2.50	0.79			Healthy
5	Corona	1.40	0.59	1.57		Healthy
6	Vista	2.20	0.79	0.90		Healthy
7	Vista	1.68	0.36			Chlorosis; limestone low Mg
8	Vista	1.82	0.71	0.81		Yellow leaf margin
9	Vista	1.66	0.83	1.31		Leaf symptoms
10	Vista	1.47	0.75	1.48		Burn between veins
11	Vista	1.63	0.81	1.04	0.28	Healthy
12	Vista	1.53	1.10	1.09	0.52	Symptoms present
13	Vista	1.85	0.80	1.00	0.31	Symptoms present
14	Vista	1.75	0.69	1.26	0.33	Symptoms; tip burn
15	Vista	1.59	0.64	1.17	0.24	Healthy
16	Vista	1.63	0.87	0.84	0.31	Symptoms; tip burn
17	Vista	1.79	0.62	0.81	0.17	Healthy
18	Escondido	3.70	0.70	0.20		Tip burn
19	Escondido	0.97	0.53	1.32	0.19	Symptoms
20	Escondido	1.63	0.65	1.08	0.52	Symptoms
21	Escondido	1.25	0.52	1.29		Low calcium and magnesium; symptoms
22	Escondido	1.30	0.46	1.38		
23	Escondido	1.81	0.86	1.09	0.31	Symptoms; tip burn
24	Escondido	1.33	0.69	1.28	0.34	Symptoms; tip burn
25	Escondido	1.45	0.77	0.95	0.60	Burn between veins; tip burn
26	Escondido	0.86	0.54	1.47	0.73	Burn between veins
27	Escondido	1.31	0.56	2.12	0.43	Symptoms; tip burn
28	Escondido	1.89	0.74	1.02	0.26	Healthy; slight tip burn
29	Escondido	1.91	0.76			Yellow margins
30	Escondido	1.85	0.82			Symptoms
31	Escondido	1.90	0.56			Symptoms
32	Escondido	2.11	0.94			Symptoms
33	Escondido	1.72	0.70			Symptoms
34	Escondido	1.74	0.67			Healthy
35	Carpinteria	1.48	0.72	0.39		Burn near center of leaf blade
36	Carpinteria	1.55	0.70	0.43		
37	La Mesa	1.56	0.87	1.08	0.40	Symptoms; tip burn
38	Rancho Santa Fe	1.13	0.51			Symptoms

FOOTNOTE TO TABLE 1

* Average of 18 samples from trees of various Mexican avocado rootstocks: Ca range,

1.50-2.37; Mg range, 0.47-0.75; K range, 0.58-1.22; total P in dry matter average 1395 p.p.m.; range 1200-1550 p.p.m.

The footnote in Table I gives some notion regarding the phosphorus values in Fuerte avocado leaves. Such leaves at Riverside were found to contain 1150, 1370, 1290 and 1520 p.p.m. total phosphorus respectively in the dry matter of different leaf samples; at Corona the values were 1500, and 1550 p.p.m. respectively; at Santa Paula 940 p.p.m; at Carpinteria 1480, 1060, and 910 p.p.m., respectively; at La Habra 1550 p.p.m.; at Santa Barbara 940 p.p.m.; whereas at Escondido the values found were 1320 and 780 p.p.m. respectively. Experiments are now under way with avocado seedlings in sand cultures in order to determine the effects of various phosphorus concentrations on their growth.

THE PROBLEM

From Table I it is seen that there is usually a greater content of magnesium and a much reduced content of calcium in avocado leaves as compared with citrus leaves. In view of this difference it seemed of interest to grow avocado seedlings in soil cultures that receive the same quantities of nitrogen, phosphorus, and potassium, but different concentrations of calcium and magnesium.

EXPERIMENTAL

A soil containing considerable clay was obtained during an excavation on the Citrus Experiment Station property. Because of its clay content the soil was quite impervious to the passage of water. After being screened the soil was mixed with an equal quantity of plaster sand that greatly improved the drainage. The soil mixture was placed in 12 gallon-capacity earthenware containers in the glasshouse.

Fuerte avocado seed of approximately equal size were germinated in the propagation bed in the glasshouse and a seedling was placed in each of the cultures. The soil cultures were first given their culture solutions on March 17, 1948. Distilled water was used at all times. The culture solution contained the following concentrations of its constituents (p.p.m.): 185 K, 175 SO_4, 105 PO_4, 7 Na, 10 Cl, and approximately 980 NO_3 furnished from various proportions of calcium and magnesium nitrate.

The seedlings made good growth and soon put out branches that interfered with growth measurements and that was prevented in later cultures. The large volume of soil made frequent soil treatments necessary in order to possibly affect the growth before the seedlings became too large for the glasshouse. The cultures were harvested on March 4, 1949.

Fig. 1 shows the various concentrations of calcium and magnesium used. The food materials for the lower leaves were provided to some extent by the seed. When the leaves on the upper portion of each seedling were mature and the plants were beginning to reflect the differences resulting from the various concentrations of calcium and magnesium (for all other treatments were similar) it was observed that as the magnesium concentration was increased, the mature leaves were larger. Fig. 1

illustrates this fact and that when magnesium was too high in relation to calcium, the fresh weight of the leaves was reduced. Magnesium is an actual constituent of chlorophyll and is not merely a catalyzer of chlorophyll as in the case of iron.

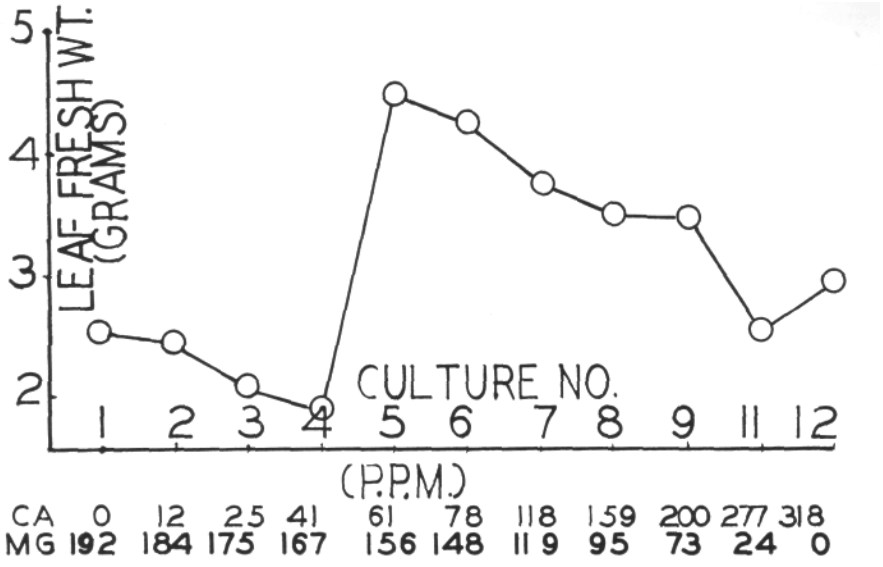

Fig. 1. *Average fresh weight of the mature leaves from the upper portion of Fuerte avocado seedlings grown in soil cultures that received the same amounts of N, P, and K but various concentrations of calcium and magnesium. The average fresh weight of the upper leaves increased from culture no. 12 to and inclusive of no. 5, and decreased when the concentration of magnesium was too high in relation to the concentration of calcium.*

This effect of the concentration of magnesium relative to that of calcium on the growth of avocado seedlings was further studied by growing Northrop avocado seedlings in 3 gallon-capacity soil cultures provided with drainage. Use of this smaller amount of soil (3 instead of 12 gallon-capacity containers) permitted a more rapid effect of the applied solution on the soil solution of the cultures. The soil and plaster sand mixture was the same as was previously used.

The Northrop avocado seed were placed in the propagation bed on October 11, 1948 and on November 15, 1948 a single germinated seed was placed in each culture. Branching of the seedlings was prevented by rubbing off the tender lateral growth while it was still very small. The terminal or vertical growth of the trunk then became of value in making growth measurements. Before growth had progressed very far it was observed that the seedlings in certain cultures were taller than in others. After several cycles of growth and maturation of the leaves, the previous differences in trunk elongation were still evident. The mature leaves on the upper portion of the trunk were of different sizes in the various cultures, some of the cultures having conspicuously wide leaves.

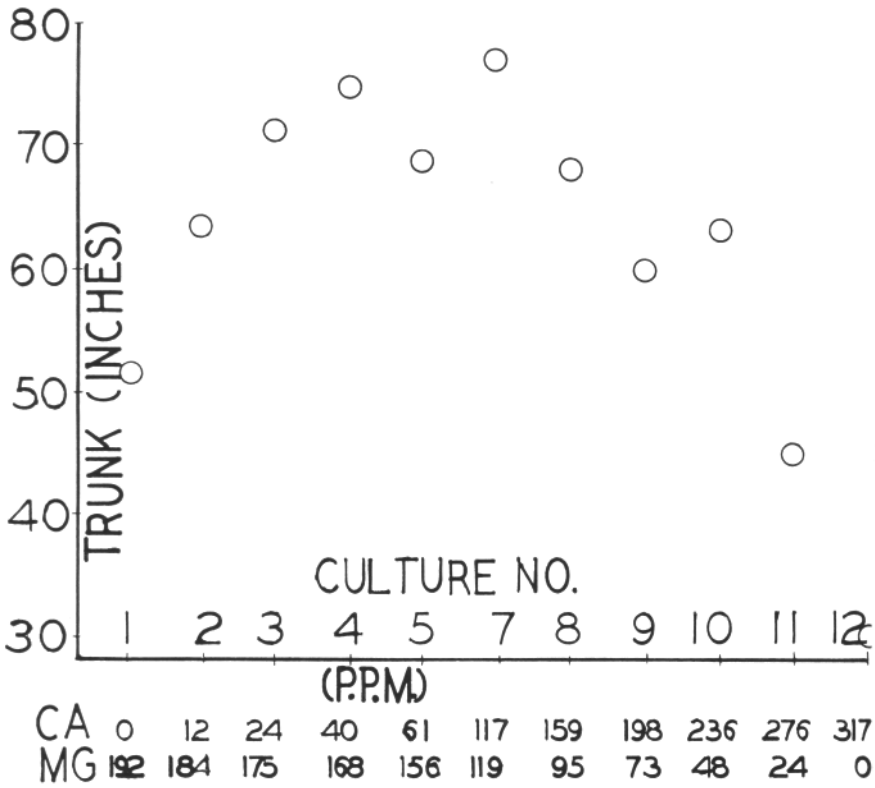

Fig. 2. *Trunk length of Northrop avocado seedlings grown in 3 gallon soil cultures in which the applied solution contained the same amounts of N, P, and K, but various concentrations of calcium relative to magnesium. Growth increased as the magnesium was increased until too much magnesium in relation to the calcium brought about a retardation of growth.*

Fig. 2 shows the height of the Northrop avocado seedlings as of September 6, 1949 and these results confirm the data obtained with Fuerte avocado seedlings. As the magnesium concentration increased, the vertical (terminal) growth increased (culture no. 12 to about no. 7). When too much magnesium and too little calcium was present (culture no. 4 to no. 1), the terminal growth was retarded.

The effect on growth brought about by the concentration of magnesium relative to that of calcium was also seen when Nabal avocado seedlings were grown in large pails filled with plaster sand and provided with drainage. These cultures were treated with magnesium-free Hoagland's solution containing 159 p.p.m. of calcium and to which was added 0, 27, 54, 81, 108, and 162 p.p.m. of magnesium in the form of sulfate. Sulfate is known to depress nitrate absorption in citrus. The resulting lengths of the Nabal avocado trunks were 60.3, 75.5, 85, 72.5, 78.8, and 75 inches respectively at the various magnesium concentrations.

The soil treatment of the Northrop avocado seedlings is being continued. On September 6, 1949 each of the leaves of the cultures was measured and it was found that the length and width of the leaves were greater when the magnesium concentration was

increased relative to that of calcium until when too little calcium was present, the excessive magnesium was accompanied by a retardation of growth, (Table II).

TABLE II
Growth of Leaves of Northrop Avocado Seedlings in Soil Cultures as Affected by the Application of Culture Solutions Containing the Same Nitrogen, Phosphorus, and Potassium but Various Calcium and Magnesium Concentrations

Soil culture number	Total number of leaves on seedling	Number of leaves (immature) discarded at tip of trunk	Number of leaves measured below the discarded leaves	Average length of leaf blade (inches)	Average width at middle of leaf blade (inches)
1	49	5	14	10.2	4.6
2	56	3	18	9.7	4.9
3	62	4	19	11.1	5.1
4	68	7	17	10.0	4.9
5	67	3	22	10.8	4.4
7	69	5	19	10.3	4.5
8	57	3	19	10.7	4.8
9	59	3	18	10.0	3.6
10	68	5	22	9.8	4.0
11	52	4	16	10.4	4.1
12	50	2	14	5.6	3.1

A study of the chemical composition of upper and lower leaves of the Fuerte avocado seedlings grown in the 12 gallon-capacity soil cultures may prove of interest. Fig. 3 reveals that the mature, lower leaves contained more calcium than the mature, upper leaves. The upper leaves show more clearly the rise in the calcium content of the leaves as the concentration of calcium in the culture solution was increased.

The mature lower (older) leaves contain not only more calcium but also more magnesium than the mature, upper (younger) leaves as shown in fig. 4. In the figure the lower leaves (instead of the upper leaves as in the case of calcium) show a decreasing magnesium content in the dry matter of the leaves as the magnesium in the culture solution decreases (culture no. 1 to no. 12). In citrus it is similarly the case with magnesium: the older (lower) leaves give up some of their magnesium to the younger (upper) leaves especially when the magnesium supply becomes limited.

The potassium content in the leaves was determined by the platinic chloride method. In the upper, mature leaves (fig. 5) it is seen that as the concentration of magnesium increased and that of calcium decreased in the culture solution there was a tendency for more potassium to be absorbed by the leaves.

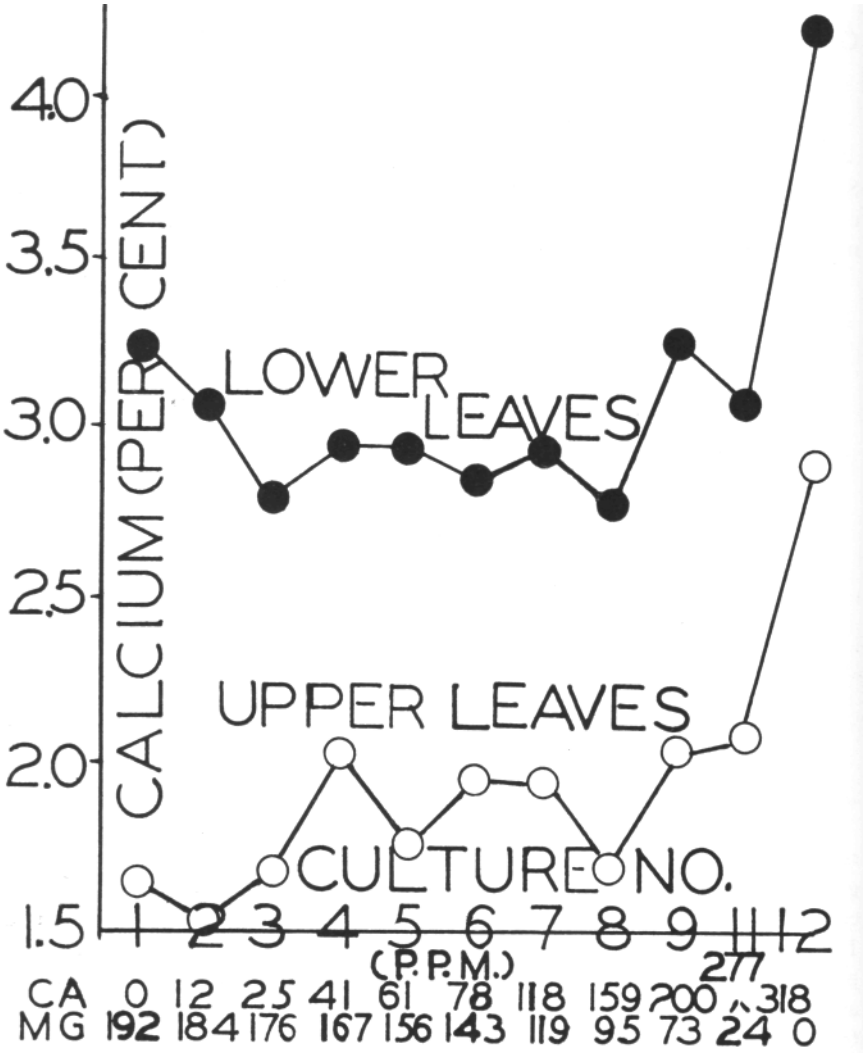

Fig. 3. *Calcium as a per cent in the dry matter of mature upper and lower leaves of Fuerte avocado seedlings grown in soil cultures in which the nutrient applied contained the same amounts of N, P, and K but different concentrations of calcium and magnesium.*

In the determination of potassium it was possible to obtain information regarding the sodium content in the leaves. The results shown in fig. 6 suggest that an increased sodium content may occur in the leaves as the magnesium concentration in the applied culture solution is increased and that of calcium decreased, with some retardation in the upper, mature leaves as the magnesium concentration becomes too high in relation to that of calcium.

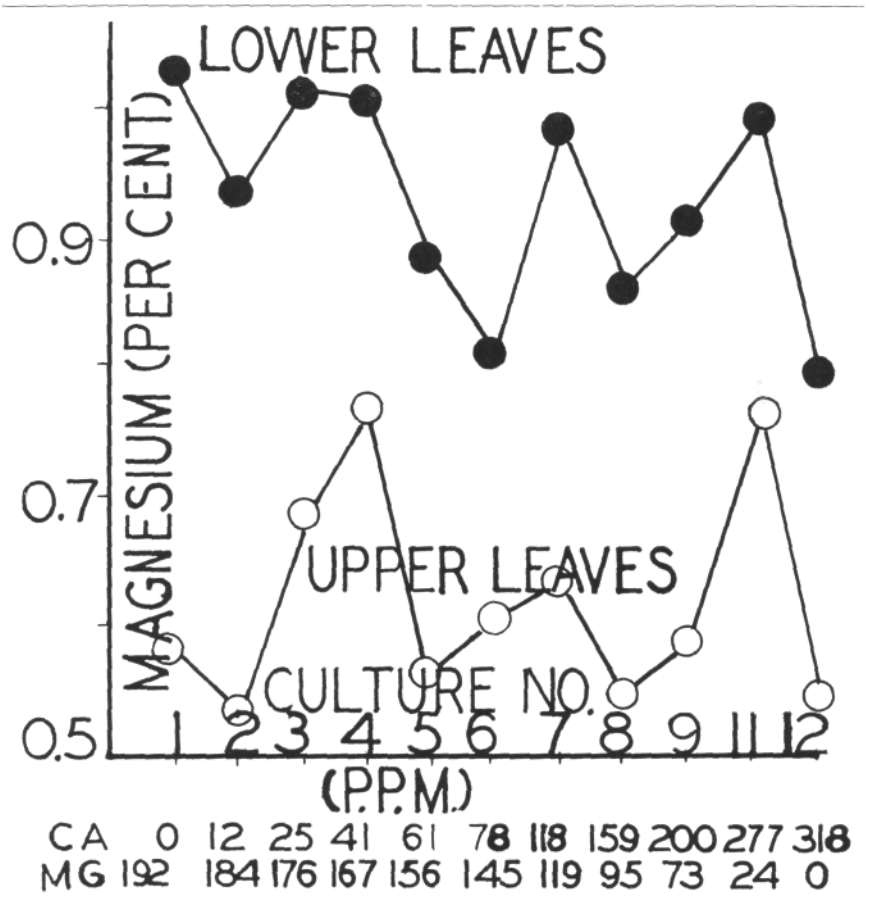

Fig. 4. *The magnesium content in the dry matter of the leaves of Fuerte avocado seedlings grown in soil cultures with similar amounts of N, P, and K in the applied culture solution. but with various calcium and magnesium concentrations.*

When the Fuerte avocado seedlings were harvested, the roots were carefully removed. The rootlets were cut away from the larger roots and were repeatedly washed with tap water and then with distilled- water, after which they •were dried at *65°C.* in a ventilated oven prior to the grinding, reheating, and weighing out of the samples for analysis. The values for the potassium content in the dry matter of the rootlets are shown in fig. 7. The general trend of the curve shows a decreasing potassium content in the rootlets as the magnesium was increased and the calcium decreased. This is the reverse of the trend of the curve for the potassium content in the leaves. The very low potassium content found in the rootlets when the culture solution contained the highest calcium and the lowest magnesium is of interest because of the very high calcium content found in the leaves of culture no. 12 (fig. 3) and of the relatively poor growth obtained when the culture solution contained the highest concentration of calcium and no magnesium.

The results obtained with these various concentrations of calcium and magnesium point to the need of some balance of these elements in the nutrient supply and tend to bring out some of the similarities and differences in the mineral nutrition of citrus and avocado trees. Studies with avocado trees grown under controlled conditions are being

continued in order to understand the better, some of their nutritional requirements.

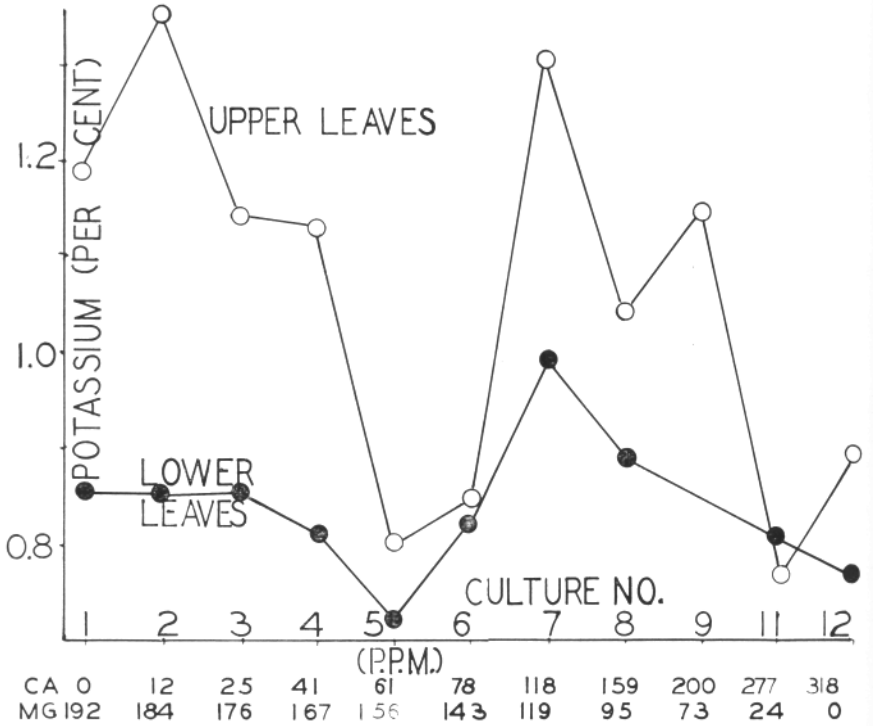

Fig. 5. *The potassium content in mature leaves of Fuerte avocado seedlings grown in soil cultures that received similar amounts of N, P, and K, but various concentrations of calcium and magnesium.*

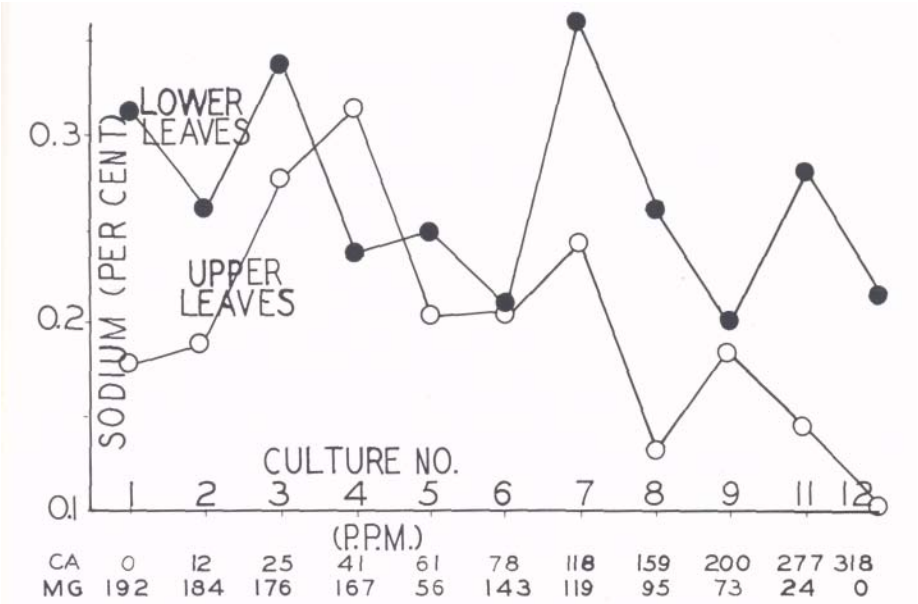

Fig. 6. *The sodium content of mature leaves of Fuerte avocado seedlings grown in soil cultures that received similar amounts of N, P, and K, but various concentrations of calcium and magnesium. The culture solution applied to each culture contained 7 p.p.m. Na and 10 p.p.m. Cl.*

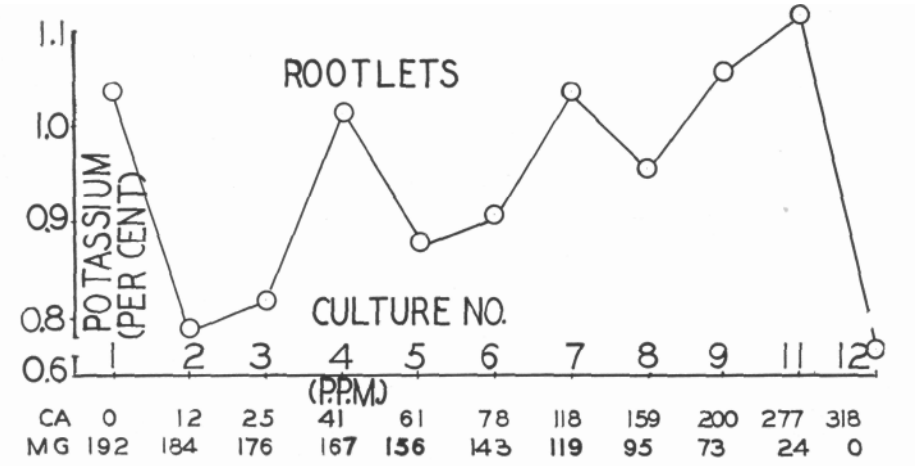

Fig. 7. *Potassium content in rootlets of Fuerte avocado seedlings grown in soil cultures that received equal amounts of N, P, and K, but various concentrations of calcium and magnesium.*

SUMMARY

The composition of mature avocado leaves obtained from orchards in different areas is briefly discussed and their mineral content is compared with that found in mature, healthy citrus leaves. One important difference lies in the smaller content of calcium and higher content of magnesium in avocado than in citrus leaves.

Soil cultures with avocado seedlings were then grown under controlled conditions, each culture receiving the same amount of nitrogen, phosphorus, and potassium, but various concentrations of calcium and magnesium.

As the magnesium concentration was increased and that of calcium was decreased in the culture solution the average fresh weight and size of the leaves and the trunk length were increased but a retardation occurred when the calcium was too low relative to the magnesium concentration.

The mature, upper leaves of the Fuerte avocado seedlings contained increased amounts of calcium as the concentration of calcium increased in the culture solution. The lower leaves showed a decreasing magnesium content as the magnesium concentration in the culture solution decreased. A greater potassium absorption occurred in the mature, upper leaves as the magnesium concentration in the culture solution increased and that of calcium decreased. To some extent this also occurs in the case of sodium absorption. In the rootlets the curve for potassium is quite the reverse of that found in the leaves. The lowest potassium content was found in the rootlets of culture no. 12 which received the highest calcium concentration and no magnesium in its culture solution.