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CALCIUM IN RELATION TO THE EFFECTS OF SODIUM IN AVOCADO SEEDLINGS

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With the extensive cycle of years of low rainfall, the quality of the irrigation water in some avocado areas has deteriorated considerably. Frequently the soil solution contains sodium and with the use of a decreasing supply of water, the concentration may reach a stage at which injury to the tree may be evident. Such injury most frequently occurs when calcium and magnesium are present in inadequate amounts.

In order to study the relationship of calcium to the effects of sodium in avocado seedlings, pure silica sand cultures were used with nutrient solutions containing a constant nitrogen and other nutrient element supply, except for various ratios of calcium to sodium. Topa-Topa (Mexican) avocado seed were prepared for germination by soaking and removing the seed coats and then removing a thin slice from the top and base of the seed. Prompt and uniform germination was obtained in the open propagation frames filled with plaster sand and maintained at 75° F. with bottom heat in the glasshouse. When the top of the germinated avocado seedling was two to three inches high, it was placed in a three-gallon capacity pure silica sand culture provided with drainage.

Distilled water and chemically pure salts were used in making the nutrient solution which contained (p.p.m): Mg, 54; K, 185; SO_4, 390; PO_4, 105; 0.1 p.p.m. of boron, iron, zinc, and manganese respectively and 3 p.p.m. of aluminum as the citrate. The nitrogen (2000 p.p.m.) in the culture solution was the same for each culture, whereas the concentrations of sodium and calcium were varied considerably in the several cultures. The seedlings were grown from March 21, 1949, to June 9, 1950.

Table I gives the concentrations of sodium and calcium and the growth response of the avocado seedlings. During the course of the experiment it was apparent at all times that growth was better in cultures containing both sodium and calcium than when either element was lacking. The best growth occurred when the calcium content of the culture solution greatly exceeded that of the sodium as in cultures nos. 5, 6, and 7.

Further confirmation of the better growth when some sodium was present is seen in the following experiment. In three-gallon capacity soil cultures (a mixture of half soil and half plaster sand to assure good drainage), Mexicola (Mexican) avocado seedlings were grown and were given a similar nutrient solution as that given the silica sand cultures except that the ratios of calcium and sodium were changed. The culture solution, for each of ten cultures, contained 493 p.p.m. of nitrate. This culture solution contained the following parts per million of calcium and sodium respectively for the ten cultures: 0, 184; 12, 170; 31, 150; 40, 137; 61, 116; 98, 68; 129, 34; 146, 14; 156, 3; 159, 0. The

cultures were started on April 27, 1950 and on October 11, 1950 the height of the trunks (no lateral branches were allowed to develop) corresponding to the above calcium-sodium ratios were: 27, 35, 44, 39, 40, 38, 45, 32, 38, and 33 inches respectively. Although this is the growth picture that has been maintained up to now, it should not be overlooked that as the seedlings advance in age a different growth condition may present itself.

TABLE I

Effect on the growth of Topa Topa (Mexican) variety avocado seedlings of various proportions of calcium and sodium in the nutrient solution applied to three-gallon capacity pure silica sand cultures.

Culture Number	In the culture solution		Length of trunk inches	Trunk, fresh weight (gms.)	Leaves, fresh weight (gms.)	Roots, dry weight (gms.)
	Ca (p.p.m.)	Na (p.p.m.)				
1	0	734	59	77	57	17
2	49	680	48	34	30	9
3	122	598	58	85	57	32
4	244	462	43	77	84	37
5	390	272	72	195	179	98
6	517	136	83	322	191	104
7	588	54	57	112	148	49
8	622	14	33	54	83	34
9	634	0	41	73	53	45

In the pure silica sand cultures referred to in Table I the leaves of plants in cultures nos. 1, 2, and 3 burned severely, even the young immature leaves showed severe burn as shown in figures 1 and 2. The small circular or oval-shaped small burned spots first occurred along the margins and also were scattered over the leaf area and each spot gradually enlarged (fig. 1) until much of the leaf area was burned (fig. 2) and the original center had dried and fallen out (fig. 2). The leaves of cultures nos. 1, 2 and 3 had to be collected before they had burned too severely and had been shed. The striking feature in this experiment was that cultures 1, 2 and 3 had severely burned leaves typical of excessive sodium whereas on none of the other cultures was there any leaf-burn whatsoever. Beginning with culture no. 5 the roots were white and of an excellent appearance whereas in the first three cultures some of the roots were obviously dark and badly injured.

Leaf samples were collected from the upper and lower portions of the trunk, avoiding leaves that contacted the nutrient solution and those that were thin and immature. In all nutrient culture work the practice of rubbing out of all the young lateral shoots, greatly facilitated the sampling and the measurements of growth.

Table II presents the analytical data in regard to the composition of the plants that were severely injured and those apparently unaffected by the use of sodium (the calcium-sodium concentrations are given in table I). The striking feature in table II is the content

of sodium and calcium in the leaves. In both the lower and upper leaves the percentages of sodium in the dry matter were markedly higher for the first three cultures that showed severe injury than for the remainder of the cultures, none of which showed apparent injury. The effect of the high sodium and low calcium is also seen in the rootlets.

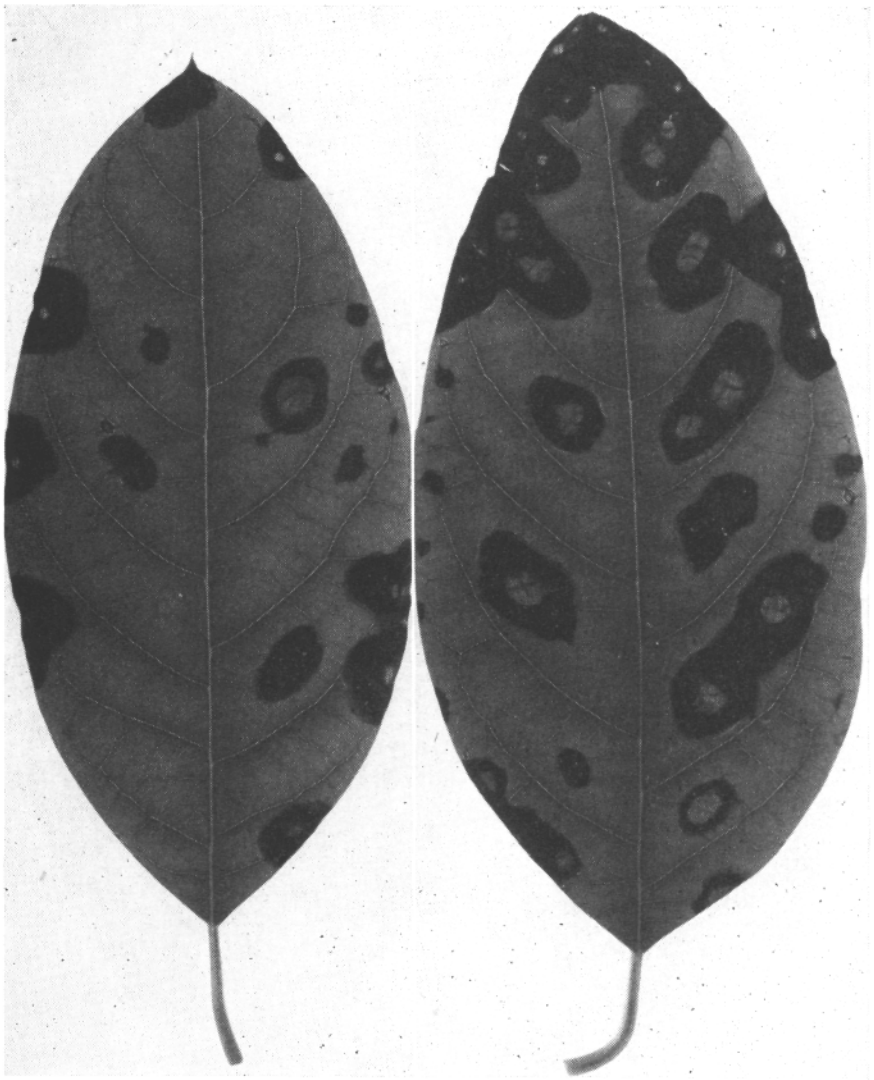

Fig. 1. *Avocado leaves from culture No. 2 in which the smallest concentration of calcium was present in the nutrient solution in which the nitrate was almost entirely supplied as sodium nitrate. Various early stages in the sodium leaf burn are shown in this leaf collection of February 7, 1950. Note, left to right: the circular burned spots on the leaf margins and blade that enlarge in concentric areas (the centers of which may fall out) and coalesce to cause continuous burn as seen in Fig. 2.*

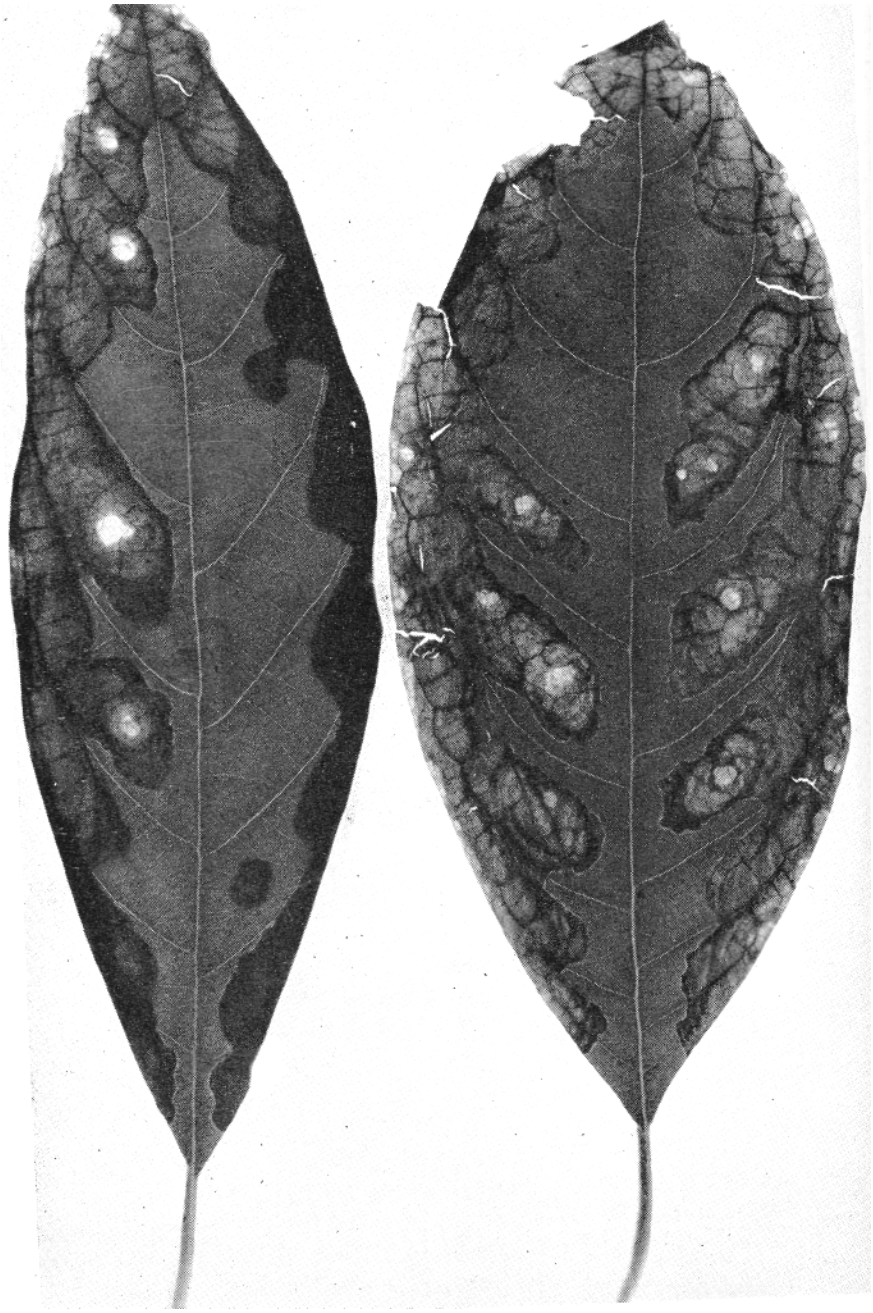

Fig. 2. *Typical and advanced sodium burn in leaves of the Topa Topa (Mexican) variety of avocado seedlings grown in three-gallon capacity silica sand cultures. The leaves were collected on October 25, 1949 from the lower portion of the trunk of cultures that received little or no calcium and relatively large concentrations of sodium (cultures Nos. 1, 2, and 3 in Table I). Note the enlargement of burned areas especially between the veins and the loss of the portion or center that had the first visible burn.*

Comparison of the percentages for the lower and the upper leaves showed the increased calcium content of leaves as they became older without any appreciable change in the potassium percentage. This would indicate a continued potassium intake by the avocado leaves as they increase in age for otherwise the percentages for potassium would tend to greatly decrease. Table II also shows the small uptake of sodium by avocado leaves when there is present an adequate supply of calcium.

Figure 3 illustrates the effect of a combination of excessive sodium and an excessive concentration of nutrient elements. These seedling avocado leaves show the circular burned spots typical of excessive sodium in addition to the marginal burning that proceeds inward between the veins that results from an excessive total concentration of nutrient salts. These leaves contained 0.86 per cent of calcium which is low and 0.58 per cent of magnesium in their dry matter, whereas the potassium content was unusually high (3.43 per cent) and the sodium content also very high (0.82 per cent). The ash constituted 12.18 per cent of the dry matter of the leaves in contrast to 8.18 per cent in leaves of orchard trees at Vista.

During the summer of 1950, numerous avocado leaf samples have been received in which small burned spots appear scattered over the leaf surface. They occurred on leaves that showed a zinc or manganese deficiency but also were present on apparently healthy leaves. The possibility of cold damage was unlikely because many of the leaves were produced after the cold period. The possibility of a water shortage having caused the spots is not to be dismissed so readily although such spots have not as yet shown themselves in our soil cultures where the water supply could be lacking.

In order to learn something regarding these spots several collections of affected leaves were made by interested growers in the La Mesa and Vista areas. The dry matter of the affected leaves showed .05, .04, .06, and .05 per cent respectively of sodium which is low, and it is unlikely that sodium is a factor. The potassium values were: 1.52, 1.60, 1.38 1.35, and 1.03 per cent respectively; values that appear satisfactory. The calcium values were: .99, .55, .64, and .97 per cent respectively whereas those of magnesium were: .44, .31, .35, and .56 per cent respectively. These values for calcium especially and also for magnesium are low and may be factors in addition to the possibility of water as a factor also. It would appear that the calcium and the magnesium values in many avocado areas may be too low for the growth of healthy trees.

TABLE II

The Effect of Various Proportions of Calcium to Sodium in the Nutrient Solution on the Composition of Mature Leaves of Mexican Avocado Seedlings (Topa Topa Variety) Grown in Three-Gallon Capacity Silica Sand Cultures, the Nitrogen, Potassium, Phosphorus and Minor Element Content of the Nutrient Solution Being Similar in All Cultures.

Culture number	Per cent in dry matter of mature lower leaves				Per cent in dry matter of mature upper leaves				Per cent in dry matter of entire root system			
	Ca	Mg	K	Na	Ca	Mg	K	Na	Ca	Mg	K	Na
1	0.84	0.41	1.01	1.20	0.59	0.35	1.03	0.56	0.22	0.12	0.72	0.32
2	1.48	0.60	1.07	1.09	0.60	0.36	0.81	0.24	0.23	0.11	0.79	0.25
3	1.32	0.57	1.27	1.21	0.78	0.42	1.32	0.14	0.49	0.16	0.60	0.28
4	1.84	0.55	0.81	0.03	0.96	0.35	0.88	0.05	0.22	0.09	0.62	0.15
5	2.44	0.63	0.66	0.05	1.15	0.33	0.55	0.03	0.24	0.08	0.52	0.22
6	1.90	0.63	0.63	0.03	1.14	0.43	0.58	0.03	0.19	0.07	0.41	0.07
7	2.55	0.51	0.79	0.07	1.22	0.28	0.90	0.03	0.38	0.12	0.69	0.11
8	2.91	0.59	0.78	0.04	1.99	0.39	0.83	0.04	0.38	0.11	0.73	0.05
9	3.05	0.48	1.05	0.05	1.91	0.27	0.83	0.05	0.38	0.21	0.72	0.08

Fig. 3. *Leaves of Mexican avocado seedlings grown in containers (8 inches wide by 12 inches deep) filled with a mixture of four-sixths turkey-run soil, one-sixth steer manure and one-sixth peat. Note the circular spots with dry centers (typical of excessive sodium) and the burned leaf margins resulting from excessive nutrient concentration (high osmotic pressure).*

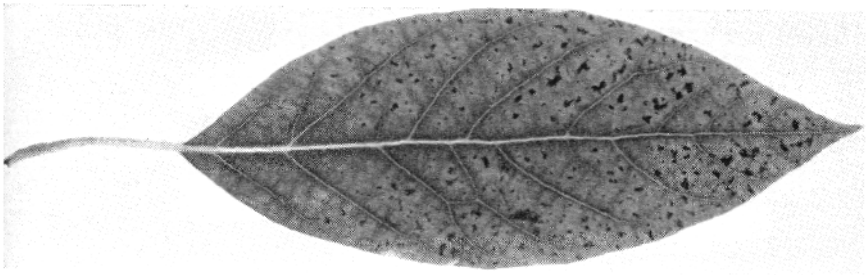

Fig. 4. *Avocado leaf with small scattered burned spots between the veins and widely distributed over the leaf. Some leaves were zinc deficient or tipburned, whereas some were otherwise healthy in appearance. Analysis did not indicate excessive sodium in the affected leaves.*

SUMMARY

This study of calcium in the growth of avocado seedlings was initiated because of the relatively small supply of calcium available to avocado trees in certain orchard areas and because of the increasing tendency toward a greater sodium uptake and injury in avocado trees during periods of low rainfall and reduced water availability.

Pure silica sand cultures with Topa Topa (Mexican) avocado seedlings were grown in which the nutrient solutions were similar in all respects except in their various ratios of calcium to sodium. For young seedlings in which no laterals were allowed to develop, the growth (during the period of the experiment) was best when a certain range of calcium to sodium values occurred in the nutrient solution. This was also confirmed for this limited growth period by means of soil cultures.

Sodium-burn in avocado leaves makes its appearance as small, circular burned spots on the margin and also scattered over the leaf area. These spots enlarge in more or less concentric areas, each of which may have a different shade of brown. As these enlarged spots join, the leaf becomes severely burned and the original burned areas of the leaf may drop out. When an accumulation of excessive chlorine or an excessive total concentration of nutrient elements in the soil solution are also involved, the injury to the leaf by sodium may be greatly increased.

Sodium was found in appreciable amounts in avocado leaves only when the concentration of sodium was very high in relation to that of calcium. Calcium increased considerably as the avocado leaves increased in age although potassium did not necessarily decrease.