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The Uptake and Accumulation of Chloride in Avocado Leaves and the Tolerance of Avocado Seedlings under Saline Conditions[1]

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Avocado trees are extremely sensitive to chlorides in the soil solution, particularly trees of the Mexican race (4, 5, 7, 9, 10, 11), which may show damage even when the soil solution has relatively low Cl content (2, 3). The first symptoms of Cl damage are necrotic tissue at the tips and margins of leaves, tipburn. Often the tipburn is found to be preceded by a marginal chlorosis. In advanced stages the necrotic tissue may cover 50% or more of the leaf which causes a great reduction in the photosynthetic activity of the tree and its eventual complete collapse.

In the experiment described here, the relative tolerance of avocado seedlings from several varieties and races was examined under saline conditions.

MATERIALS AND METHODS

Eight seedling varieties of avocado were included in the test: 3 of the Mexican varieties—Mexicola, Northrop and G1 7[2]; 1 Mexican x Guatemalan hybrid, Fuerte; 1 Guatemalan x West Indian hybrid, Lula; and 3 Guatemalan varieties—Anaheim, Benik and Nabal. The seeds were germinated in vermiculite boxes and in the spring of 1957 after the seedlings reached the height of 15-20 cm, they were graded according to size. The 72 most uniform seedlings from each variety were selected and transplanted to the experimental plot in a screen house.

The seedlings were planted in 96 metal barrels 50 cm in diameter and 85 cm deep. Barrels were painted with special acid-base resistant paint (H-300), on the inside and with regular asphalt on the outside. The barrels were arranged in groups. Each group of 8 barrels formed a replica of the seedling population in randomized form; there were 12 such replicas. In each barrel 6 seedlings were planted all of the same variety. The barrels were placed in ditches in the ground so that the upper edge was 10 cm above the soil level. A 10 cm layer of coarse gravel had been spread previously in the bottom of the ditches. The bottom and the lower part of each barrel's walls were punctured in many places and a 10 cm layer of gravel was spread over the bottom to provide good drainage of excess water. Each barrel was then filled with 150 kg (about 65 cm deep) of light loamy virgin soil with very low salt content.

From the date of seedling transplanting until the beginning of the experiment, the plants in each barrel received a weekly irrigation of 5.0 L of tap water containing 60 ppm of Cl

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[2]G1 7 was the name given to a large Mexican seedling tree which produces very uniform seedlings.

and 40 ppm of Na. A short time after transplanting all seedlings started new growth.

At the end of June 1958, seedling height was measured from the top part of the seed to the tip of the plant. Stem diameter was measured at about 1 inch above the seed top, and leaf samples were taken, (the 2 upper fully grown leaves of each plant including petiole and blade). The leaves were taken separately from each barrel and analyzed for Cl and Na. In addition, soil samples were taken from 2 layers (0-30 cm and 30-60 cm) from several barrels, and analyzed for salt content.

The experiment was started on July 1, 1958. The plants were irrigated with water containing 500 ppm NaCl. On September 1, 1958 the salt concentration was increased to 830 ppm NaCl, and irrigation was given with this water, 5 l/barrel/week throughout the experiment, except for 2 winter seasons when the plants received only rain water. In the first period irrigation ceased November 30, 1958 and started again May 1, 1959; (the total rainfall during that period was about 41.1 cm). In the second period irrigation was stopped December 15, 1959 and started May 1, 1960; (the rainfall was about 28.3 cm). The total amount of salt added per barrel during the experiment was 285 g NaCl (171 g Cl and 114 g Na). During the first period (July 1958 to winter 1958/59), the amount of salt added was 60 g; during the second period (spring 1959 to winter 1959/60), 112 g, and during the third period (spring 1960 to November 1960), 112 g NaCl.

At 2 month intervals the height and stem diameter of the plants were measured, plants were graded for leaf scorch (Table 1), and leaf samples were taken for analysis. Soil samples were also taken at random and analyzed for Cl, Na and electric conductivity of the soil saturation extract. From November 1, 1958 leaf samples from the lower, greatly damaged leaves were also analyzed in addition to the upper leaves. The plants were fertilized 4 times: in spring and summer 1959 and spring and summer 1960 (fertilizer applied with irrigation included 4.20 g $(NH_4)_2\ SO_4$; 3.55 g $NH_4\ H_2PO_4$ and 1.96 g K_2SO_4 per barrel each time).

Methods of Leaf Analysis: Leaf samples were rinsed thoroughly with water and then with distilled water. Care was taken not to dip the samples too long in the water to avoid possible loss of minerals from the leaves. After cleaning, the leaves were oven dried for24 hours at 65 °C and ground in a Wiley mill with a 40 mesh screen. Two-g samples were taken for Cl and 1 g for Na determination. The material was dry-ashed first on electric plate and then in a muffle furnace for 5 hours at 550° C (1). Cl was determined by the method of Husband and Gudden (12); Na was determined by flame photometer.

Table 1.—Grades of leaf scorch and description of damage on leaves of avocado plants irrigated with saline water (500 ppm of Cl).

Grade	Description of the plant
1	Color of leaves green; no scorching.
2	Color of leaves light green; some leaves show tip and margin burn.
3	Chlorotic spots on some leaves; medium to severe scorching on most leaves; loss of the severely affected leaves; (necrosis of ¼—½ of leaf tissue).
4	All leaves on plant show severe scorching; severe defoliation; symptoms of decline; blackening and drying of twig edges.
5	Complete defoliation; main branches and often the stem black and dry, plant approaching complete decline.

RESULTS

Plant behavior: During the first month there was almost no leafburn, plant development was good. During the second month light tipburns were observed on the leaves of most plants. During this early period the damage was most apparent on the Lula and Fuerte seedlings. From the third month on, the leaves showed severe necrosis, which expanded from the tips to the margins and sometimes covered half of the leaf area, mostly on fully matured leaves. The original dark green color became lighter in most plants. At this stage there was not much consistent difference in the grade of damage between the various populations, except for the more severely damaged Lula and Fuerte seedlings. The variability among the seedlings of each variety was generally small, but a few plants in each group were outstanding in their dark green color and small amount of leafburn.

During later periods the differences between the Lula and Fuerte seedlings and the seedlings of the other varieties gradually disappeared, but the difference between the seedlings within each group became more pronounced. From November 1959 until the end of the experiment, all Northrop seedlings showed markedly more damage than the other populations. Many Northrop seedlings showed characteristic necrotic spots which were associated with high Na content in the leaves, while leaves not showing these spots contained low Na.

Statistical analysis for the grade of damage at the end of the experiment after 28 months showed significant differences at 1% level between the seedling populations. Northrop seedlings were in the worst condition (Table 2).

Table 2.—Average grades[a] of damage to avocado plants after 4 and 28 months of irrigation with saline water (500 ppm Cl).

Sampling dates	Varieties								S.E.
	Ana-heim	Benik	Nabal	Fuerte	Lula	Mexi-cola	North-rop	Gl.7	
Nov. 1, 1958 (4 months)	2.0	1.9	1.8	2.6	2.6	2.1	2.3	2.3	0.1
Nov. 1, 1960 (28 months)	2.6	2.4	2.6	2.8	2.6	2.7	3.3	2.5	0.1

[a]See Table 1 for grade description.

Growth measurements: The mean additional growth in height and stem diameter of the plants from the beginning until the end of the experiment was calculated for each population and statistically analyzed (Table 3). Significant differences in growth on the 1% level were found between 3 groups of populations: Northrop and Fuerte had the least additional growth; Mexicola and G1 7 were in the middle group; Lula, Anaheim and Benik had the most additional growth.

Leaf analysis: The mean value of all replications of each seedling population for Cl and Na was calculated. The Cl increased in the leaves of all populations. The average Cl content in the upper and lower leaves as calculated for sampling dates are shown in Table 4. The Cl content was significantly higher (at 1% level) in the autumn of each year than in the spring. The reason for that is probably, the leaching of Cl from the soil and from the leaves by the rains. Table 5 shows the mean values of Cl content in the upper and lower leaves as calculated for varieties. Significant differences in Cl content (at *5%* level) were found between the population groups. The Mexican varieties and Fuerte

showed high Cl content, the Guatemalan varieties and the Lula showed lower Cl content.

Soil analysis: Analyses of the soil samples showed high increase in the electric conductivity of the soil saturation extract from 0.42 millimhos/cm at the beginning of the experiment to 2.28 millimhos/ cm at its end. The Cl content in the soil showed marked seasonal variations. During the first summer it was quickly increased from 0.08 meq/100g to 0.67 meq/100g. During the rainy season it dropped to 0.36 meq/100g by leaching, then increased to 1.13 meq/100g during the summer and autumn of 1959, dropped again to 0.53 meq/100g in the winter of 1960 and amounted to 0.82 meq/100g at the end of the experiment. The sodium content on the other hand showed gradual constant increase from 0.17 meq/100g at the beginning to 2.3 meq/100g at the end of the experiment.

Table 3.—Additional growth – (difference of height[a] and diameter[b] of stems between the beginning and end of the experiment), of avocado plants irrigated with saline water.

	Varieties								S.E.
	Ana-heim	Benik	Nabal	Fuerte	Lula	Mexi-cola	North-rop	Gl.7	
Additional height, cm	130.3	124.2	109.7	97.4	132.8	112.3	94.8	115.7	4.1
Additional diameter, mm	11.6	12.5	11.7	7.6	11.0	9.2	7.4	8.8	0.4

[a]Height measured in cm from the top of the seed to the tip of the plant.
[b]Diameter measurement in mm about 1" above the seed.

Table 4.—Mean % of Cl in the upper and in the lower leaves of avocado according to sampling dates in spring and autumn.

	Sampling dates						S.E.
	1958		1959		1960		
	July 1	Nov. 1	May 1	Nov. 1	May 1	Nov. 1	
Upper leaves	0.35	1.33	0.78	1.06	0.50	1.11	0.08
Lower leaves	—	2.09	0.72	1.56	0.64	1.52	0.09
Average		1.71	0.75	1.31	0.57	1.32	

DISCUSSION

In the present experiment it was proved again that differences exist between various horticultural races of avocado in their tolerance to NaCl. In general, Guatemalan varieties and the West Indian hybrid showed higher tolerance than Mexican varieties. These results are in agreement with field observations made in Texas (4, 5, 6) and in Israel (11) and also with results obtained in various experiments carried out in California (7, 9, 10).

In statistical analysis of the data obtained it was found, however, that the seedlings of the Mexican type G1 7 did not show less tolerance with respect to leaf scorches than the average of the Guatemalan (Table 2). Leaf analysis showed higher concentrations of Cl in the Mexican and Fuerte seedlings than in the Guatemalan and Lula (Table 5).

In general a close correlation was found between the Cl content in the leaves and the

leaf scorch, so that for practical purposes scorches of this type can be identified with Cl accumulation in the scorched tissues.

The Cl content in the leaves increased with its increase in the soil. Its reduction in leaves during the winter and spring as compared to summer and autumn (Table 4) was probably due to leaching of Cl from both soil and leaves by the rains.

Other criteria used in our experiment to express tolerance, such as height and diameter growth of the trunks cannot be used by themselves as criteria for tolerance, because of the great degree of variability that exists among the seedlings of each variety in the rate of growth. This is governed by genetic factors of vigor as well as salinity tolerance. A connection was found, however, between the rate of growth and the plant tolerance under saline conditions. Strong-growing plants showed more tolerance than weak-growing plants, but this was not always expressed in less leaf scorch. Seedlings of Lula and Fuerte varieties, which during the first stages of the experiment showed a higher rate of growth showed at the same time more leaf scorch. The Lula seedlings showed high tolerance, while the Fuerte seedlings showed low tolerance during later stages of the experiment (Tables 2 and 3).

Table 5.—Mean % of Cl in the upper and lower leaves of avocado according to varieties.

	Varieties								S.E.
	Ana-heim	Benik	Nabal	Fuerte	Lula	Mexi-cola	North-rop	G1.7	
Upper leaves	0.78	0.77	0.81	0.88	0.78	0.91	0.95	1.01	0.09
Lower leaves	1.09	1.06	1.19	1.22	1.14	1.20	1.33	1.40	0.15
Average	0.94	0.92	1.00	1.05	0.96	1.06	1.14	1.21	

In statistical analyses, carried out to establish the reliability of the various criteria used in our experiment to express plant tolerance to NaCl, it was found that a certain combination of the grades expressing the height and width of the plants and the grade of leaf damage: $Y = X_1 + X_2 — X_3$; where Y = tolerance; X_1 = height, X_2 = width and X_3 — grade of damage, give a good criterion for tolerance which accounts for a high percentage of all the variability of the 3 criteria. Although each of the 3 criteria individually is not fully satisfactory for assessing NaCl damage, the combination of all 3 gives us a good criterion for tolerance valuation.

The Cl content in the leaves alone cannot be used in all cases as a criterion for tolerance. Although in most cases the more tolerant seedling populations had, on the average, a lower Cl content than that of the saline-sensitive seedling populations, in at least one case the situation was different. The leaves of seedlings of the Mexican type G1 7 contained the highest amount of Cl among the seedling populations (Table 5), but they showed high tolerance (Tables 2, 3).

These results suggest the existence of 2 kinds of tolerance to high Cl concentration in the growth substance. The first is less uptake and transfer of Cl from the substrate to the leaves by the more tolerant plants, which seems to be the case in most of the tolerant avocado populations. The second is the tolerance of the plant to higher Cl

concentrations within the leaves, as was the case in the G1 7 seedlings.

Apparently the use of rootstocks of the G1 7 type under saline conditions may result in high Cl content in the scion leaves and therefore may not be satisfactory.

In the present experiment Na was found to have harmful effects on Northrop seedlings. Na uptake and accumulation seems to be of a more complicated nature than that of Cl. Work aimed on the study of Na behavior is still in progress and will be discussed in a separate paper.

SUMMARY

Avocado seedlings of 8 varieties were grown under saline conditions produced by irrigation with water containing 500 ppm Cl as NaCl. The plants were graded for leaf scorches, growth was measured and leaf samples were taken for analysis every two months.

In general a close correlation was found between Cl content in the leaves and the grade of leaf scorch, except for the Mexican G1 7 variety. The seedlings of that variety showed the highest Cl content in their leaves and yet their damage rating was among the lowest.

The reliability of the various criteria used for valuation of salinity tolerance of avocado seedlings is discussed.

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