California Avocado Society 1950 Yearbook 34: 139-148

SALT TOLERANCE OF AVOCADO TREES GROWN IN CULTURE SOLUTIONS*

A. D. AYERS, Chemist
U. S. Regional Salinity and Rubidoux Laboratories, Riverside

Introduction

Tip burn of avocado leaves has been severe in a number of areas of Southern California during 1947, 1948 and 1949. It has been the belief of some men connected with the industry that the severity of burning has increased as a result of several successive seasons of deficient rainfall and the subsequent accumulation of salts within the soil profile.

In order to obtain information on the salinity factor, leaves and soils were collected from a number of affected areas in San Diego County. Analyses of scorched leaves showed an accumulation of chloride and occasionally of sodium. The values for chlorides were five to ten times higher than those for normal leaves, but were in the same range as those reported earlier by Haas (1) for burned leaves. In substantiation of the theory that salinity was involved, leaf injury was frequently more severe in locations where trees were irrigated with water containing appreciable concentration of salts, particularly of chlorides. However, analyses of the soils under trees suffering from leaf burn usually showed salt concentration lower than the accepted levels which would classify a soil as saline (3). Only in a few instances were the concentrations of the saturation extracts as high as 4 millimhos/cm.

The presence of abnormally high concentrations of chlorides in the scorched leaves and the low concentrations of salts found in the soil under these trees led to the question of the relative salt tolerance of the avocado and the causes of the injury observed in the field. Was this injury due to high concentrations of salt in the soil solution or to the excessive accumulation of one or more toxic ions within the plant so that it was not able to function in a normal manner? Small avocado trees were grown in culture solution to study these questions and to see if the leaf symptoms could be reproduced in the greenhouse. With the water culture technic it was possible to regulate and control accurately the composition and concentration of the solution in contact with the root system.

Experimental procedures

In the late fall of 1948, small Mexican seedling avocado plants tip-grafted to a Fuerte selection were transferred from soil to two-gallon crocks containing aerated nutrient solutions. The plants were slow to start new growth, and salt treatments were not initiated until May, 1949. Sodium chloride was added to one series of cultures so that the final solutions had osmotic pressures of 0.5, 1.0 and 1.5 atm. higher than the 0.4 atm. OP of the base nutrient solution. The salt was added in one-third increments at intervals of three days. Calcium chloride was added to a second series to produce equal osmotic pressures and sodium sulfate in a similar manner to a third series. Periodic growth measurements and two sets of leaf samples were taken prior to the conclusion of the experiment in October, 1949. The solutions were changed weekly during the course of the experiment and the pH was adjusted twice each week with HNO_3 or with the hydroxide of the dominant cation. Iron and minor elements were included in the nutrient solution. The solution had the following composition:

Treatment	Na	Ca	Mg	K	H_2PO_4	NO_3	SO_4	Cl[1]	EC[2]	OP[3]
Added salt in Atm. OP.	m.e./l.				m.e./l.					Atm.
Control	Trace	5.0	2.0	2.5	0.5	5.0	4.0	Trace	1.5	0.4
0.5 NaCl	11.5	5.0	2.0	2.5	0.5	5.0	4.0	11.5	2.9	0.9
1.0 "	23.0	5.0	2.0	2.5	0.5	5.0	4.0	23.0	4.0	1.4
1.5 "	34.5	5.0	2.0	2.5	0.5	5.0	4.0	34.5	5.1	1.9
0.5 $CaCl_2$	Trace	21.0	2.0	2.5	0.5	5.0	4.0	16.0	3.2	0.9
1.0 "	Trace	37.0	2.0	2.5	0.5	5.0	4.0	32.0	4.7	1.4
1.5 "	Trace	53.0	2.0	2.5	0.5	5.0	4.0	48.0	6.2	1.9
0.5 Na_2SO_4	17.8	5.0	2.0	2.5	0.5	5.0	21.8	Trace	3.1	0.9
1.0 "	35.6	5.0	2.0	2.5	0.5	5.0	39.6	Trace	4.5	1.4
1.5 "	53.4	5.0	2.0	2.5	0.5	5.0	57.4	Trace	5.9	1.9

[1] To convert m.e./l. Cl to p.p.m. multiply by 35.5.
[2] Electrical conductivity in millimhos per centimeter.
[3] Osmotic pressure of solution in atm.

At the time differential treatments were started, all plants were approximately of the same size. Growth in the more saline cultures was affected almost immediately, and within a month the control plants were larger than those in all treatments except the lowest level of calcium chloride. Growth measurements are given in Table 1. Figure 1 shows the plants eight weeks after treatments were initiated. At this time both the sodium chloride and sodium sulfate salts had caused marked reductions in growth even at the lowest concentration of salt in the substrate (0.9 atm. OP). Calcium chloride additions produced a less severe, but noticeable effect.

The plants at the end of the experiment are shown in Figure 2. At that time all plants in the sodium sulfate treatment were dead or had been harvested because they were in a dying condition. Trees on the higher NaCl treatment were dead or in poor condition, and those on the 1.0 and 1.5 $CaCl_2$ treatments had made little recent growth (Table 1).

Fig. 1. *Avocado plants eight weeks after the initiation of differential salt treatments. Plants were grown in a series of culture solutions to which NaCl, $CaCl_2$ or Na_2SO_4 had been added to increase the osmotic pressure of the base nutrient solution by 0.5, 1.0, and 1.5 atm.*

Fig. 2. *Avocado plants twenty-three weeks after the initiation of differential salt treatments. All plants in the Na_2SO_4 series had been harvested prior to this time as they were already dead or in a dying condition.*

TABLE 1. Growth Measurements

Date	BN[1]	NaCl			$CaCl_2$			Na_2SO_4		
	Added salt — as atmospheres osmotic pressure									
	0	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5
	Height of plant, centimeters									
6-9-49	64	39	33	38	71	49	51	40	44	45
7-20-49	78	47	34	44	79	56	55	49	44	D*
9-1-49	116	57	34	56	80	68	66	D	D	D
	Diameter of trunk 1 in. above graft union, centimeters									
6-9-49	1.25	0.93	0.81	0.94	1.04	0.97	0.95	0.87	0.91	0.77
7-20-49	1.66	1.00	0.83	0.95	1.34	1.05	.98	.95	.98	D
9-1-49	1.97	1.07	0.86	0.98	1.39	1.17	1.05	D	D	D

* Dead

[1] Base Nutrient—control solution containing only the essential plant nutrients.

Leaf symptoms

The saline treatments resulted in leaf injury as well as reduced growth and the severity of the symptoms increased with time and with increase in the osmotic pressure of the culture solution. Figure 3, shows leaves from the NaCl series. The first observable effect produced by the sodium chloride treatment was a slight burning or scorch at the tip of the leaf. This was not pronounced at the 0.5 OP level, but at the 1.0 and 1.5 levels the scorch became progressively more severe working down the margins and into the blade until little live tissue remained in the older leaves. These leaves soon dropped leaving only young leaves on the plants.

Calcium chloride produced essentially the same leaf burn as sodium chloride at corresponding salt levels except that the symptoms were not quite as severe, did not occur as soon, and did not appear to affect the interveinal portion of the leaf as severely.

Sodium sulfate produced a leaf injury unlike that found in the $CaCl_2$ and NaCl series. Leaf scorch did not start at the tip of the leaf, the first symptoms occurring as small spotted areas between the veins. These dead areas were more pronounced at the higher salt levels and increased in size and number with time until most of the leaf was dead or until it dropped. The leaf at the right in Figure 4, illustrates the predominant type of leaf injury incurred with Na_2SO_4; the single enlarging necrotic spot on the leaf at the left occurred much less frequently.

Accumulation of sodium and chloride

In order to see if there was a correlation between the observed injury and the accumulation of any of the major inorganic ions within the avocado tree, analyses were made on leaves and other vegetative parts of the trees grown in the culture solutions.

TABLE 2. Composition of avocado leaves harvested 7-19-49.

Treatment added salt in atm. OP	Degree of Leaf Burn	Constituents				
		Cl	Na	Ca	Mg	K
		m.e./100 gms. dry Wt.				
B.N.	None	1.0	0.7	44.6	33.7	31.2
0.5 NaCl	Slight	18.0	15.5	50.7	40.3	33.8
1.0 NaCl	Mod.-severe	23.0	36.8	43.8	33.7	26.5
1.5 NaCl	Severe	47.6	59.8	20.7	31.9	56.7
0.5 $CaCl_2$	Trace	19.6	5.9	60.4	30.4	39.5
1.0 $CaCl_2$	Moderate	37.1	0.9	70.1	32.1	45.7
1.5 $CaCl_2$	Mod.-severe	44.7	0.9	83.6	30.4	38.4
0.5 Na_2SO_4	Slight	1.0	22.6	41.8	30.4	38.6
1.0 Na_2SO_4	Moderate	2.0	68.0	45.3	28.8	19.9
1.5 Na_2SO_4*	Severe	2.0	72.5	59.9	41.9	34.2

* Harvested 7-5-49.

TABLE 3. Composition of avocado leaves harvested 10-13-49.

Treatment added salt in atm. OP	Degree of Leaf Burn	Constituents				
		Cl	Na	Ca	Mg	K
		m.e./100 gms. dry Wt.				
B.N.	None	Trace	0.6	32.2	20.6	33.3
B.N.	None	0.6	0.6	30.8	23.0	28.2
0.5 NaCl	None	13.2	25.4	26.7	21.4	28.8
0.5 NaCl	Sl. to Mod.	27.0	24.6	67.6	27.1	27.3
1.0 NaCl[1]	Severe	32.4	24.2	10.9	11.5	20.7
1.5 NaCl	Severe	109.5	135.6	35.3	25.5	73.6
0.5 $CaCl_2$	None	13.0	0.7	38.3	19.7	36.3
0.5 $CaCl_2$	Sl. to Mod.	28.2	0.9	71.9	28.0	38.8
1.0 $CaCl_2$	None (young)	27.6	0.7	64.8	23.9	45.7
1.0 $CaCl_2$	Moderate	49.1	0.9	111.4	38.6	49.4
1.5 $CaCl_2$	None (young)	49.8	1.1	82.3	37.0	89.1
1.5 $CaCl_2$	Severe	84.8	1.1	145.8	43.6	78.1

[1] Harvested 8-31-49—Leaves badly burned. The high percent of dead tissue may account for low mineral content.

The analytical methods used have been described in another paper (1). Table 2 gives data on leaves collected 7-19-49. Leaf injury was associated with high concentrations of chlorides in the chloride cultures, and in the sodium sulfate cultures with high sodium. Sodium was also relatively high in leaves from the sodium chloride treatments and calcium content was high in leaves from the calcium chloride series. Table 3 shows similar data for leaf samples collected 10-13-49, and gives analyses of unburned and burned leaves from the same plant. In all cases the scorched leaves were higher in chloride than those which showed no injury. With low levels of salinity in the culture solution the normal appearing leaves were not necessarily the young leaves, but at the

1.0 and 1.5 atm. levels it was only the very young leaves which were free of scorch.

The distribution of the major ions in several parts of the avocado plant is shown in Table 4. The greatest accumulation of chloride always occurred in the leaves. Sodium accumulation was also high in the leaves, but it was usually as high or higher in the small stems.

Discussion

Tip burn of avocado leaves similar to that observed in a number of Southern California orchards has been produced by growing plants in the greenhouse using nutrient solutions to which sodium or calcium chloride had been added. This type of injury starts at the tip of the leaf and hence the term tip burn. With low concentrations of the salt solutions, only the tips of some leaves were killed, but with higher salt levels the injury became more severe. In such cases the dead area at the leaf tip increased in size and progressed along the leaf margins and finally into the interveinal areas. This latter condition was more noticeable in the sodium chloride treatment than with the calcium chloride.

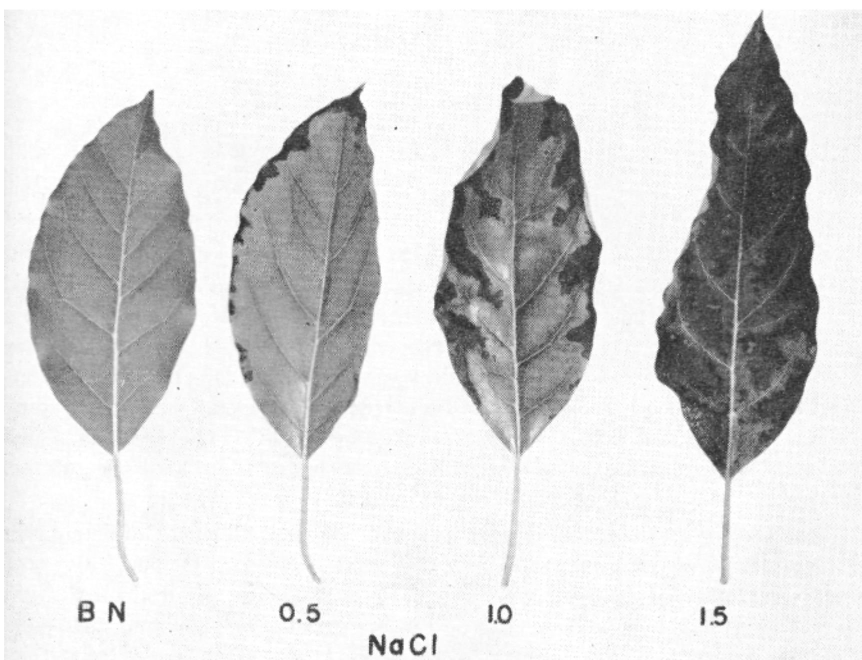

Fig. 3. *Typical injury of avocado leaves produced by adding NaCl to the culture solutions.*

TABLE 4. Composition of various plant parts and tissues.

Plant Part	Treatment	Cl	Na	Ca	Mg	K
		m.e./100 gm. dry Wt.				
Leaves	Control	trace	0.6	32.2	20.6	33.3
Stems	"	"	0.7	25.7	20.6	38.3
Peeled stems	"	"	0.7	9.6	12.3	22.2
Stem bark	"	"	1.0	41.2	22.2	49.1
Large roots	"	"	1.4	13.0	6.6	36.1
Small roots	"	3.3	1.7	22.7	12.3	27.4
Leaves, unburned	0.5 $CaCl_2$	13.0	0.7	38.3	19.7	36.3
" , Sl. to Mod. scorch	"	28.2	0.9	71.9	28.0	38.8
Stems	"	7.7	1.2	76.9	27.1	39.0
Peeled stems	"	1.0	4.4	19.8	8.2	9.0
Stem bark	"	8.8	2.0	88.7	9.1	49.0
Large roots	"	10.0	2.2	21.9	8.2	35.6
Small roots	"	13.8	—	—	41.9	—
Leaves, unburned	0.5 NaCl	13.2	25.4	26.7	21.4	28.8
" , Sl. to Mod. scorch	"	27.0	24.6	67.6	27.1	27.3
Stems	"	9.6	52.2	70.8	25.5	16.0
Large roots	"	7.6	9.7	18.7	11.5	29.0
Small roots	"	7.5	10.5	20.4	8.2	21.9

The severity of the tip burn was closely associated with the chloride content of the older leaves. Concentrations in the range of 18 m.e. Cl per 100 grams of dry leaf material (0.6%) were found in leaves which showed only slight tip burn. When as much as 30 m.e. was present (1.0%) leaf burn was moderate to severe. The younger leaves had a lower chloride content than the older leaves and showed less burn.

Sodium sulphate in the nutrient solution also produced leaf injury, but it was of a different type and did not resemble the characteristic tip burn pattern.

Burning of the leaves usually started as spots between the veins and approximately midway between the margin and the midrib. (See Fig. 4) These burned areas increased in number and in size with increase in the concentration of the culture solution and with the age of the leaf. As little as 0.5 Atm. of added sodium sulfate (total OP of 0.9 atm.) caused almost complete defoliation within a few months and eventual death of the plant.

The salt tolerance of the avocados tested in this experiment with culture solutions was lower than that of any of the plants grown under similar conditions at this Laboratory.

Salinity of soil solutions or of culture solutions may affect the growth of plants in two ways: (1) the osmotic pressure of the solution may be high enough to limit the availability of water to the plant, or (2) high concentrations of salts in the solution may facilitate the uptake of one or more of the ions present so that an accumulation may result and cause a derangement of the normal metabolism of the plant. The concentration of salts added to the nutrient solutions in this experiment were so low that it would be difficult to attribute the observed injury to the osmotic factor. The leaf burn observed, and the presence of abnormally high amounts of chloride or sodium in the leaves and stems would indicate that accumulation rather than physiological drought was the dominant factor concerned.

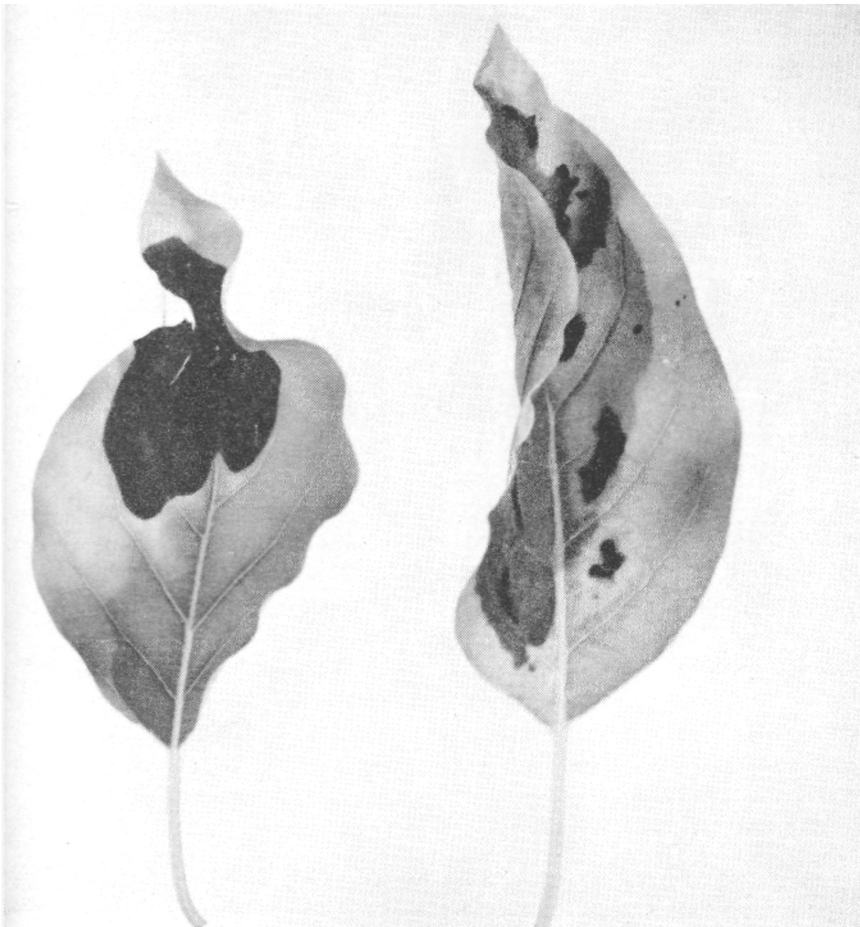

Fig. 4. *Injury of avocado leaves produced by adding Na_2SO_4 to the culture solutions.*

Observations made in the field agree closely with the foregoing hypothesis. Trees were frequently noted where leaf burn was severe and where large amounts of chloride, sodium or both were found in the leaves, but soil analyses showed no large concentrations of salts in the soil. The avocado tree thus appears to be able to accumulate injurious amounts of chloride or sodium or both from soils or solutions which have low concentrations of salt and which would support growth of many other plants without causing noticeable injury.

LITERATURE CITED

1. *Bernstein, L., Ayers, A. D., and Wadleigh, C. H. 1950. The salt tolerance of White Rose potatoes. Amer. Soc. Hort. Sci. Proc. (Accepted for publication.)*

2. *Haas, A. R. C. 1929. Composition of avocado leaves in relation to chlorosis and tip burn. Bot. Gaz. 87:422-430.*

3. *U S. Regional Salinity Laboratory. 1947. Diagnosis and improvement of saline and alkali soils. By Laboratory Staff, L. A. Richards, Editor. Multilithed.*

Contribution from the U.S. Regional Salinity and Rubidoux Laboratories, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U.S. Dept. of Agriculture, Riverside, Calif., in cooperation with the eleven Western States and the Territory of Hawaii. (In lieu of talk given at 1950 Annual Meeting of the California Avocado Society.)