SALINE IRRIGATION WATER

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THE NOXIOUS EFFECTS of saline irrigation waters on the growth and fruit production of citrus have been recognized for many years. Citrus trees are sensitive to relatively low concentrations of the salts of sodium, chlorine, and sulfur. Boron is toxic to citrus at concentrations of about 0.5 parts per million (ppm) and lithium at about 0.05 ppm. A number of interdependent factors determine the degree of success in the use of a given irrigation water. These include: total soluble salts and specific ion species, soil type and drainage characteristics, amounts of water used and method of application, cultural practices, climate, and the rootstock and associated scion variety.

This report summarizes results of five years of studies made at two orchards in southern California.

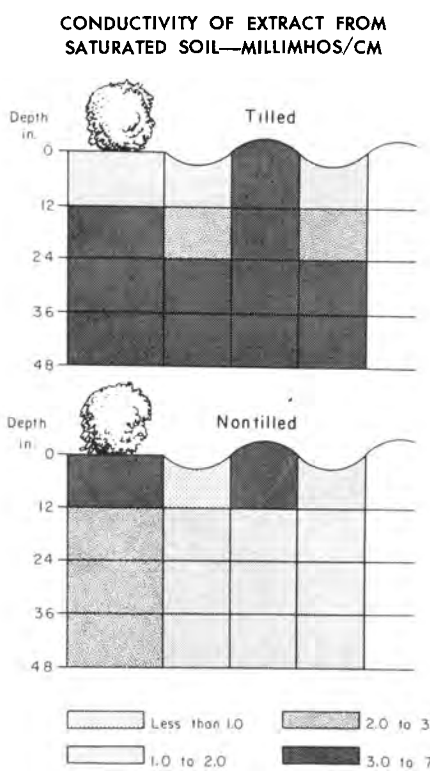


Figure 1. Soil salinity distribution in Plot 1 (tilled) and Plot 2 (nontilled) at orchard A.

Interior valley test

Orchard A was at Piru, an interior valley location with summer temperatures often averaging above those at Riverside, while average relative humidities were similar to those recorded at the Citrus Research Center except for June, when they are generally lower at orchard A. Three experimental plots were studied at orchard A. Plots 1 and 2 were adjacent, 35-year-old Valencia oranges on sweet and sour rootstocks respectively. Plot 3 was an adjoining 30-year-old navel block on sour orange rootstock. Plots 2 and 3 were under nontillage for the period of study; previously they had been summer tilled with a winter cover crop of mustard and volunteer growth. Plot 1 had been tilled and was kept under this program during the study. The acreage for each plot was: plot 1, 11.1 acres; plot 2, 6.4 acres; and plot 3, 3.7 acres.

All trees received the same treatment (other than noted above): annual soil applications per tree of 1½ lb of nitrogen from various sources, and ½ lb from urea spray. Zinc and manganese were applied yearly at recommended rates. Copper sprays were applied occasionally.

The irrigation water was analyzed at least five times each year of the study. The average composition in ppm was as follows: bicarbonate (HCO_3), 293; chloride (Cl), 96; nitrate (NO_3) 3; sulfate (SO_4), 864; calcium (Ca), 176; magnesium (Mg), 98; sodium (Na), 196; and potassium (K), 8. Boron averaged 0.5 ppm, while lithium (Li) was less than 0.02 ppm. The soil at orchard A is Sorrento loam which is considered to have good internal drainage. Three sets of dial-type, commercial tensiometers were placed in each plot. The tensiometers, installed at 18- and 26-inch depths for each set, were used as guides to irrigation needs; water was available on demand, and irrigation was not restricted to a given time interval. For 1960, 5.84 acre-feet of water per acre was the average application for the entire 600 acres of this large planting. By 1963, the amount of water use had been decreased approximately 10 acre-inches per acre.

Table 1 shows the yield of the three plots during the five years of nontillage of plots 2 and 3, compared with the previous five years when the plots were tilled. The difference in yield during the two periods for plot 1 (tilled during both periods) was not significant; that for plot 2 was significant at the 7% level. This level of significance was not high but suggests the increase was real and probably not due to chance. The yield difference for plot 3 was significant at the 1% level. The Valencia plot 1 had consistently produced about half as much fruit per tree as did the Valencias of plot 2. Plot 1 trees were on sweet rootstock while plot 2 (and 3) trees were on sour rootstock.

Leaf analysis

The results of analyses of six-month-old leaf tissue of nonfruiting terminals from the three plots (table 2) indicate no excesses of elements except for boron in plot 1, and sulfur in plot 3, although at no time was any leaf burn noted in any of the plots. Leaves of plot 1 showed typical yellow boron tipping but less than expected. It is doubtful that the yield differences can be explained on the basis of excesses or deficiencies of any of the elements noted in table 2.

Figure 1 shows diagrammatically the typical accumulation of soluble salts in the soil of the tilled and nontilled plots, as indicated by conductance values of saturation extracts. Considerably larger amounts of soluble salts were found in tilled than in nontilled plots—mainly gypsum, in the upper two feet of the soil.

Tensiometer records for the tilled and nontilled plots of orchard A indicate little root activity in tilled plots (at 36 inches), while it was far greater in the nontilled plots. It has been shown that in a number of mature California citrus orchards, the tap root of sweet orange stock has been so severely infected by soil fungi that few, if any, functioning roots occur below a soil depth of 2 ft. Studies indicate that soil salinity, lack of oxygen, or any other

AND CITRUS PRODUCTION

E. J. CURRAN

TABLE 1. FRUIT YIELD COMPARISONS DURING TWO FIVE-YEAR PERIODS IN EACH OF THE THREE EXPERIMENTAL PLOTS OF ORCHARD A

Plot No.	Scion	Rootstock	Years of record	Cultural practice	Av. yield field boxes per tree
1	Valencia	sweet	1954–58	tilled	2.06
			1959–63	tilled	2.29†
2	Valencia	sour	1954–58	tilled	4.16
			1959–63	nontilled	5.12‡
3	navel	sour	1955–59	tilled	3.14
			1960–64	nontilled	5.27**

† Difference not significant.
‡ Difference significant at approximately the 7% level.
**Difference significant at the 1% level.

TABLE 2. REPRESENTATIVE ANALYSIS OF SIX-MONTH-OLD LEAF TISSUE OF NONFRUITING TERMINALS FROM PLOTS 1, 2, AND 3 OF ORCHARD A

Plot No.	Constituent in % dry matter: Ca	Mg	K	Na	N	P	S	Cl	ppm B
1	3.73	0.30	1.03	0.07	2.70	0.111	0.559	0.03	265
2	3.76	0.30	0.70	0.0B	2.47	0.073	0.492	0.03	155
3	3.90	0.42	0.88	0.08	2.55	0.104	0.619	0.03	200

TABLE 3. COMPARISON OF MINERAL CONSTITUENTS IN MAJOR PORTION OF LEMON ORCHARD FROM LEAVES OF REPRESENTATIVE TREES OF ORCHARD B AND SMALLER AREAS OF REPRESENTATIVE STUNTED TREES WITH LEAVES SHOWING TIPBURN AND EXCESS SYMPTOMS OF ONE OR MORE ELEMENTS

Type of tree	Constituents in % of dry matter: Ca	Mg	K	Na	N	P	S	Cl	ppm B
Large	4.7	0.37	1.00	0.034	2.76	0.122	0.364	0.047	110
Stunted	5.0	0.32	0.29	0.070	2.16	0.086	0.621	0.430	345

unfavorable factor, can predispose sweet orange rootstock to invasion and severe damage by fungi such as *Fusarium* and *Phytophthora* species.

The greater soil salinity below 2 ft, as shown in figure 1, certainly would predispose roots of trees in plot 1 to destruction by soil fungi. However, with few active roots below 2 ft, soluble salts in the lower depths would probably not be taken up in amounts expected if there were numerous active roots. This may be the reason for the failure to find excessive amounts of sodium and/or chloride in leaves from plot 1.

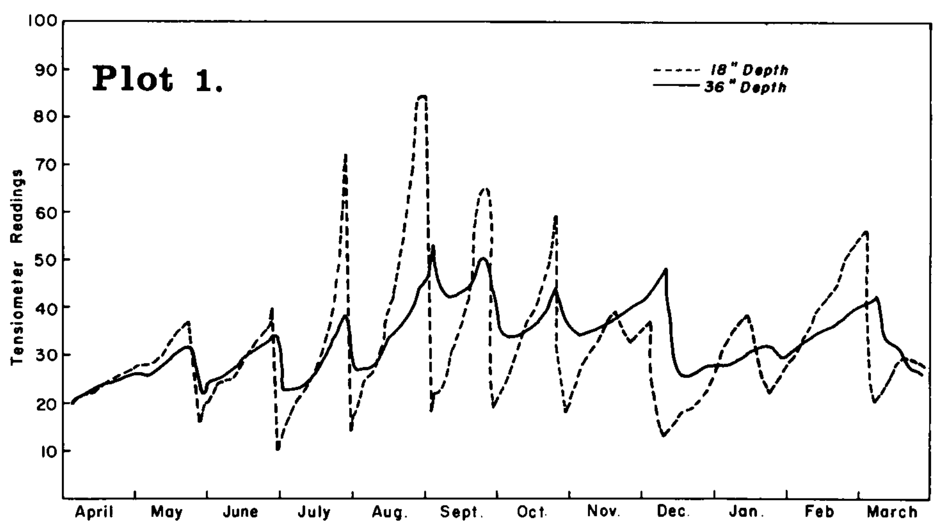
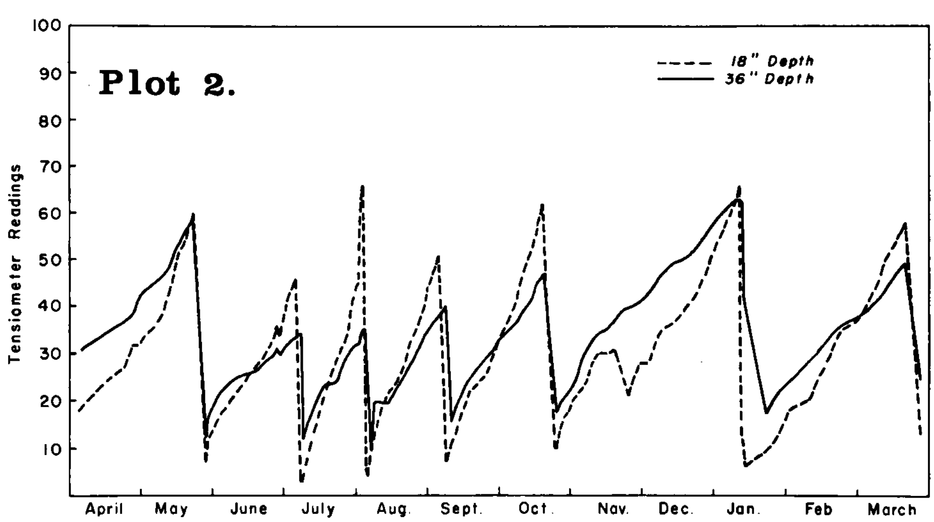


Figure 2. Typical soil suction records for Plot 1 (tilled) and Plot 2 (nontilled) at orchard A.



Compaction

A distinct zone of compaction (plowsole) was noted in the tilled plot, which reduced water penetration and probably soil aeration also. Usually about eight hours were required before tensiometers (at 18 inches) responded to water application in this plot—while at the same depth in the untilled plots, tensiometers usually responded to water application after four hours or less. This indicates the presence of a zone of compaction under tillage, and emphasizes the fact that, as the salinity in the irrigation water increases, a program of nontillage becomes increasingly important in water management. Further, the use of soil moisture indicating devices is a valuable aid as a guide to irrigation needs as well as a help in prediction of orchard problems such as the low yields of plot 1 in orchard A.

Coastal valley test

Orchard B, a mile south of Camarillo, was located in a coastal valley with relative humidities usually higher, and summer temperatures moderated by oceanic influences—both factors important in this area, because of the high salinity hazard of the irrigation water in use.

The average composition of the irrigation water in ppm was HCO_3, 366; Cl, 277; NO_3, 68; SO_4, 706; Ca, 250; Mg, 92; Na, 216; and K, 8. Boron averaged 0.53 ppm and lithium averaged 0.032 ppm. The soil is an unclassified sandy loam in the surface 6 inches and becomes more sandy with depth. In some localized areas, however, sandy clay was found at depths of 30 to 36 inches. While the surface soil was only slightly calcareous, below 6 inches the soil becomes more calcareous and at four feet was highly calcareous. The parent material was sedimentary sandstone alluvium.

Orchard B

Orchard B consists of 55 acres of 10-year-old selections of Frost, Allen, and Brewer Eurekas on rootstocks of sweet orange and rough lemon. These combinations were planted in six blocks of approximately the same acreage. Four pounds of urea were applied annually per tree. Most of the urea was distributed in split applications in the irrigation water: 1 lb per tree was applied in January, February, June, and September. Zinc, manganese, and copper sprays were applied each year.

Orchard B was tilled once annually, in early spring, and had three broad-basin furrows. This orchard was under a program of "alternate-middle irrigation." Each middle received water every second month. When both middles were irrigated simultaneously, severe iron chlorosis developed in this calcareous soil. Under the alternate-middle program, only transient chlorosis was noted in winter and early spring. At each irrigation, approximately 27 acres received water at a rate of 9 acre-inches per acre. The estimated annual amount of irrigation water received by the orchard was 36 acre-inches per acre. Rainfall at this location during the years since planting was below normal but averaged about 12 inches per year. Rainfall was usually received in amounts sufficient to wet this sandy soil through the top 2 ft of soil.

Analysis of the soil for soluble salts indicated that the tree furrows were essentially no more saline than the irrigation water. Soluble salts tended to increase in the middles and also with soil depth. In the small localized areas where sandy clay lenses were found, soluble salts in the soil were quite high, and stunted trees showed considerable leaf burn and excess patterns of chloride, sulfur, and boron in leaves of stunted trees (table 3).

Average per-acre yield, however, for the 55 acres was 1818 field boxes per acre in 1964, as compared with about 625 field boxes per acre for the 1962 and 1963 harvests. It was not possible to obtain records regarding different rootstock-scion combinations, but observation of comparatively young trees showed no marked differences in size.

The successful use to date of irrigation water with a high salinity hazard as well as high chloride content appeared to be a combination of several factors. First, the major portion of the orchard has excellent internal drainage. This was expected since the soil, with a few exceptions, was coarse textured to a considerable depth. In addition, copious amounts of water were used at each irrigation. Leaching of salts out of the root zone at each irrigation was achieved. Alternate middle irrigation in this calcareous soil was a practice which reduced the hazards of iron chlorosis. Also, roots appeared to extract moisture mainly beneath tree furrows where maximum leaching occurred. This has been noted in the past.

Chloride injury

Previous investigators reported the injury from chloride damage appears more severe under conditions of high temperature and rapid evaporation than in cool, moist climates. This is related, in part at least, to differences in transpiration rates, which in turn affect the rates of accumulation of toxic salts in vegetative parts of the plant. It has also been reported in previous experiments that a somewhat larger quantity of mineral salts accumulates in plants under conditions favoring high transpiration than where transpiration rates are low. It is highly doubtful that the irrigation water used at orchard B could be used successfully except under a combination of factors as noted above.

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Foliar In

FOLIAR ABSORPTION of salts from irrigation waters during sprinkler applications can result in accumulation of sufficient sodium and chloride ions to cause leaf burn and defoliation—as directly related to high temperatures, low humidity and water quality. An additional important factor in the accumulation of specific salts in leaves from irrigation waters is that more sodium and chloride are accumulated under intermittent type sprinkling than under continuous sprinkling. Intermittent sprinkling permits evaporation from leaf surfaces, thereby concentrating the salts in water films remaining on the leaves.

Ventura study

This report, of a study conducted in Ventura County, shows that excessive amounts of boron may also be absorbed by citrus leaves from sprinkler-applied water. The study was made to evaluate factors causing poorer tree conditions under sprinkler irrigation, compared with tree conditions in the adjacent, furrow-irrigated, block.

Several trees were selected from different areas in the furrow- and sprinkler-irrigated blocks of the Valencia orange orchard. Following fruit set in early summer, fruiting and nonfruiting terminals were tagged for future leaf sampling and analyses. In addition to leaf samples, irrigation water samples and soil samples were analyzed. Soil suction and fruit growth measurements were also made.

Soil, water

Analyses of soil samples taken at different soil depths are shown in table 1. At all of the soil depths, the chloride and exchangeable sodium percentage levels are well within the ranges that are considered satisfactory for citrus. The electrical conductivity and boron levels also are not excessive but for some depths, the values approach the upper safe limits.

Analyses of constituents in the irrigation water at different times of the year showed a range of 600 to 900 ppm total soluble solids (table 2). The salts in the water were primarily calcium and sulfate. Chloride levels were low. Sodium levels were marginal (for sprinkler use) at some