Effects of tillage and fertilizers on

Use of Water and Soil Salinity

in irrigated orange orchard at Riverside

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Where furrow irrigation is practiced there is extreme variability in concentrations of soluble salts in the soil, and the effects of cultural practices and different fertilizers determine the distribution of the salts.

Part of a long-term fertilizer experiment in an orange grove at Riverside was the study of water intake by the soil when different nitrogen fertilizers were supplied, under tillage and nontillage practices. The plots had been differentially fertilized for a period of 18 years. The tilled plots had cover crops in winter and were cultivated in summer. Similarly fertilized plots, originally clean-tilled, were converted to nontillage four years before the tests. When clean-tilled, the plots had less intake of irrigation water than the summer-tilled plots with winter cover crops, but after conversion to nontillage there was a relatively rapid increase in water intake.

The orchard soil is a Ramona sandy loam derived from granitic alluvium. Each plot consisted of eight navel orange trees. Between the plots were guard rows of Valencia oranges alternating with grapefruit. Fertilizers were added to the irrigated middles, which represented approximately 70% of the plot area.

The water used for irrigation was of excellent quality, with an electrical conductivity of about 570 micromhos per centimeter. Sodium made up 35% of the total cations, but there was no residual sodium carbonate. The soluble constituents in the water remained relatively constant over the years, although there was an increase in nitrate from about 6 ppm —parts per million—in 1940 to about 18 ppm in 1958.

Irrigation water was applied in five furrows on each side of the trees, at 3-week intervals during the summer months and at longer intervals during the rainy season. Each irrigation was run for 48 hours. Discharged water usually did not exceed 10%–15% of that applied, and the difference was interpreted as the amount of water intake. The rate of water application for each individual furrow was adjusted by the irrigator according to the amounts of water taken by the furrows. Rates of water application were measured on June 4, October 7, and December 2.

Four years after the clean-tilled plots were converted to nontillage, soil samples were taken from each furrow and ridge, at depths of 1′, 2′, 3′, and 4′. Each sample was a composite of eight cores taken opposite each test tree. In some of the more saline plots, samples were taken in the tree rows as well as in the fertilized, irrigated middles. All samples were screened to pass a 2-mm—millimeter—sieve, air-dried, and stored in closed containers pending analysis.

Soluble Salts

The distribution of soluble salts in the ridges and furrows of nontilled and tilled plots, based on measurements of ECe—electrical conductivity of extracts from saturated soil—is shown in the graphs on page 10. ECe values of 3 mmhos/cm—millimhos per centimeter—and above are considered high when associated with citrus.

In plots receiving no fertilizer, the soil samples from the ridge areas usually had more soluble salts than the samples from the furrows, particularly in the surface foot, but there was a low level of salinity throughout the irrigated middles of the unfertilized treatments. However, in the nontilled treatment it was evident from the ECe value of 8.5 mmhos/cm that there had been a considerable accumulation of soluble salts in the surface foot of the ridge bordering the center furrow. An accumulation was present also in the deeper samples from the center furrow ridge.

In the nontilled treatment plot without fertilizer the ESP—exchangeable sodium percentage—values in the furrow just north of the tree row were 2, 2, 3, and 2 for the first, second, third, and fourth foot, and in the adjacent ridge the values for the same depths were 15, 8, 7, and 6. As no irrigation water was applied directly to the ridge, the salt accumulated there was carried by water that moved outward and upward from the furrow. There was a considerable increase in the amount of sodium relative to calcium and magnesium in the movement of water and salts from furrow to ridge.

In the nontilled plots treated with sodium nitrate fertilizer, the soil in the area of the tree furrows was low in total soluble salts. Most of the ESP values in those furrows were below seven, and the highest was 12. However, soil salinity was extremely high in the center of the irrigated middles, particularly in the ridges bordering the center furrow. ECe values were as high as 50.0 mmhos/cm in the first foot and ESP values were in excess of 60. In the center furrow area the soil to a depth of 4′, in ridge or furrow, gave ECe values in excess of 6.0 mmhos/cm.

In the tilled treatment receiving sodium nitrate, the north-tree furrow showed considerable salinity. ECe values ranged between 4.7 and 6.9 mmhos/cm, while ESP values were 28, 34, 24, and 16 for the first, second, third, and fourth foot of soil. In the south-tree furrow, however, lesser amounts of soluble salts were found. ECe values ranged from 1.8 mmhos/cm in the surface foot to 3.6 mmhos/cm at the fourth foot, and ESP values were seven for the first foot and 13 for the fourth foot. There was considerable surface concentration of salts in the ridges, even though each cultivation redistributes the salts in the surface soil. The results indicate a rather rapid surface concentration of salts in ridges through capillary rise and evaporation of moisture from adjacent furrows and deposition of salts transported by the capillary stream. With the exception of the soil of the south-tree furrow, the whole area between the tree rows was quite saline throughout the 4′ of soil. ECe values of 9.0 mmhos/cm and higher

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SOIL SALINITY

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characterized most of the soil of this treatment.

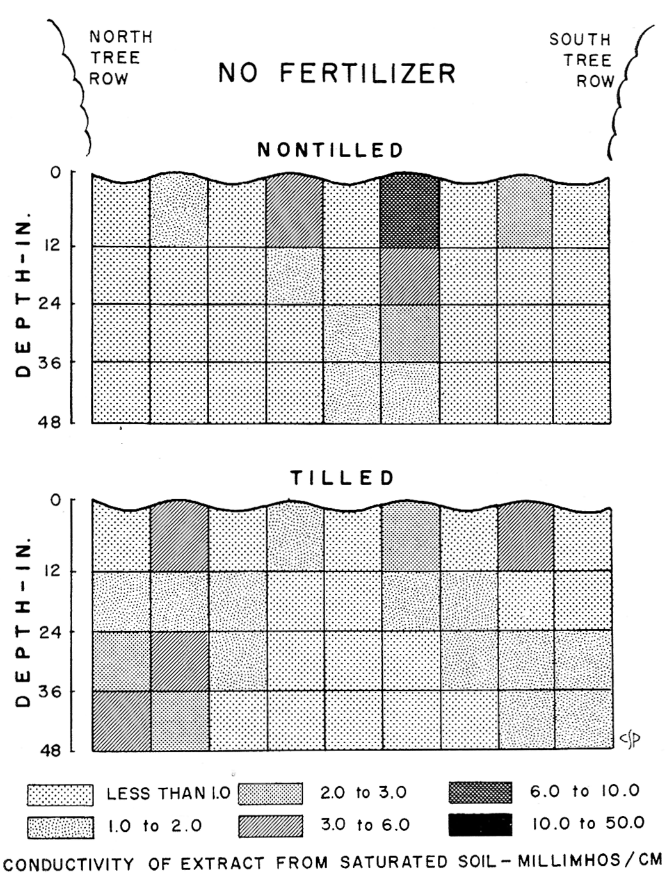
In the nontilled treatment receiving ammonium sulfate, both tree furrows had low levels of soil salinity through 4′ of soil. A value of 1.4 mmhos/cm was the highest ECe found in these areas. The soil reaction in these two furrows was pH—relative acidity-alkalinity—5.7 or higher in the surface foot and increased with depth to pH 7.2 at 4′. The ammonium ion found in the extracts amounted to one me/liter—one milliequivalent per liter—or less. Salts accumulated in the ridges gave ECe values from 14.3 to 31.6 mmhos/cm for the surface foot, and the soil reactions were all below pH 3.6. The ammonium ion accumulated in the surface foot of the ridges ranged between 117 and 282 me/liter in the saturation extract, while the nitrate ion ranged between 62 and 139 me/liter. Though higher in salinity than the tree furrows, the soil in the surface foot of the three center furrows was markedly less saline than the surface foot of adjacent ridges. ECe values in the surface foot of the furrows ranged between 2.3 and 3.1 mmhos/cm and the pH was 3.2 to 3.6. The ammonium ion in the saturation extracts was about five me/liter. Below the surface foot, the plots were generally high in soluble salts, under ridges and furrows, except the tree furrows. Wherever salts accumulated in tratments receiving ammonium sulfate, the pH of the surface was below 3.6, with substantial amounts of ammonium ion present. The accumulation of ammonium ion causes soil dispersion and results in poor water penetration.

In tilled plots receiving ammonium sulfate, ECe values in north-tree furrows were 0.7, 3.1, 4.3, and 6.4 mmhos/cm for the first, second, third, and fourth foot, and soil reactions were pH 3.6, 4.0, 6.9, and 7.2. On the other hand, the south-tree furrow was low in salinity, with ECe values of 0.6, 0.8, 0.5, and 0.7 for the first to fourth foot. The soil reactions at the four depths were pH 6.1, 6.5, 6.8, and 7.2. These results emphasize the relationship between low pH and accumulation of ammonium ion. The surface foot of soil of the three center furrows was low in soluble salts. The highest ECe value was 1.9 mmhos/cm. However, below the surface foot depth ECe values increased. In the fourth foot the values ranged between 5.2 and 6.6 mmhos/cm. The surface foot of soil in the ridges had more salt than the surface foot of adjacent furrows. In the ridges, ECe values ranged between 4.7 and 6.7 mmhos/cm in the surface foot. Below the surface foot the amounts of soluble salts generally increased with depth in both furrows and ridges. In general, the soil below the ridges had higher amounts of soluble salts than the soil below the furrows.

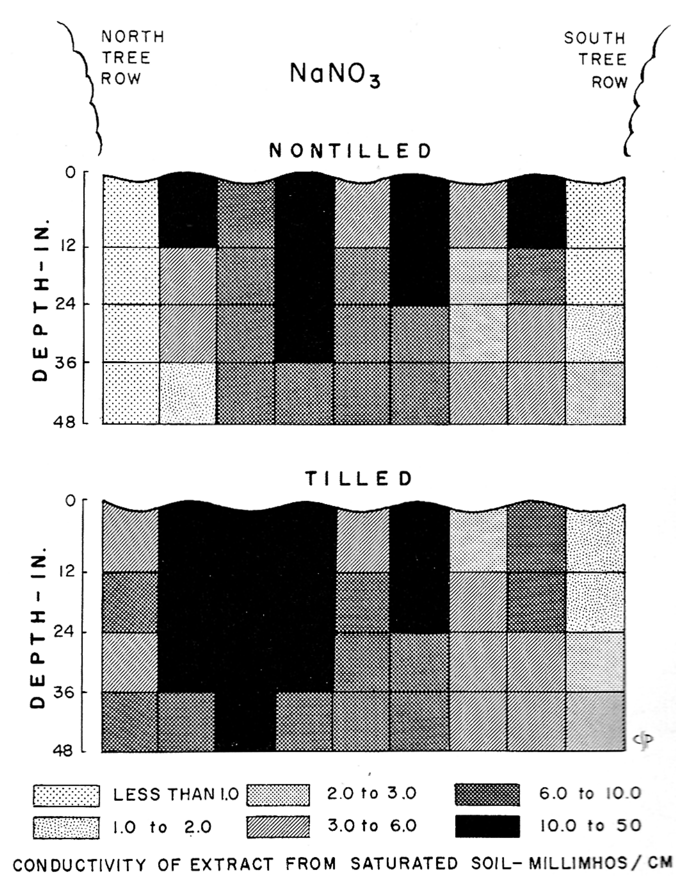
Salinity is much less in soils of the type in the test plots when treated with calcium nitrate than when treated with sodium nitrate or ammonium sulfate. In the nontilled plot treated with calcium nitrate, salts were low except in the two ridges bordering the center furrow, where ECe values were 8.1 and 10.0 mmhos/cm in the surface foot depth. Most of the soluble salts present were accounted for by calcium and nitrate ions. Salt concentrations under the two center ridge areas decreased at the greater depths but were higher than in the soils at comparable depths beneath the adjacent furrows.

In the tilled treatment receiving calcium nitrate, soil beneath all the ridges accumulated some soluble salts, but in the furrow areas salts were generally low.

Soil salinity distribution in nontilled and tilled plots receiving no fertilizer.



Soil salinity distribution in nontilled and tilled plots receiving sodium nitrate.



There was not the marked accumulation of salts in the surface foot that there was in the ridges of many of the other treatments. ECe values in the 4′ of soil averaged 1.3 mmhos/cm for the five furrow areas and 3.3 mmhos/cm for the four ridges.

The tree rows, which constitute about 30% of the total soil area, received no fertilizer or irrigation water directly. Soil salinity was low in the tree row area, even in the most saline plots. For example, in the nontilled sodium nitrate plot, where ECe values reached 50 mmhos/cm in the center of the fertilized area, the tree-row area had maximum values of 2.4 mmhos/cm in the surface foot and 1.4 mmhos/cm in the second, third, and fourth feet.

Distribution of Irrigation

Because the distribution of soluble salts in the several treatments was extremely variable, the distribution of irrigation water to individual furrows was measured, to ascertain whether there were any relationships between the two. On the average, nontilled plots received 5.7 gal/min—gallons per minute—and tilled plots received 2.4 gal/min. There appear to be relatively small differences in amounts of water received by the three middle furrows, whether nontilled or tilled, but the two furrows adjacent to the tree rows received 78% of the water in nontilled plots and only 61% in the tilled plots. The soil which received the most water, that beneath all tree furrows of nontilled plots, was low in soluble salts, but salts accumulated in the ridges bordering the center furrow, which received relatively small amounts of water.

Under nontillage the improvement in water intake and the accompanying low soil salinity was confined primarily to the tree furrows. Apparently, there is sufficient orchard equipment traffic in the remainder of the irrigated middles, even under nontillage, to affect soil structure adversely.

More water was applied in south-tree furrows than in north-tree furrows, whether plots were nontilled or tilled and, in all the tilled treatments studied, soil beneath the south-tree furrow was less saline than soil beneath the north-tree furrow. The differences in salinity between north- and south-tree furrows were particularly outstanding in tilled treatments receiving sodium nitrate and ammonium sulfate, where south-tree furrows received about twice as much water as north-tree furrows. Evaporation might account for part of the difference in water applied to the soil, as the south-tree furrows are more exposed to the sun than north-tree furrows.

Salt distribution in the soil shows a definite inverse relationship to water distribution. In the soil of the experimental orchard the downward movement of water from furrows was primarily vertical, and little leaching of salts from the soil occurred as a result of horizontal water movement. In a number of instances soil under furrows was low in salinity although soil to a depth of 4′ under adjacent ridges had high salinity.

Local differences in salt concentrations affect soil sampling and interpretation of results. Composite samples of soil from furrows and adjacent ridges often do not reflect the true soil environment and make difficult the interpretation of tree response in relation to soil analyses.

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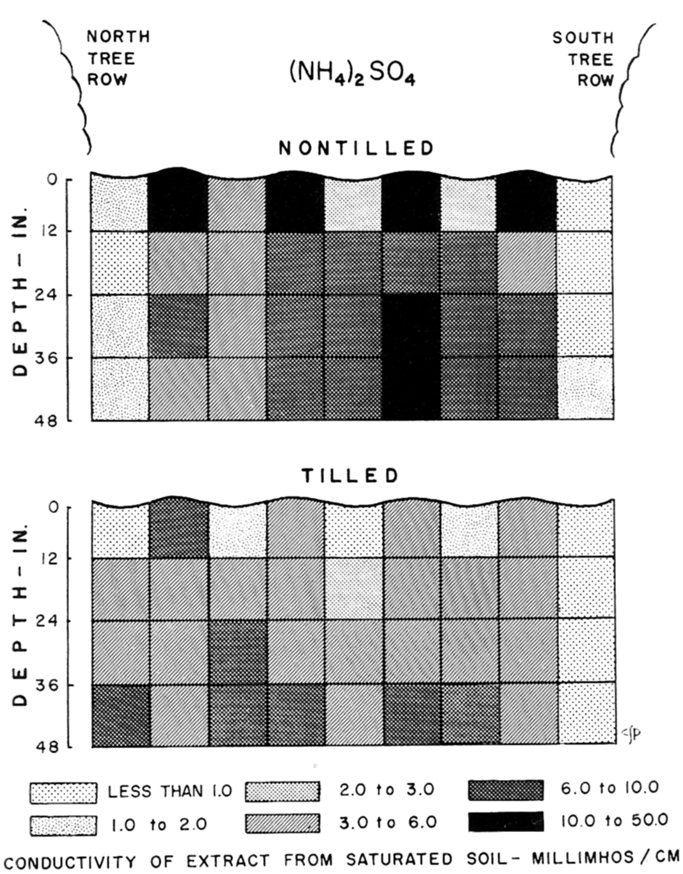
Soil salinity distribution in nontilled and tilled plots receiving ammonium sulfate.



Soil salinity distribution in nontilled and tilled plots receiving calcium nitrate.