# Adequate Soil-oxygen Supplies Increase Nutrient Concentrations In Citrus Seedlings

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OXYGEN IS ESSENTIAL for nutrient uptake by plant roots, but little information has been available concerning the influence of soil oxygen on the nutrient concentrations in citrus. The study reported here involved sweet orange seedlings (*Citrus sinensis* var. Bessie). Nutrient concentrations in the tops and roots of the citrus seedlings were used as criterion to show effects of different soil-oxygen diffusion rates on citrus plants.

Sweet orange seedlings were grown for a year in the greenhouse before applying soil-oxygen treatments. The soil containers were 11.5-liter buckets with tightly fitted lids in which the seedlings were grown. Plant stems extended through holes in the lids. Three soil-oxygen treatments were maintained in the root zone of these plants by passing air, mixtures of air and nitrogen, and nitrogen-gas over the soil surface. Thus, there were three oxygen treatments: (1) high-oxygen—21% (air); (2) medium-oxygen—1.8% (air + $N_2$ gas); and (3) low-oxygen—nitrogen gas ($N_2$). Platinum micro-electrodes pushed into the soil through access ports were used to measure soil-oxygen availability to plant roots. This measurement is called oxygen diffusion rate (O.D.R.). (The platinum wire acts as a small root, which consumes oxygen from the soil solution.) Rates at which oxygen moves to the wire (or root) are controlled by various soil properties such as soil water, compaction, pore-distribution, and texture.

Each treatment was replicated four times for a period of 60 days from September 12 through November 12, 1962. The above-ground portions of the seedlings were exposed to the regular greenhouse temperature. The experiment was repeated from February 8 through April 8, 1963. The citrus seedlings were harvested at the end of each experiment. Preparation of the samples and the methods used to determine the nutrients were the same as those used in previous tests.

## Soil-oxygen effects

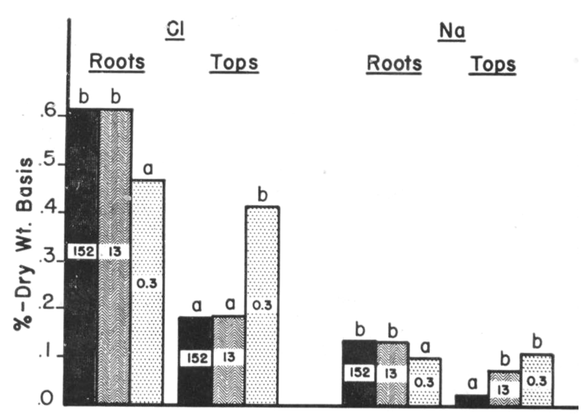
Dry weight of tops and roots of the citrus seedlings was reduced by a decreased oxygen supply over the soil surface. The dry weight of tops was not affected as drastically as the dry weight of roots by the three different soil-oxygen treatments.

The decreasing soil-oxygen supply reduced the concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, boron, and iron, and increased the concentrations of sodium, chloride, copper and manganese in the tops of the seedlings. The concentrations of nitrogen, potassium, magnesium, chloride, and sodium were decreased while calcium, copper, and manganese increased in the roots with decreasing soil-oxygen supplies. The concentrations of phosphorus, boron, and iron in the roots were not affected by differential soil-oxygen treatments.

Concentrations of chloride and sodium, found in the roots and tops of citrus seedlings, as affected by differential soil-oxygen supply, show inverse relationships (see graph). Concentrations of chlorides and sodium in the roots supplied with low concentrations of soil-oxygen were lower, perhaps because more chlorides and sodium were translocated to the tops under those particular conditions; or possibly because of the adverse effect of low soil-oxygen supply on the uptake of chlorides. Low chlorides and sodium concentrations were found in the roots and high in the tops of plants whose roots were supplied with the lowest soil-oxygen treatment. Data obtained in this experiment show that reduced soil aeration due to compaction and/or excess water may contribute to sodium and/or chloride toxicity problems in plants sensitive to salt accumulation, even though the soil is not particularly high in chloride and/or sodium.

Concentration of zinc was not significantly different in plant tops and roots due to oxygen treatments. The copper concentration, however, was sig-

Chloride and sodium concentrations in tops and roots of citrus seedlings as affected by differential soil-oxygen treatments. Each value is a mean of 8 internal replications obtained on each of 2 sampling dates. Letters a and b above the columns indicate statistical populations. Mean values are statistically significant only if they do not have a letter in common above the columns.



nificantly increased in tops and roots of the citrus seedlings supplied with low concentrations of soil oxygen. The roots in general contained significantly higher concentrations of zinc and copper than the tops. Manganese concentration was higher in the roots of plants grown in the two lower oxygen treatments, and was highest in the tops of plants grown in the lowest treatment. This increase in manganese concentration in the roots of plants supplied with low soil-oxygen levels is perhaps due to the fact that in poorly aerated soils, there is an increase in soluble manganese ions due to reduction from manganic to the more readily available manganous manganese. Boron concentration in the tops of plants decreased slightly with decreasing soil-oxygen supply to the roots. Tops of the citrus seedlings contained higher boron concentrations than the roots. Translocation of this nutrient from roots to tops does not seem to be dependent on oxygen.

Iron concentration in the roots of the seedlings was not affected by differential levels of soil-oxygen supply. The reason may be that, regardless of how carefully roots are cleaned, there always is some doubt that all soil particles have been removed from the feeder roots. Iron concentration in the tops of the seedlings decreased with a decreasing soil-oxygen supply. In general, the roots contained 20 times higher iron concentration than the tops. However, concentrations of nutrients in vegetative parts of plants do not always represent a true picture of nutrient uptake and translocation as influenced by soil-oxygen supply, particularly if the total amount of dry weight of plant is affected.

TABLE 1.—INFLUENCE OF OXYGEN DIFFUSION RATES ON DRY WEIGHT AND NUTRIENT CONCENTRATIONS IN DRY MATTER OF TOPS AND ROOTS OF CITRUS SEEDLINGS

| Unit | | | Soil-oxygen treatments Per cent of oxygen in the gas[a] 21 | 1.8 | 0 | F | C.V. % |
|---|---|---|---|---|---|---|---|
| Dry wt./grs. | | tops | 16.60b | 17.10b | 11.00a | ** | 17 |
| | | roots | 10.30c | 7.60b | 4.10a | ** | 16 |
| % | N | tops | 2.13b | 1.84a | 1.75a | ** | 8 |
| | | roots | 1.79b | 1.84b | 1.58a | ** | 9 |
| % | P | tops | .10b | .09ab | .08a | ** | 4 |
| | | roots | .08 | .07 | .08 | NS | 8 |
| % | K | tops | 1.45b | 1.15a | 1.29ab | ** | 8 |
| | | roots | 1.71b | 1.79b | .80a | ** | 17 |
| % | Ca | tops | 2.21b | 1.87a | 1.88a | ** | 3 |
| | | roots | .56ab | .50a | .62b | ** | 11 |
| % | Mg | tops | .17b | .14a | .17b | ** | 7 |
| | | roots | .17b | .15b | .14a | ** | 9 |
| ppm | Zn | tops | 12 | 14 | 14 | NS | 42 |
| | | roots | 28 | 30 | 27 | NS | 15 |
| ppm | Cu | tops | 8a | 12a | 25b | ** | |
| | | roots | 18a | 18a | 22b | * | |
| ppm | Mn | tops | 32a | 27a | 43b | ** | 16 |
| | | roots | 208a | 292b | 254ab | ** | 18 |
| ppm | B | tops | 39b | 35a | 35a | * | 6 |
| | | roots | 15 | 14 | 13 | NS | 16 |
| ppm | Fe | tops | 83b | 60a | 69ab | ** | 15 |
| | | roots | 1523 | 1370 | 1594 | NS | 16 |

[a] Each value is a mean of 8 internal replications obtained in each of 2 sampling dates. Subscript letters a, b, and c after values indicate statistical populations. Mean values are statistically significant from each other only if they do not have a common subscript letter in a column. (Read horizontally.)
* = F value significant at the 5% level.
** = F value significant at the 1% level.
NS indicates that differences between means are not significant.
C.V.—coefficient of variability expressed in per cent.

TABLE 2.—INFLUENCE OF SOIL-OXYGEN ON TOTAL DRY WEIGHT AND TOTAL NUTRIENT CONTENT IN CITRUS SEEDLING

| Unit per plant | | Soil-oxygen partial Pressures in flowing gas[a] 21 | 1.8 | 0 | F | C.V.% |
|---|---|---|---|---|---|---|
| Dry wt. g. | | 27y | 25y | 15x | ** | 9 |
| mg. | N | 536z | 451y | 254x | ** | 14 |
| mg. | P | 25y | 21y | 12x | ** | 16 |
| mg. | K | 420y | 340y | 175x | ** | 16 |
| mg. | Ca | 422y | 350y | 224x | ** | 16 |
| mg. | Mg | 46z | 36y | 24x | ** | 16 |
| mg. | Cl | 91y | 77y | 58x | ** | 15 |
| mg. | Na | 18xy | 22y | 15x | ** | 29 |
| mg. | Zn | 0.50y | 0.44xy | .25x | ** | 31 |
| mg. | Cu | 0.28y | 0.22xy | .16x | ** | 33 |
| mg. | Mn | 2.67y | 2.64y | 1.52x | ** | 20 |
| mg. | B | 0.80y | 0.71y | 0.43x | ** | 16 |
| mg. | Fe | 17.29y | 11.60x | 7.42x | ** | 22 |

[a] Each value is a mean of 8 internal replications obtained on each of 2 sampling dates. Letters x, y, and z after values indicate statistical populations. Mean values are statistically significant from each other only if they do not have a common subscript letter in a column. (Read horizontally.)
** = F value significant at the 1% level or more.
C.V. is coefficient of variability expressed in per cent.

## Nutrient comparisons

The absolute amounts of nutrients were calculated in the whole plant for comparison with concentrations of the same nutrients found in tops and roots of citrus seedling plants. Data presented in table 1 show that soil aeration has a substantial influence on the dry weight and nutrient concentrations in the tops and roots of citrus seedlings. The concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, boron, and iron decreased while sodium, chloride, manganese, and copper increased in the tops of citrus seedlings with decreasing soil-oxygen supply to the roots.

The decreasing soil-oxygen supply decreased dry weight of roots, nitrogen, potassium, magnesium, chloride, sodium, and increased calcium, copper, and manganese concentrations in the roots. However, the data presented in table 2 show that the absolute amounts of nitrogen, phosphorus, potassium, calcium, magnesium, chloride, sodium, zinc, copper, manganese, boron, and iron decreased in the citrus seedlings with decreasing soil-oxygen supply to the roots.

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# Live Performance
# Carcass Trait
# Of Crossbred
# Hereford and

W. C. ROLLIN

**Angus bulls generally produced smaller but meatier and higher-conditioned animals with more palatable meat than did Hereford bulls in these limited comparisons of crossbreds with each of the breeds separately (using four presumably representative bulls of each breed).**

THIS TESTING PROGRAM is aimed at determining the amount of hybrid vigor or hybrid advantage resulting from crosses of the British beef breeds under temperate climatic conditions. Experiments reported here are being conducted at the University of California, Davis, but similar tests are also in progress at several other state and federal experiment stations including: Fort Robinson, Nebraska; Miles City, Montana; and Front Royal, Virginia. Results of all the current experiments are expected to be compiled in about five years; it is hoped that they can be used by cattlemen and the industry as a whole to better evaluate the relative costs and expected returns from crossbreeding as compared with grading up, or straightbreeding.

This experiment was designed to compare the average performance of the reciprocal crossbred calves, Hereford × Angus and Angus × Hereford, with the performance of the straightbred calves averaged over both breeds. This design has the virtue that each bull contributes both crossbred and straightbred offspring to the comparisons. Thus the effect of non-