**California Agriculture. 1949. 3(12):8-9.**

# Further Investigations on Avocado Decline

## *Effect of oxygen supply in nutrient solution on avocado and citrus seedlings studied in greenhouse tests*

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The oxygen requirements of avocado roots were studied as part of a general investigation on the causes and control of avocado decline.

Field evidence indicates that avocado trees are especially susceptible to over-moist conditions, and thus that an adequate oxygen supply at the roots is vital to the health and productivity of these trees.

**Effect of Oxygen Concentration in Nutrient Solution on Avocado and Citrus Seedlings (10-day Treatment)**

| Culture number | Oxygen concentration | | Avocado | | | | Citrus** | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Root growth | | | | Root growth | |
| | Minimum | Maximum | Root injury | During treatment | After treatment | Leaf wilt | Root injury | During treatment | After treatment |
| | *ppm | ppm | | | | | | | |
| 1 | 0.05 | 0.06 | Severe | None | None | Delayed | Moderate | Poor | Fair |
| 2 | 0.4 | 0.4 | Moderate | None | Poor | Severe | Slight | Poor | Fair |
| 3 | 0.6 | 0.7 | Slight | None | Poor | Severe | Slight | Poor | Fair |
| 4 | 1.0 | 1.1 | None | Poor | Fair | None | None | Fair | Fair |
| 5 | 1.3 | 1.4 | None | Fair | Fair | None | None | Fair | Good |
| 6 | 1.9 | 2.3 | None | Fair | Good | None | None | Fair | Good |
| 7 | 2.2 | 2.9 | None | Good | Good | None | None | Fair | Good |
| 8 | 6.4 | 6.8 | None | Good | Good | None | None | Good | Good |
| 9 | 8.0 | 8.6 | None | Excellent | Excellent | None | None | Excellent | Excellent |
| 10 | 10.6 | 12.4 | None | Good | Good | None | None | Good | Good |
| 11 | 16.0 | 17.2 | None | Fair | Good | None | None | Fair | Good |
| 12 | 28.8 | 32.0 | None | Stubby | Good | None | None | Stubby | Good |

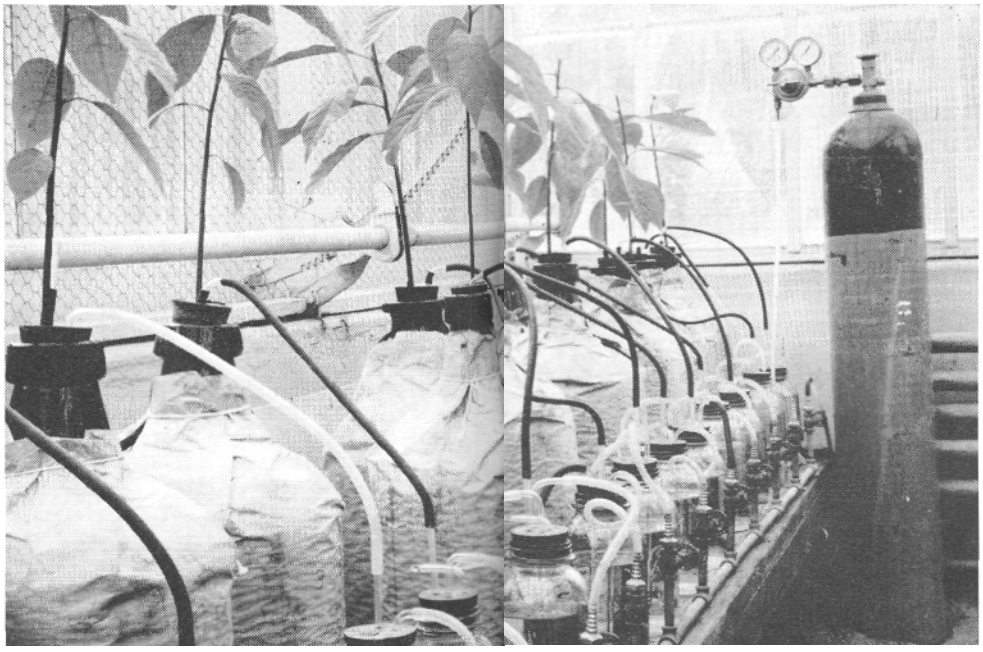
* ppm—parts per million.
** None of the citrus seedlings showed leaf wilt.

Aeration experiments on avocado and sweet orange seedlings—as comparatives—were run in a greenhouse. The seedlings were germinated in river bottom sand and then were transferred to nursery solution cultures, where they were kept in readiness for subsequent controlled experiments.

The accompanying tables show the effects of treating avocado and citrus seedlings at different oxygen levels for 10 days and the effects of exposing

avocado seedlings to low oxygen level for different intervals.

Roots of both avocado and citrus seedlings were injured in cultures having an oxygen concentration of 0.7 ppm—0.7 part of oxygen per million parts of water—or less, but no injury due to oxygen deficiency was found in any of the other cultures. Injury began at the root tips and progressed up along the fleshy white succulent roots, becoming more extensive as the time of exposure to low oxygen concentration was increased, and progressing more rapidly at the lowest oxygen concentrations.



Aeration experiment with avocado seedlings. Compressed nitrogen gas and compressed air are led into 2-quart mixing which are connected by aeration tubes to the 20-liter bottles in which the avocado plants are growing.

Injured avocado root tips became constricted or shrunken in the region of cell elongation and turned off-color. At first they turned various shades of pink, yellow, and lavender, but darker discolorations followed a few days later. Injury was more extensive and more severe on avocado roots than on citrus roots, which did not show constricted areas but became very soft and slowly turned orange-yellow. After several days, injured citrus roots sloughed off. The constricted tips of avocado roots and the soft, pliable tips of citrus roots were detected during the first day of exposure to low oxygen concentrations which ranged from 0.05 to 0.7 ppm.

Although both avocado and citrus roots showed injury due to oxygen deficiency at a concentration of 0.7 ppm, the maximum concentration at which root injury did not occur was 1.0 ppm. Evidently the critical value lies somewhere between 0.7 and 1.0 ppm.

At oxygen concentration of 0.05 to 0.06 ppm avocado roots failed to grow during

and after the 10-day treatment, and all the roots were killed. At slightly higher concentrations, ranging from 0.4 to 0.7 ppm roots failed to grow during the 10-day treatment, but there was some growth, although poor, after treatment.

As the oxygen concentration increased, root growth showed improvement, both during and after treatment, until an oxygen level of 8.0 to 8.6 ppm was reached. At higher oxygen levels growth was somewhat retarded, and at the highest level where the solution was bubbled with pure oxygen gas, the roots became short and stubby with frequent branching.

Roots of citrus seedlings continued to push through the cortex of older roots both during and after all oxygen treatments including a 10-day exposure to a concentration of 0.05 to 0.06 ppm, although growth at this oxygen level was extremely slow. As the oxygen concentration increased, root growth showed improvement, as was observed for avocado roots, until maximum growth was reached at 8.0 to 8.6 ppm.

**Effect of Time of Exposure to Low Oxygen Concentration in Nutrient Solution on Avocado Seedlings**

| Culture number | Oxygen Concentration | | Root growth | | | Leaf wilt | | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Root injury | During treatment | After treatment | Interval between treatment and first wilt | Interval between treatment and recovery | Interval between treatment and second wilt |
| | *ppm | ppm | | | | hours | hours | days |
| 12-hour treatment | | | | | | | | |
| 1 | 0.10 | 0.10 | Slight | None | Fair | 2 | 4 | —** |
| 2 | 0.12 | 0.14 | Slight | None | Fair | 2 | 4 | — |
| 3 | 0.08 | 0.10 | Moderate | None | Poor | 4 | 6 | — |
| 4 | 0.10 | 0.12 | Slight | None | Fair | 8 | 10 | — |
| 5 | 0.10 | 0.12 | Slight | None | Fair | 2 | 4 | — |
| 24-hour treatment | | | | | | | | |
| 6 | 0.10 | 0.12 | Moderate | None | Poor | 2 | 4 | 8 |
| 7 | 0.08 | 0.14 | Moderate | None | Poor | 4 | 6 | 8 |
| 8 | 0.10 | 0.12 | Severe | None | None | 2 | 4 | 10 |
| 9 | 0.08 | 0.12 | Severe | None | None | 6 | 10 | 6 |
| 10 | 0.10 | 0.14 | Moderate | None | Poor | 8 | 10 | 10 |
| 96-hour treatment | | | | | | | | |
| 11 | 0.10 | 0.12 | Severe | None | None | 8 | 10 | 8 |
| 12 | 0.08 | 0.14 | Severe | None | None | 2 | 4 | 10 |
| 13 | 0.10 | 0.12 | Severe | None | None | 2 | 4 | 6 |
| 14 | 0.08 | 0.10 | Severe | None | None | 4 | 6 | 10 |
| 15 | 0.10 | 0.12 | Severe | None | None | 2 | 4 | 10 |
| Control (normal aeration) | | | | | | | | |
| 16 | 8.20 | 8.60 | None | Excellent | Excellent | — | ... | — |
| 17 | 8.20 | 8.42 | None | Excellent | Excellent | — | ... | — |
| 18 | 8.20 | 8.40 | None | Excellent | Excellent | — | ... | — |
| 19 | 8.24 | 8.60 | None | Excellent | Excellent | — | ... | — |
| 20 | 8.20 | 8.60 | None | Excellent | Excellent | — | ... | — |

* ppm—parts per million.
** Dash indicates no leaf wilt evident.

At higher oxygen levels there was a decrease in root growth similar to that of avocado roots and at the highest level the roots became short and stubby, with the same tendency toward frequent branching as that observed for avocado roots.

Roots of avocado did not grow during exposure to low oxygen concentrations, but new roots grew from uninjured root areas when regular aeration was supplied after 12 hours exposure to oxygen levels ranging from 0.08 to 0.14 ppm. After the 24-hour exposure new roots grew in three out of five cultures; after the 96-hour exposure new roots failed to grow in all cultures, and the plants died.

On warm bright days the immature leaves of the avocado seedlings wilted to some extent—lost turgor—in all cultures, regardless of oxygen supply, but pronounced wilting was prevalent only where the oxygen concentration was limited to 0.7 ppm or less. The leaves passed through stages of wilting, recovery, and wilting again. The first wilt included only immature leaves and occurred within two to eight hours after exposure. The leaves regained their normal turgor after four to 10 hours and remained turgid for six to 10 days. The second wilt included mature and immature leaves but did not occur unless the seedlings were exposed to low oxygen supply for 24 hours and did not begin until six to 10 days after treatment. This second wilt began with the immature leaves and increased in severeness until all the leaves hung in a limp, flaccid condition, after which the entire seedlings withered and died.

The second wilt was somewhat delayed at the lowest oxygen level for although all the roots had been killed, the leaves continued to absorb water and nutrients for several months. The leaves became leathery and hung partly wilted at *a* position slightly below the horizontal.

Leaves of the citrus seedlings studied did not wilt at any time during these experiments.

The extreme sensitivity of avocado roots to low oxygen concentration confirms the field evidence that extra precautions must be taken to prevent waterlogging of the soil. Over irrigation must be avoided on heavy soils or on soils with imperfect drainage.

*Denzel S. Curtis was Associate in the Experiment Station, Soils and Plant Nutrition, Riverside, during the investigations reported here.*

*The above progress report is based on Research Project No. 1263. This investigation was aided by a grant from The California Avocado Society.*