transpiration and induced higher leaf water deficits, fruit and trunk shrinkage.

DISCUSSION. The high apparent transpiration in Florida appeared to be induced by the following conditions; (A) full hydration of the leaves and wood by heavy dew and rainfall; (B) the very high soil water level; (C) rough lemon stock which increases transpiration (13). Under full sun, water was lost very rapidly. However, a larger root and/or conduction system or a larger internal water reserve prevented development of high deficits in leaves and fruit.

In Arizona, approximately equal transpiration but greater leaf water deficits and fruit shrinkage accompanied the much higher potential transpiration conditions. This situation indicates the following conditions were involved: (1) the root system and/or the water conduction capacity limited the amount of water to leaves; (2) high leaf water deficits induced partial closing of stomates which limited transpiration; (3) the extreme day stress and dry nights prevented full hydration of the tree at night; (4) relatively low soil water.

The data indicate that on sunny days, transpiration rates of leaves in Florida and Arizona are not greatly different. Evapotranspiration studies, based on changes in soil water, confirm this. Water usage in July, August and September are reported to be 13.5 inches in Florida (11) and 15.2 inches in Arizona (7).

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INDUCED ANAEROBIOSIS CAUSED BY FLOOD IRRIGATION WITH WATER CONTAINING SULFIDES[1]

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ABSTRACT

A grove in St. Lucie County, that had shown poor growth for many years, was evaluated for the possibility that sulfides in the irrigation water were damaging citrus roots. Roots extended only to a depth of 10 inches, which was the

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approximate height of the water table during flood irrigation. Sulfides remained in the flooded furrows for up to 18 hours. Flooded depth zones under the trees were found to be in a state of anaerobiosis (an environment without oxygen) after 20 hours of flooding with water containing 1.5 ppm of total sulfides. Iron was reduced to the ferrous form, and nitrites were detected. After 48 hours of flooding, sulfides were found in the ground water at toxic concentrations of 0.1 to 0.2 ppm. Up to 50% of the feeder roots of 'Cleopatra' seedlings buried in the beds were killed. A heavy accumulation of gelatinous black insoluble iron sulfide had formed under the furrows. The layer was found to restrict the movement of water. Hydrogen sulfide released when the layer slowly oxidized could kill roots above the water table.

Introduction

Flooding the furrows had been used extensively in the Indian River area as a means of irrigating bedded citrus groves. Water obtained from wells, particularly artesian wells, may contain detectable amounts of hydrogen sulfide. Concentrations of sulfides greater than .2 ppm in soil solutions are lethal to citrus feeder roots (2). Roots of young citrus trees were apparently injured when submerged for several hours in a drainage ditch containing sulfides. Many of the trees died when planted in the grove (3).

A grove in St. Lucie County on Felda fine sand that had shown poor growth for many years was evaluated for the possibility that sulfides in the irrigation water were damaging citrus roots. Most of the roots extended only to a deph of 10 inches, which was the approximate height of the water table during flood irrigation.

Methods

A single bed 28 inches high, 32 feet wide, and 1320 feet long was selected for flooding. An artesian well was located near the east end of the bed. The 25-year-old grapefruit trees were spaced 20 feet on the bed. The water furrows on each side of the bed were flooded for 24 hours in February 1965 and for 48 hours in April and June 1965. The water in the furrows was approximately 2 feet deep and extended to the drip line of the trees. The water table under the crown of the bed was 10 inches *below* the surface.

Samples of ground water during flooding were collected for analysis from aluminum tubes installed at 330-feet intervals to a depth of 1.4 feet below the crown of the bed.

Oxidation-reduction potentials (redox) were measured with a platinum electrode attached to a Beckman Model N pH meter. Redox is expressed as positive or negative voltages depending on the direction of current flow across the electrode. An increase in positive voltage (+100 to +500 millivolts) indicates a more oxidized condition. An increase in negative voltage (+100 to —400 millivolts) indicates that the soil is more reduced or anaerobic.

Nitrates were detected by the sulfanilic acid method (1). Iron was estimated by a spot test using o-phenanthroline (1). A colorimetric test utilizing N, N-dimethyl-p-phenylenediamine and ferric chloride (4) was used to detect total sulfides as low as 0.1 ppm in water.

'Cleopatra' seedlings were planted in ¼-inch wire mesh containers (6 inches x 10 inches) that had been lined with fiberglass. The fiberglass was highly permeable to the lateral movement of water. Containers with seedlings were buried 18 inches below the soil surface and 2½ feet from the furrows. After 48 hours of flooding, the containers were dug and held in the greenhouse for 7 days. The roots of the seedlings were then evaluated for visible root damage and for potential damage by staining with 1% 2,3,5-triphenyltetrazolium chloride.

Hydraulic conductivity of iron sulfide deposits found under the furrows and in ditch banks of several groves was measured. Undisturbed, 1-inch cores, 1⅞ inches in diameter, were collected from the deposits and placed in glass cylinders. Hydraulic conductivity was recorded as the time required for 3 inches of water to pass through the 1-inch core.

Results and Discussion

Sulfides were detected in the artesian irrigation water along the entire 1320 foot flooded furrow. Concentrations of sulfides varied from 1.5 ppm near the well to 0.1 ppm at the end of the furrow. After 22 hours, sulfides could still be detected in trace amounts in the flooded furrows for a distance of 600 feet from the artesian well. It should be noted that water flowed from the well for only 4 hours—the time required to fill the furrows. Thus, it required more than 18 hours to oxidize the sulfides even though the surface of the water was exposed to the atmosphere. The detection of sulfides indicated that the water was devoid of oxygen since sulfides cannot exist in water when oxygen is present.

Twenty hours of flooding resulted in an anaerobic condition in the flooded root zone under the citrus trees as indicated by a redox measurement of 90 millivolts in sections of the bed within 600 feet of the well. Fifty percent to 90% of the iron content of the ground water was found to be the reduced ferrous-form—a further indication of an anaerobic condition. Nitrites were detected in amounts from a trace to 5 ppm. The irrigation treatments had been applied shortly after the winter fertilizer application. Nitrites are formed from nitrates by the activitiy of nitrate reducing bacteria and can be toxic if concentrations are greater than 100 ppm (2). The bacteria can develop only under oxygen deficient conditions.

A state of complete anaerobiosis existed in the root zone after 48 hours of flooding. All of the iron was in the ferrous form and redox values were between —30 and —150 millivolts. Sulfides were found in the ground water at toxic concentrations of 0.1 to 0.2 ppm. It was not ascertained whether the sulfides were residual amounts direct from irrigation water or increasing concentrations from the activity of sulfate reducing bacteria. These bacteria could develop rapidly under anaerobic flooded conditions when substrates and sulfates are present in adequate amounts. In laboratory studies, it required 1 to 2 days for anaerobiosis to occur using nonsulfide water in soils with sufficient substrates; however, it required 5 days when substrates were limiting (2). In the St. Lucie County grove, substrates in the form of citrus and grass roots appeared to be deficient in the flooded zone.

Fig. 1.—Iron sulfide impregnated layer 6 inches under the water furrow of a bedded grove irrigated with water containing sulfides.

Thus, the sulfide ion from irrigation water appeared to be the factor most responsible for the anaerobic condition that occurred within 1 to 2 days.

A few feeder roots were found in the flooded zone. They were placed in tetrazolium chloride for 20 hours to note the formation of reduced insoluble red triphenyl formazan. Up to 50% of the roots had unstained segments. The absene of red color on a segment of feeder root has been used to indicate that the root was beyond recovery (2).

Feeder roots of 'Cleopatra' seedlings buried in the flooded rooting zone were damaged by 48 hours exposure to sulfide irrigation water. Destruction of feeder roots varied from 0% to 50% in comparison to nonflooded plants.

A layer of black greasy iron sulfide was found on top of the clay layer about 6 inches below the bottom of the water furrows (Figure 1) in the grove in St. Lucie County. The layer was about 1 inch think, and appeared to be about 4 feet in width. The odor of hydrogen sulfide eminated from the layer even when it was above the water table. No citrus or grass roots were in the layer. Hydrogen sulfide released when the layer slowly oxidized could kill roots above the water table. A survey of 8 groves using flood irrigation indicated that the formation of iron sulfide in the soil profile may be rather extensive.

The texture of the deposits indicated that iron sulfide might restrict the movement of water. To test this hypothesis, cores of undisturbed iron sulfide impregnated fine sands together with cores containing no visible iron sulfide were collected in a problem grove in Manatee County. It required 12 to 18 hours for 3 inches of water to pass through soil cores containing iron sulfide as compared to 5 to 7 minutes for sands with no visible iron sulfide.

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GROWTH, YIELD, AND FRUIT QUALITY OF MARSH GRAPEFRUIT ON VARIOUS ROOTSTOCKS ON THE FLORIDA EAST COAST—A PRELIMINARY REPORT

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Introduction

According to Savage (4, 5) in 1963-64 and 1964-65, the last two seasons reported for movement of nursery stock, 390,000 grapefruit trees of all varieties were planted in Florida. Slightly more than half, or 210,000, were Marsh variety planted on the East Coast in the two principal grapefruit-producing counties, Indian River and St. Lucie. Plantings of Marsh trees in this area are predominantly on sour orange rootstock and continue to increase. This report compares the performance of Marsh grapefruit on 42 miscellaneous rootstocks, including sour orange, on a Felda soil in the Ft. Pierce area.

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Materials and Methods

Rootstocks and scion variety. Seeds for producing the rootstocks were secured from the variety collection at the Hiawassee Experiment Station near Orlando. Sour orange No. 2, important in this test as a reference stock, is a typical sour orange selection not distinguished by any unusual characteristics. We have used it in many of our rootstock trials. A nucellar Marsh grapefruit tree, which had fruited only a few years previously, provided the scions. The test trees were somewhat slow in starting to fruit because they were the first generation of budlings from the original seedling. The planting was made on February 18, 1959, on Felda soil near Ft. Pierce, Florida, in a randomized block design, with two trees of each rootstock