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EIGHT YEARS OF ROOT INJURY FROM WATER TABLE FLUCTUATIONS

Harry W. Ford

IFAS Agricultural Research and Education Center
Lake Alfred

Abstract. **A grove in Manatee County has been under observation and study because it was one of the first sites where hydrogen sulfide was detected in the root zone during periods of flooding. The periphery of an old pond site in the center of the grove became plugged with iron sulfide restricting flow to ditches. Root kill during periods of flooding correlated with detectable sulfide levels. Hydrogen sulfide was also present above the water table in fragments of palmetto roots and where iron sulfide had been deposited on organic matter in the old pond area. Attempts to improve deep rooting by mixed soil columns indicated that root growth was profuse in columns of alkaline slag gravel and sand. Tree size correlated with rooting depth. Over the 8-year period, drainage per se did not eliminate all root growth problems. Light sandy subsoils in certain blocks acted as physical barriers to root growth and low subsoil pH seemed to restrict deep rooting.**

A 50-acre 12-year-old orange grove on sour orange rootstock in Manatee County has been under long-term observation and study because of root damage associated with flooding. The grove was one of the first sites where toxic hydrogen sulfide was detected in the root zone. The site apparently had been used for vegetable crops prior to grove development as indicated by 150 lb. per acre of copper in the top soil. A 3-acre area, where the soil exhibited particularly poor drainage characteristics (6), was found to be an old pond site based upon soil borings and aerial photographs. The single bedded grove had ditches that were supposed to be 4 ft. deep spaced 320 ft. apart. From 1965 to 1972, ditch depths were shallow—averaging only 3 ft. because of erosion and lack of maintenance. Soil type was predominantly Immokalee fine sand.

The primary purpose for this long-term study was to measure and evaluate hydrogen sulfide as a citrus root toxicant; however, it became apparent that other growth inhibiting factors, not eliminated by drainage, were also present.

Attempts were made to reduce the level of hydrogen sulfide by eliminating sulfates from the fertilizer and by soil applications and injections of sodium nitrate and lime. In laboratory studies (5, 7), nitrates inhibited the production of hydrogen sulfide and liming reduced the destruction of roots during flooding. Fluctuations of the water table, root growth, and characteristics of the soil environment were recorded in an effort to evaluate growth of the trees.

Methods

In 1964, 4-tree plots with 6 replicates for each soil treatment were selected near the poorly drained old pond area of the grove. The study involved 5 nitrate and lime treatments applied in 6 applications from April to September. Treatments and applications for the year were: 1) solutions of sodium nitrate, equivalent to 400 lb. of N per acre, pressure injected through bayonet nozzles to a depth of 2 ft. into the subsoil, 2) hydrated lime, equivalent to 3 tons per acre, injected as a slurry to 2 ft., 3) lime equivalent to 1 ton per acre plus sodium nitrate equivalent to 400 lb. per acre injected to 2 ft.,

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4) surface application of sodium nitrate equivalent to 300 lb. of N, and 5) surface application of calcium nitrate equivalent to 300 lb. of N.

The rates of water movement in soil from ditch banks and peripheries of the old pond were measured in the laboratory (10). Six water stage recorders were spaced between ditches in 3 locations. Piezometers were used to detect subsoil water pressures. Sulfide sorption cells (9) and water sampling cells (8) indicated the presence of hydrogen sulfide in relation to water table fluctuations. Eight-inch diameter augers were used to sample feeder roots.

In 1970 and 1971, 8-inch diameter soil columns 5 ft. deep and located at tree drip lines were used to evaluate vertical root growth. Mixtures consisted of: 1) native sand, 2) phosphate slag gravel and native sand, and 3) Lakeland fine sand. At intervals of 6 months and 1 year, columns were dug to note root development in comparison to adjacent undisturbed cores. Copper in the subsoil was detected by the Spencer color test (14). Nitrates and nitrites were detected with spot tests (3) and compared to suitable color standards. Hydrogen sulfide was detected by odor and in the groundwater by the p-aminodimethylanaline test (15).

Results and Discussion

Elimination of sulfates from the fertilizer confirmed laboratory findings (5) that there are usually sufficient sulfates in the soil profile or as impurities in the fertilizer mix for the activities of sulfate reducing bacteria. Over a period of 8 years, eliminating sulfates from the fertilizer did not eliminate the production of hydrogen sulfide at a depth of 3 ft.

Applications of nitrates either by pressure injection or surface application did not improve rooting or root survival in the 18 to 36-inch depth zone. The mean root depth in the untreated plots was 18 inches and in treated plots 19 inches. Nitrites, a reduced form of nitrates, produced by certain denitrifying bacteria under waterlogged conditions (1, 11, 12) were detected in the saturated subsoil. Nitrites were detected in amounts above 100 ppm within 1 week after the injection of sodium nitrate. Nitrites *per se* can be toxic to citrus roots although no critical threshold has been established (2, 5, 7). Sulfides were not detected while nitrites were present. Certain studies have shown that nitrites inhibit ferrous iron and sulfide production in flooded soil systems. One suggested explanation is a tie-up of energy sources by nitrate reducing bacteria which can function with traces of oxygen in the groundwater (11, 12). The other is a stabilizing effect on the oxidation-reduction potential (13) so that sulfate reducing bacteria cannot function. Nitrites and sulfides are also chemically antagonistic to each other in the same environment. In the laboratory and in the Manatee County field test, nitrites disappeared within 4 to 8 days after initial detection. The loss of nitrites was followed by the reappearance of sulfides. The disappearance of nitrites signaled the apparent complete loss of nitrates in the waterlogged region. Use of nitrates to inhibit sulfides appeared to be impractical for grower use because of costs and no improvement in root growth. The experiment was abandoned after one season.

The periphery of the pond site contained a considerable number of palmetto root pieces that proved to be an excellent medium for production of hydrogen sulfide. No citrus roots survived in zones where the hydrogen sulfide could be smelled in a handful of soil. The odor of hydrogen sulfide was often detected above the water table even in the dry season. Soil organic matter in the periphery zone also accumulated black greasy iron sulfide. Iron sulfide can oxidize during drying and release hydrogen sulfide. Palmetto roots, insofar as possible, should be removed during land preparation. Twelve years after the site was developed for citrus, palmetto roots were still present and producing hydrogen sulfide.

Sealing of the pond periphery with bacterially induced sludges (mostly iron sulfide) has been described elsewhere (6). During the 8 years of observations, the sealing action has been increasing so that the water table curve as shown in Fig. 1 has changed shape. Increasing amounts of groundwater must flow to the west ditch because of the sealant near the east ditch. Hydraulic conductivity (rate of water movement) measurements from the east ditch bank during 1967 indicated a water percolation rate of only .004 inches per hr. (9).

The water table fluctuated extensively during summer rains. In 1970, 3-inch rains raised the water table to the surface within 75 ft. of the ditches. The rate at which the water table receded was 4 inches per day in 1966 and 3 inches per day in 1970. During the summer rainy season, hydrogen sulfide was produced in the profile within 4 days after a zone became flooded. Hydrogen sulfide was usually produced more quickly and in greater amounts in September

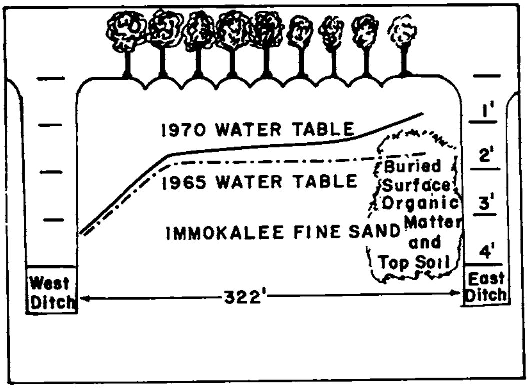

Fig. 1. Changes in the shape of the water table curve 1965-1970.

than in June. This was probably associated with a build up of the sulfate-reducing bacteria during the wet conditions caused by summer rains. Dead feeder roots could usually be observed within 3 weeks after sulfides were initially detected. Because of overlapping periods of sulfide production (rains were not uniformly continuous), the exact time from physiological root injury to visible death of roots could not be ascertained.

Ditches in the grove did not receive adequate maintenance so that surface water furrows (14 inches deep) established the general depth of rooting. Rooting depth as measured in spring and fall is shown in Table 1 and tree size in relation to mean maximum root depth and soil pH is in Table 2. The killing of new roots was associated with flooding and the largest trees, only 10.9 ft. at 12 years of age, had the most new vertical root growth during dry periods.

Table 1. Mean maximum root depth of 25 trees in the old pond site.

Year	March-May (inches)	Aug.-Sept. (inches)
1966	25	8
1967	14	9
1968	18	9
1969	17	6
1970	28	9
1971	13	6
1972	22	--

Table 2. Tree size in relation to mean maximum root depth and soil pH in one selected block.

	Sampling location							
	Within 50-75 ft of a ditch				Within 120-150 ft of a ditch			
Year	Tree ht. (ft)	Root depth dry season (inches)	Root depth wet season (inches)	Sub-soil pH	Tree ht. (ft)	Root depth dry season (inches)	Root depth wet season (inches)	Sub-soil pH
1967	6.9	12	10	--	7.8	18	12	--
1970	7.8	12	9	4.6	9.0	14	7	5.2
1972	9.0	12	10	4.3	10.9	18	6	4.9

Regardless of location, trees were usually smaller if no new vertical root growth occurred during dry periods. Consequently, at several sites (Table 2) trees were smaller near ditches than in the middle of blocks.

The inhibition of vertical root growth in the dry season was associated with factors other than drainage. It is well-known (4) that citrus roots grow poorly in white leached subsoil; however, this could not account for all of the limited vertical root growth in the Manatee County grove. Subsoil pH values of 4.2 to 4.6 (below the 12-inch depth zone) were common in several blocks under observation. No roots grew into zones with a subsoil pH of 4.2. Only a few sparse roots were found at pH 4.6 and then

Table 3. Vertical root growth after 1 year in mixed soil columns as measured in May 1971.[z]

Treatment	Max. depth of rooting (ft)
Native sand plus slag gravel	4 - 4.5
Sand mix (top and sub-soil sand)	3 - 4
Lakeland fine sand	3 - 4
Undisturbed, nonmixed	0.8 - 1

[z]Holes were dug at the drip line of selected trees using an 8-inch diameter auger in July 1970. The holes were refilled with materials as indicated.

only if no copper was detected by spot tests. No feeder roots were found where 50 lb. of copper per acre was detected in the subsoil in combination with pH values of 5.0. The grove owner applied 2 tons of high calcium limestone to one block with subsoil pH values below 4.6. The subsoil pH increased to 5.0 to 5.3 in the 12 to 18 inch depth zone within 2 years. New root growth could be detected, but it was sparse in the white sand subsoil.

The use of mixed soil columns (Table 3) served to indicate that low subsoil pH and physical resistance to root penetration in selected sites could be factors in poor root regeneration. The profound increase in depth of roots in mixed soil columns in 1970 (which was followed by extensive root kill in 1971 because of poor drainage) seemed to indicate that good grove management for the flatwoods involves, in addition to drainage, elimination of the other factors that restrict vertical root growth. The only factor in established groves that could be changed would be the use of lime to raise subsoil pH. Any long-term advantages from soil mixing to aid root penetration must be weighed against costs. A complete soil mix cannot, in the opinion of the writer, be justified on a large scale for the majority of groves at this time.

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EVALUATION OF NEW PRESSURIZED OIL GROVE HEATING SYSTEMS

J. F. Bartholic
and
D. W. Buchanan

IFAS Fruit Crops Department
Gainesville

Abstract. **The Brader heater used extensively along the West Coast and the Georges heater which is a modification of the Lazy Flame were evaluated during the winter of 1971. Both systems were new to Florida and cleared by the Department of Pollution Control in 1971. Data are presented on air temperatures sensed at 17 locations throughout a heated area during several nocturnal periods. Temperature inversion data outside and inside the heated area, radiation flux and wind speed were also obtained. Advantages and disadvantages of the 2 systems were discussed.**

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Background

Heating of citrus groves in Florida for freeze protection has been common practice for more than a century. Pine "lighter" wood, old tires, and fuel burned in open pots were gradually superseded by various types of heaters, such as the jumbo cone, lazy flame, and return stack, which were designed for more efficient combustion. Wind machines were widely adopted in areas of California where strong temperature inversions occur and have been utilized in Florida. The latest development has been automatic central systems where fuel is pumped through inexpensive plastic pipe to heaters scattered through a grove.