WATER MANAGEMENT IN POORLY DRAINED CITRUS SOILS

Harry W. Ford[1]

Water management is one of the most difficult problems of citrus production in poorly drained soils. Water management includes both irrigation and drainage. Adequate irrigation is important due to the limited root system in wetland areas; however, the methods, equipment, and research information available are more complete and better understood (except for clogging in drip-irrigation systems) than is the subject of drainage. Adequate drainage includes both surface and subsoil drainage. Surface drainage is necessary to remove excess surface water rapidly during and after heavy rains. This is usually accomplished by bedding unless the natural topography has a slope of at least 0.5%. Beds may contain from 1 to 4 rows of trees. The height and slope of beds need only be enough to move surface water (0.5% or more), assuming adequate profile drainage. In practice, beds have usually been up to 1 m in height and have unintentionally served for both surface and profile drainage since ditches are often more than 250 m apart.

Surface water is diverted into collection ditches by means of drop pipes. Water that soaks into the soil and raises the water table must be removed by subsurface drainage. This can be done through the use of subsurface drains (usually corrugated plastic pipe) or open ditches. Both surface and profile drainage are necessary for water control in most poorly drained wetland soils subject to a high yearly rainfall such as in Florida.

An economically efficient drainage system is one involving maximum spacings and minimum depths that will prevent destruction of citrus feeder roots during periods of flooding. Measurements of water table fluctuations over periods of 10 years in 4 citrus groves in Florida suggest that drains spaced 30 to 40 m with depths of 120 cm will permit citrus roots to grow to depths of 90 cm in fine sandy flatwood soils. Trees located midway between drains may experience some damage to feeder roots, particularly in the spodic (organic pan) horizon at depths of 70 to 100 cm during prolonged wet periods. Ditch spacings of 66 m in sandy soil yielded water table draw-down characteristics similar to 40-m spacings for tile drains in studies in Hendry County, Florida. Data were collected from sites with shallow beds 30 cm in height that had good surface drainage. The data indicated in general that 91 m spacing of ditches, a very common practice in acid flatwoods soils, may not prevent root damage under severe flooded conditions (11). Spacing and depth recommendations are based on assumptions that sludges and other factors do not reduce drainage efficiency more than 20%. Depth and spacing requirements for fine-textured soils and organic soils would be different than for the figures cited. Most drains in Florida are designed to remove 2 cm per day of surface water through the soil profile (1).

Engineers need in the final analysis to know the ramifications of a drainage design as related to plant response in the field.

Relationship Between Rooting Depth, Root Distribution, Tree Size, and Soil Type

Measurements in a grove near Largo, Florida indicated that lowering the water table from 76 to 117 cm doubled the quantity of feeder roots in the soil profile and increased the size of the trees (4). Tree size and total feeder roots were reduced for trees that were more than 39 m beyond the end of the drainage system. Lowering the water table only 13 cm resulted in a 25% increase in root concentration with a visible increase in tree size.

Citrus roots were found to grow downward 60 cm in 1 year following a lowering of the water table with newly installed drains. Thirty percent of the entire feeder root system and 66% of the new root growth was destroyed

[1]Horticulturist, Agricultural Research and Education Center, IFAS, University of Florida, Lake Alfred.

when the water table ascended to the 1 m level. Similar results have been noted on the Florida east coast (23) where root distribution studies indicated that the yearly high water mark established the average depth of rooting.

Soil characteristics influence tree growth even when the grove has excellent drainage with the water table below 1.5 m (16). Root growth in the soil profile practically ceased when roots entered white sand. Feeder roots were in greater concentration in sands containing more color and organic matter throughout the profile. It was concluded after studying microorganisms, citrus feeder roots, nitrate production and nutrient content that the characteristic most closely related to tree size was quantity of citrus feeder roots per unit volume of soil. A minimum rooting depth of 91 cm appeared to be necessary for reasonable growth of citrus trees on the predominantly acid flatwoods soil type in Florida. The soft organic pan layer (spodic horizon) found in the profile of certain sandy soils and wetland areas has been found to be a satisfactory medium for feeder root development under conditions of adequate drainage (5). About 50% of the entire root system of each tree was found in the spodic horizon of Immokalee fine sand. The thickness of the spodic horizon averaged 43 cm under 12-year-old trees that were 4.5 m tall. The spodic layer was 75 cm below the surface.

Mixing the spodic horizon with the white leached layer together with the incorporation of dolomite or high calcium limestone has been under evaluation. Mixing the profile and adding lime resulted in marked improvement of young tree growth (2, 28).

Factors That Destroy Citrus Roots Under Flooded Conditions

It has been assumed that citrus roots, when flooded, die from a deficiency of oxygen resulting in anaerobic respiration. This has been reported in extensive reviews (22,26,29,30). The possibility that anaerobic conditions in the root zone foster certain types of microbial activity that could kill the roots more quickly than oxygen deficiency *per se* must be considered. Such action has been recognized in extensive reviews (25,30).

Hydrogen sulfide is a toxin produced by anaerobic bacteria under water-logged conditions that has been shown to be lethal to citrus roots (12). The degree of toxicity appears to be associated with the molecular concentration of dissolved hydrogen sulfide in the root rhizosphere. Generation of hydrogen sulfide in the root rhizosphere is logarithmic, as indicated by doubling of the concentration every 24 hours under controlled experiments. Toxicity is also a concentration-time relationship since 2.3 ppm molecular hydrogen sulfide caused more root damage in 7-day tests to citrus seedlings than 2.8 ppm in 5-day tests. The root system appears to be differentially permeable to molecular hydrogen sulfide. Killing of citrus root tissue by hydrogen sulfide seems to be a slow process. Stained root segments suggest that sulfides must be in excess of a certain threshold concentration before the tissues are beyond the point of regenerating a functional root system. It was found in controlled studies that hydrogen sulfide in the root zone may be 14 times higher than in the soil solution. Important sources of energy for the bacteria are organic acids such as lactic and citric (7), which are exudates of living root systems (24).

Citrus apparently is reasonably tolerant to oxygen deficiency *per se* in the rhizosphere. Seven-day exposures to oxygen deficiency in a multi-celled controlled apparatus did not seriously injure roots (3).

Nitrites are toxic to citrus roots under anaerobic flooded conditions (8). Nitrites formed within 18 hours and reached levels of 25 to 50 ppm without apparent damage to feeder roots in laboratory containers with an exposure time of only 48 hours. Nitrite concentrations greater than 50 ppm at pH 6 were necessary in order to damage citrus feeder roots in solution cultures. Nitrites, although capable of damaging roots, have not been found extensively when flooded feeder roots have been injured in flatwoods citrus groves.

Tolerance of Citrus to Flooding

Studies in the greenhouse indicate that root survival under flooded conditions is influenced by rootstock, soil type, and soil pH (6). The root damage to 8 different citrus rootstocks after 7 days of flooding is shown in Table 1.

Table 1. Depth of live roots after flooding a 76-cm column of Leon fine sand.

Rootstock	Soil pH	Depth of live feeder roots (cm)	Relative recovery 4 weeks after flooding
Estes rough lemon	5.0	50	excellent
	7.0	76	
Carrizo citrange	5.0	58	excellent
	7.0	76	
Rangpur lime	5.0	55	excellent
	7.0	74	
Milam lemon	5.0	66	good
	7.0	71	
P. trifoliata	5.0	38	good
	7.0	76	
Sweet orange	5.0	30	fair
	7.0	48	
Sour orange	5.0	23	fair
	7.0	46	
Cleopatra mandarin	5.0	10	poor
	7.0	38	

The odor of hydrogen sulfide was detected in the area where citrus roots were killed. The odor of hydrogen sulfide can be used as a means of determining whether citrus roots will die under flooded conditions in the field. A handful of soil and roots should be collected from below the water table in an area suspected of being in an anaerobic condition. The odor of hydrogen sulfide usually indicates that the root system in the sampled zone is damaged beyond the point of rejuvenation. New feeder roots may grow from lateral roots if the length of exposure is not prolonged from severe flooding.

Fluctuations of the Water Table and Piezometric Surface in Drained Commercial Groves

Rains of 12 cm within several hours are common in Florida and the water table may rise rapidly and flood the root zone within 6 hours following such showers. The extent of the rise is dependent upon the depth and spacing of drains or ditches as well as the type of surface drainage and soil. The rate at which the water table falls following heavy rains without additional rainfall is being used as an indication of drainage efficiency. It has been recognized and shown by the use of water level recorders that frequent daily showers will maintain the water table close to the surface even though the water is moving toward drains.

Many factors contribute to root damage under flooded conditions, hence it is doubtful that a minimum rate of drawdown that will prevent root damage can be established with accuracy. Our data in Florida suggest that a drawdown rate of 12 cm per day may be an indication of adequate drainage while rates of 5 cm per day should be considered insufficient to prevent root damage under severe flooding. These figures have been suggested to Florida citrus growers as guidelines. It has been suggested that growers evaluate their own systems by installing water table observation wells midway between drains or ditches. The observation wells can be made of 10-cm irrigation pipe, tile, fiber pipe or corrugated plastic tubes installed to depths of 120 cm. It is usually desirable to place filtering materials around the outside and at the bottom to minimize piezometric effects. The rate at which the water table recedes following heavy rains is recorded after 24 and, if possible, 48 hours (10).

Oxidation-reduction potential, iron and hydrogen sulfide measurements of flooded containers of soil and roots as well as selected field measurements have yielded a practical method for growers to use in detecting anaerobiosis. It was discovered that flooded citrus and grass roots have a disagreeable odor when the mass becomes anaerobic. The unpleasant odor is noticeable 24 to 48 hours before sulfides can be smelled. Growers have been instructed to take soil samples from the root zone if flooding should occur and quickly smell for the presence of the unpleasant anaerobic odor which may be followed by the odor of hydrogen sulfide (11).

The presence of zones of piezometric pressures have resulted in poor drainage of locations that normally should have excellent drainage. Unfortunately, pressures have usually not been discovered until after the grove sites have been prepared for citrus. It has been recommended to industry that soil borings be taken prior to grove development, particularly if there is adjacent land of higher elevation that could be the source of pressure. In one location, the pressures caused the free water table to be only 76 cm below the surface even though the drainage ditch had been dug 2.4 m deep.

Sludge in Drains

Numerous tile lines were found in Florida with considerable amounts of red, hydrophilic, filamentous iron sludge at the tile outlets in 1959 (27). Lines with the most sludge had been laid with fiberglass sheets as a filtering material. The fiberglass was clogged with a red deposit so that certain tile lines ceased to flow within 6 months.

Experiments were initiated in 1961 to control the sludge problem. Treatments consisted of alkaline filtering materials to precipitate the iron, as well as bactericides such as copper to kill the organisms (17). The results of these tests indicated that an alkaline filtering material such as slag or crushed shell would effectively eliminate iron from the groundwater, providing the pH of the filter remained above 8.2. The buffering capacity of slag at pH 8.8 proved to be an excellent filter; however, slag was discontinued as a filter envelope by 1965 because of rapid disintegration from the action of hydrogen sulfide.

Iron sludge has been found on ditch bank seepage zones and as thin iron films on ditch water. The film, which resembles oil to the naked eye, is being used as a diagnostic aid to pinpoint iron deposits in ditch banks.

The presence of ferrous iron in the groundwater is common in the wetland areas of Florida. It is also present in muck soils in the northern United States and Canada, in California and many areas of Europe. Amounts are dependent on soil pH, clay, presence of reduced layers, thickness of spodic horizons, amounts of organic matter in the profile and deposits of iron polysulfides (pyrites). The red sludges usually contain a preponderance of iron bacteria of the genera of *Leptothrix* and *Gallionella*, which can easily be identified by placing glass slides at the outlets of the drains. The organisms will stick and grow on the glass and continue to deposit precipitated iron. An extensive review of bacterially precipitated iron reactions has been reported elsewhere (20,21). These experiments, including observations in Florida (12,13), indicate that about 80% of the iron precipitation commonly called "ochre" is associated with primary and secondary reactions of bacteria. True chemical precipitation accounts for only about 20% of the reactions.

One experiment to illustrate the role of iron bacteria in the formation of ochre was illustrated from research in

Florida (12). Calcium hypochlorite was added to 3 drains in amounts sufficient to exceed 0.3 ppm free hypochlorous acid in the drain outflow water after the line was first flushed to remove most of the residual ochre. Calcium hypochlorite dripped slowly into the shallow end of the drains over a period of 1 month. Ochre in the drain water was eliminated even though more than 1.0 ppm ferrous iron was present in the outflow. No iron bacteria grew on slides mounted in the drains during chlorine treatment. Ochre accumulated in drain outlets and *Leptothrix* bacteria grew on detector slides within 3 weeks after chlorination was stopped.

Iron bacteria can also develop in the gravel envelope surrounding the drains if the environment is suitable. Special traps constructed from glass and mounted in holders installed abutting drain envelopes trapped some iron bacteria (14).

Iron bacteria have a wide range of pH tolerance and have been found from 4.5 to 8.5. No iron bacteria of the genus *Leptothrix* or *Gallionella* were found in a pH range of 4.0 to 4.5 even though iron was present in the groundwater (14). These lines showed little if any significant reduction in drain outflow. However, several drains were found with ochre present at a pH of 4.2 when a survey was conducted of many drains throughout the wetland areas. The organism in the ochre of one site was found to be *Metal–logenium,* an iron bacterium that is acid-resistant. There is an iron bacterium called *Ferrobacillus* that can oxidize iron and sulfur when the pH is below 3.5. This situation usually occurs in coastal areas where pyrites (iron sulfites) have accumulated in submerged sites. *Ferrobacillus* attacks the pyrites when these areas are drained and produces iron sludge and sulfuric acid. The sulfuric acid causes a reduction in pH so that the soil may be unsuitable for agriculture. It is a situation called "kattezand", "cat clay" or acid sulfate soils.

A survey made in 1966 indicated that groundwater under Florida citrus groves contained varying amounts of hydrogen sulfide (11). The hydrogen sulfide also reacted with iron to produce iron sulfide which was found to be a factor in reducing soil permeability in the vicinity of drain envelopes. The iron sulfide sorbed readily on the surface of fine particles of organic matter that were trapped near filter envelopes.

Sulfur slime is a bacterial product that occurs when hydrogen sulfide is oxidized by bacteria in tile, ditches and well outflow water. It can be readily distinguished from elemental sulfur by the presence of long filamentous white strands. No evidence has been reported that sulfur slime presents a serious problem in drainage, but its presence in drainage water is an indication of an anaerobic condition. Recent research involving sulfur slime blockage in drip irrigation systems suggests that sulfur slime might increase entry resistance to drains under suitable conditions (13). Iron sludge cannot exist in anaerobic water, hence sulfur slime is found most frequently in alkaline soils where sulfides are present in more profuse amounts. Iron has been found precipitated by marl and shell in the subsoil.

Situations That Affect Soil Permeability Associated With Drainage

Accumulations of iron sulfide and iron hydroxide lower hydraulic conductivity of filter materials abutting soils and ditch banks, thus complicating the problem of designing adequate subsurface drainage systems. Microscopic examination samples of black deposits abutting drain envelopes indicate that minute particles of humus can be transported through the white sandy subsoil. Some particles become trapped in and between crevices of sand grains. The particles gradually increase in size with accumulations of black greasy iron sulfide resulting in reductions in hydraulic conductivity up to 96% (11). Submerging tile lines underwater has been suggested as a method of removing hydrated iron from inside the drains. Drains underwater in Florida for 7 years contained deposits of iron sulfide on the periphery of sawdust filters and in top soil used to "blind" tile during installation. Iron sulfide in areas abutting the drains drastically reduced permeability although there was no iron sludge in the pipes (9).

A greasy iron sulfide layer that impeded the movement of water was also observed under water furrows in east coast Florida groves. The layer was found to be iron sulfide (18).

One of the serious problems in attempting to develop citrus on old pond sites involves the permeability of ditch banks. The organic debris accumulated during leveling operations has served as a trap for iron sulfide. Hydraulic conductivity measurements of soil from an impermeable ditch bank have shown practically no water movement. Usually a strong odor of hydrogen sulfide emanates from the disturbed soil in the muck pond area when cores were taken for permeability studies.

The organic fraction of soil was found to be the principal medium for sorbing iron sulfide in sandy soils. A simple test was devised to illustrate the sorption properties of organic matter compared to clay. Cores of fine sand topsoil containing approximately 2% organic matter sorbed all of the iron sulfide from 24.5 liters of a 5-ppm solution. In contrast, Fuller's earth in red sandy clay subsoil samples from a citrus grove sorbed only 50 ml of solution. Sawdust sorbed more iron sulfide than clay, but to a considerably less extent that the soil cores containing 2% humus. The mechanism of sorption has not been established.

Reductions in hydraulic conductivity resulting from accumulations of iron sulfide and ochre have modified recommendations for draining flatwoods land used for planting citrus in Florida: Filled-in muck ponds are not recommended for planting. Drains are not being installed directly in organic pan layers. Topsoil is no longer recommended for backfill to "blind" tiles. Filters that can disintegrate or plug or react with anaerobic microbial products are no longer recommended.

Sludge Removal From Drains

The author has found that sludge formation in drains in Florida usually occurs within the first month after installing the drains. Sludges continue to be a problem as long as ferrous iron can flow into the drains from the subsoil. Control is difficult because of the many facets of the sludge problem contributing to a reduction in drainage efficiency. The syndrome of interacting factors are associated with bacteria, organic matter, iron, hydrogen sulfide, pH and temperature. Observations in a recent experiment designed to evaluate the rate of sludge formation under conditions where the field received 15 cm of intermittent irrigation per week showed that extensive amounts of sludge sorbed on organic particles can be deposited in drains within a week after installation. Removing the sludge during the first 10 days after installation and again 6 weeks later minimized reductions in drainage efficiency. Drainage outflow was temporarily 32 to 66% greater in clean lines under the same hydraulic head (12). The most promising procedure for cleaning the inside of plastic drains and envelopes under Florida conditions is a self-propelled low pressure water jet utilizing 7 atmospheres pressure at the nozzle and high volumes of water (15). The soil should be under a hydraulic head when attempting to clean the envelope. High pressure self-propelled jet type nozzles utilizing 40 atmospheres pressure have been used for flushing ochre deposits in Europe and the Imperial Valley in California. Studies in Florida involving high pressure jetting showed that the gravel envelope was disrupted and fine sand flowed into plastic drains.

Sulfur dioxide has been used in California (19) to dissolve iron deposits from drain lines. Attempts to dissolve iron sludge in drains in Florida have not been successful with sulfur dioxide using the methods commonly practiced in California. The solution flowed out of the drains during the holding period and it did not dissolve the organic matrix which holds the sludge together. Jetting was necessary to remove this material from the drain.

A key factor in minimizing the issue is the method and care used in drain installation for Florida or wherever sludges are a problem. No organic matter or disturbed soil should abut the envelope in sandy soils. Movement of organic matter in the backfill trench area (assuming no clay layers) may be impeded with a plastic sheet extending the width of the trench.

LITERATURE CITED

1. Beville, B. C. 1972. Theory and design of subsurface drains. *In*: Use and interpretations of soil surveys and engineering principles of water management, U. S. Dept. Agr. Soil Conc. Service, Gainesville, Fla.
2. Bryan, O. C. 1962. The response of young trees to lime mixed with the soil profile on Leon-Immokalee fine sands. *Citrus Ind. Mag.* 43(9):9-10.
3. Culbert, D. L. and H. W. Ford. 1972. The use of a multi-celled apparatus for anaerobic studies of flooded root systems. *HortScience* 7(1):29-31.
4. Ford, H. W. 1954. Root distribution in relation to the water table. *Proc. Fla. State Hort. Soc.* 67:30-33.
5. ____________. 1963. Thickness of a subsoil organic layer in relation to tree size and root distribution of citrus. *Proc. Amer. Soc. Hort. Sci.* 82:177-179.
6. ____________. 1964. The effect of rootstock, soil type and soil pH on citrus root growth in soils subject to flooding. *Proc. Fla. State Hort. Soc.* 77:42-45.
7. ____________. 1965. Bacterial metabolites that affect citrus root survival in soils subject to flooding. *Proc. Amer. Soc. Hort. Sci.* 86:205-212.
8. ____________. 1965. Growth of citrus on drained flatwoods land. Fla. Agr. Expt. Sta. Annu. Rept. (Proj. 920) p. 229.
9. ____________. 1967. Relationship between excessive soil moisture and citrus root damage. Fla. Agr. Expt. Sta. Annu. Rept.
10. ____________. 1968. Fluctuations of the water table in drained flatwoods groves. *Proc. Fla. State Hort. Soc.* 81:75-79.

____________. 1969. Water management of wetland citrus in Florida. *Proc. 1st Intl. Citrus Symp.* 3:1759-1770.

12. ____________. 1973. Obstacles to water control in Florida citrus groves. *Congreso Mundial de Citricultura,* Murcia, Spain. Vol. I., p. 247-251.
13. ____________. 1974. Blockage of drip irrigation filters and emitters by iron-sulfur-bacterial products. *HortScience* 10:62-64.
14. ____________. 1974. Biochemical factors contributing to reductions in drain outflow in a modified spodosol. *Proc. Soil Crop Sci. Soc. Fla.* (In press).
15. ____________. 1974. Low pressure jet cleaning of plastic drains in sandy soil. Trans. *ASAE* 17:895-897.
16. ____________ and C. F. Eno. 1962. Distribution of microorganisms, citrus feeder roots, nitrate production and nutrients in the profile of Leon, Scran-

ton, Immokalee and Blanton fine sands. *Proc. Fla. State Hort Soc.* 75:49-52.

17. ______________. W. F. Spencer. 1962. Combatting iron oxide deposits in drain lines. *Proc. Fla. State Hort. Soc.* 75:27-32.

18. ______________ and D. V. Calvert. 1966. Induced anaerobiosis caused by flood irrigation with water containing sulfides. *Proc. Fla. State Hort. Soc.* 79:106-109.

19. Grass, L. B. and A. J. Mackenzie. 1970. Reclamation of tile drains with sulfur dioxide treatment. *Sulfur Inst. J.* 6(1):8-13.

20. Hanert, H. 1974. In situ-untersuchungen zur analyse und intensitate der eisen (III)-Fallung in dranungen. *Kulturtechnik und Flurbereinigung* 15:80-90.

21. Khrutskaya, A. T. 1971. Cloggifig of drains with ferrous iron. Pub. House "Kolos" Moscow, K-31 Dsenzhrsk Stv. No 1/19. (Translated from Russian).

22. Prevatt, R. W. 1959. Tolerances in certain citrus seedlings to free water in soil. Ph.D. thesis, Univ. of Fla.

23. Reitz, H. J. and W. T. Long. 1955. Water table fluctuations and depth of rooting of citrus trees in the Indian River area. *Proc. Fla. State Hort. Soc.* 68:24-29.

24. Rovira, A. D. 1965. Plant root exudates and their influence upon microorganisms. *In*: Ecology of soil borne plant pathogens, Baker *et al.*, ed. Univ. of Calif. Press, Berkeley. p. 170-184.

25. Rowe, R. N. and D. V. Beardsell. 1973. Waterlogging of fruit trees. *Hort. Abst.* 43:534-544.

26. Russell, M. B. 1952. Soil aeration and plant growth. *In*: Soil physical conditions and plant growth, B. T. Shaw, ed. Academic Press, Inc. New York. p. 253 301.

27. Spencer, W. F., R. Patrick and H. W. Ford. 1963. The occurrence of iron oxide deposits in tile drains. *Soil Sci. Soc. Amer. Proc.* 27:134-137.

28. Stewart, E. H., D. V. Calvert and J. S. Rogers. 1975. Water management for citrus on spodosols in Florida. *Amer. Soc. Civil Eng.* (In press).

29. Stolzy, L. H. 1971. Soil atmosphere. *In*: The plant root and its environment, E. W. Carson, ed. Univ. Press of Virginia, Charlottesville. p. 335-363.

30. Van't Woudt, B. D. and R. M. Hagan. 1957. Crop responses at excessively high soil moisture levels. *In*: Drainage of agricultural lands, J. N. Luthin, ed. *Agronomy* 7:514-578.

QUESTIONS

Q: If you have an organic hardpan, can you simply drill holes through it and alleviate the problems of poor drainage caused by the pan?

Ford: This question has come up many times over the years. Whenever we have tried this, we generally encountered another problem. When the pan gets wet, it becomes gelatinous and tends to seal off again as far as drainage is concerned. Too, the water pressure underneath the pan will force water up through the drilled holes. However, if you can be sure that the soil is drained beneath the pan, then drilled holes should permit drainage from above. That's the reason for putting drain lines below the pan.

Q: Will liming alleviate the sludge problems associated with tile drains?

Ford: As far as hydrogen sulfide is concerned, you can delay the toxicity to the roots by higher pH. This is one reason why you don't get as much damage as quickly to trees on the East Coast, where the pH is higher, as you do in Indiantown or Immokalee, on an acid soil. Contrary to chemistry where the dissociated ions are the reactive agents, in this case the hydrogen sulfide molecules cause the trouble, as the molecules can be absorbed by citrus roots. Toxicity apparently results due to dissociation of the hydrogen sulfide molecules after absorption by the root system. At higher pH, you simply have fewer hydrogen sulfide molecules. With liming to raise the pH, you can maintain this situation for a few days, but it's only a temporary effect.