SL-246

UF UNIVERSITY of FLORIDA
IFAS Extension

Improving Citrus Nitrogen Uptake Efficiency: Linking Citrus Irrigation Management To Citrus Fertilizer Practices [1]

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This document is one in a series of three EDIS publications dealing with citrus nutrition and its relationship to both fertilizer management and irrigation scheduling. The objectives of this document are:

1. To match irrigation management with nitrogen fertilization practices;

2. To explain the components of an effective irrigation system for citrus that provides for high water uptake and fertilizer-uptake efficiency; and

3. To describe nutrient management planning and the possible role that precision agricultural techniques might play in both irrigation and fertilizer management for citrus production in Florida.

The target audience for this series dealing with citrus nutrition includes Certified Crop Advisers, citrus producers, irrigation designers, fertilizer dealers, and other parties interested in citrus fertilization practices.

Production Areas and Constraints

Ridge

The Florida ridge lies in a generally north and south direction through the center of the peninsula, and is characterized by deep, well drained soils comprised mostly of sand (Figure 1). These soils permit rapid infiltration of rain and irrigation water, setting the scene for nutrient movement out of the citrus root zone (Figure 2). When nutrients are leached beyond the rootzone, the nutrients are no longer available to the plant, and may become an environmental pollution concern. Nitrate leaching is a major concern for citrus producers on ridge soils. In a survey of water wells in the Ridge citrus producing areas (McPherson et al., 2000), 63% of the wells had detectable levels of nitrate-nitrogen in the water, and 15% of the tested wells had concentrations greater than the regulatory maximum of 10 mg nitrate-nitrogen per liter (10 ppm).

1. This document is Fact Sheet SL-246, one of a series of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Publication date: February 2007. Please visit the EDIS Web site at http://edis.ifas.ufl.edu.
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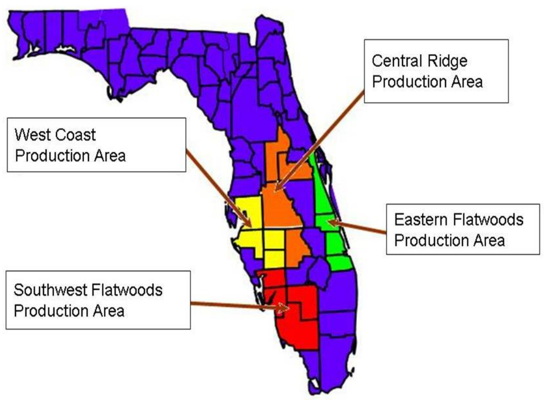

Figure 1. Florida citrus production areas by county.

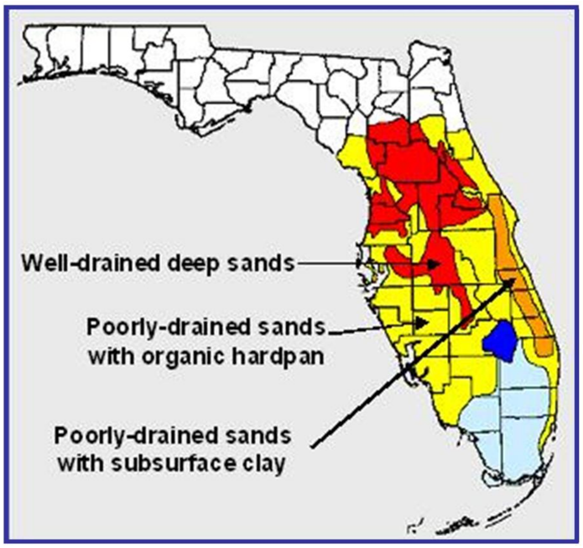

Figure 2. Soils in citrus production areas of Florida (Obreza et al., 2006).

West Coast

The West Coast citrus production area (Figure 1) is described as a transitional area from the deep well drained soils found on the Ridge to the poorly drained soils found in the Flatwoods near the coasts. As with the Ridge, these soils have low water and nutrient holding capacities because they are composed mostly of sands (Figure 2).

Flatwoods

The Gulf Coast and Indian River citrus production areas are dominated by so-called Flatwoods soils (Figure 1). Soils in the Flatwoods are characterized by poorly drained conditions requiring some form of drainage to develop a deep enough root zone to permit high quality citrus production (Figure 2). Many groves use beds to provide additional drainage, as well as drainage ditches and canals. Nitrate leaching in Flatwoods soils is greatly reduced compared to the well-drained soils found on the Ridge. Due to confining soil horizons and/or a perched water table, nitrates are reduced through a process called denitrification, the reduction of nitrate by microbial activity to N gases that disperse in the atmosphere. Nitrate concentrations are also reduced through lateral flow of water through the soil often entering surficial water bodies, rather than transporting the nitrates to the groundwater or surficial aquifers where the nitrates would be measured by well water testing. In Flatwoods soils, citrus growers must face the constraints of possible runoff and/or the accumulation of nutrients within drainage water or weeds in the grove.

Water Supply

In all citrus production areas, the competition for water supply is increasing. Residential and commercial users demand more water from utilities, which, in turn, reduces the availability of water for agricultural and environmental uses. As Florida's population continues to grow, water available for agricultural purposes will continue to decrease or become more expensive. The growing of commercially acceptable crops, including citrus, is a water intensive activity; however, growers do have options. By increasing water uptake efficiency, a measure of the amount of water used by the plant compared to the amount of water added to the grove, growers can still produce high quality citrus while reducing their demand on the water supply. Reducing water consumption in commercial groves reduces the risk of insufficient water availability in the future.

Water Uptake Efficiency

Water Uptake Efficiency is defined as:

$$\text{Water Uptake Efficiency (\%)} = \frac{\text{Tree Water Uptake}}{\text{Irrigation Amount}} \times 100$$

While the calculation is simple, measurements needed to evaluate this equation are quite complex. Rather, growers should focus on the idea of improving water uptake efficiency through management techniques described in this document without actually trying to go to the time and expense of measuring efficiency of their water use.

Irrigation Scheduling

As seen in the production constraints described above, most of Florida's citrus producing soils have low water and nutrient holding capacities. Therefore, appropriate irrigation scheduling is critical for proper citrus tree health as well as for minimizing water requirement. Healthy citrus trees are better able to withstand pest and disease pressures, as well as produce a high quality commercial product. Irrigation management should be geared toward maintaining optimal moisture and nutrient concentrations within the tree root zone. If that goal is achieved, trees will take up their maximum amounts of water and nutrients with minimum wastage. Equally important, as can be seen, excessive irrigation will reduce water uptake efficiency, as well as require more water and contribute to potentially negative environmental impacts.

Nutrient Uptake Efficiency

Nutrients, especially nitrogen, move with water as the water passes through the soil (leaching) due to drainage, either downward to groundwater or laterally toward ditches and canals. Therefore, maximizing water uptake efficiency will also improve **nutrient uptake efficiency**. Nutrient uptake efficiency refers to the effectiveness of adding nutrients that are actually taken up by the plant, and not lost to leaching or other environmentally sensitive pathways.

Nutrient Uptake Efficiency is defined as:

$$\text{Nutrient Uptake Efficiency (\%)} = \frac{\text{Nutrient Taken Up by the Plant}}{\text{Nutrient Added in Fertilizer}} \times 100$$

The important point here is that Nutrient Uptake Efficiency and Water Uptake Efficiency are intrinsically linked. Management measures that improve one will likely improve the other.

Many different experiments have shown that citrus yield and quality do not increase meaningfully at nitrogen fertilization rates that are greater than **200 to 240 pounds nitrogen per acre** (for example, Alva and Paramasivam, 1998). Rates lower than 200 pounds N per acre can produce maximum yields if uptake efficiency is high. Other experiments with citrus fertilization have shown advantage in making **split fertilizer applications** throughout the season to reduce exposure of the soluble fertilizer to leaching from rainfall or excessive irrigation. Fertigation, (liquid fertilizer applied though the irrigation system) can effectively deliver split applications. Another common sense management technique is to avoid soluble fertilizer applications during Florida's rainy season, especially those sources containing nitrogen. Recent discussions concerning citrus fertilization best management practices may hold promise for cost sharing of controlled-release fertilizer applications (Obreza et al., 2006). Controlled-release fertilizers have been demonstrated to decrease the number of applications per year needed for appropriate citrus fertilization. In some instances, particularly for young trees, controlled-release fertilizers have higher nutrient uptake efficiencies compared with traditional soluble fertilizers. The UF/IFAS recommendations for soluble fertilizers include a maximum annual application rate, recommendations to use split fertilizer applications during the year, and avoiding applications during the wet season. Current UF/IFAS recommendations for the number of split applications of soluble fertilizers per year are 4 to 6 for young trees and at least 3 for mature trees. A minimum of 10 applications is recommended for fertigation. These recommendations are based upon the research findings described above.

Management Goals and Tools

Maintain adequate water and soil nutrient levels to maximize plant growth and health.

> There are a number of instruments available to help manage water within grove operations. Almost all of these instruments will do a better job of assisting with water management decisions than looking at the water level in field ditches or irrigating on the same day of the week. A number of extension documents are available through the UF/IFAS EDIS

system (http://edis.ifas.ufl.edu/) describing a number of approaches to proper water management. As noted above, appropriate water management directly affects soil nutrient levels. By improving water management techniques and decision-making, growers are also improving their nutrient management.

Decrease production cost and resource depletion

By optimizing water and nutrient uses within the grove, growers will automatically decrease their production cost, as well as decrease their demand on limited water resources. Implementing measures to achieve this goal directly facilitates sustainable citrus production in Florida.

Reduce nutrient losses and environmental impacts

By focusing on improving both water and nutrient uptake efficiencies, growers will also be potentially reducing nutrient losses along with negative environmental impacts. Some nutrient loss due to seasonally frequent rains is unavoidable but loss due to poor management decisions can be minimized. Said another way, growers who focus on minimizing nutrient losses will also be facilitating maximum uptake by controlling fertilizer and water use, and improving water and nutrient uptake efficiencies within their grove operations.

Management Method Options

Irrigation Scheduling and Nutrient Management Plans

Addressing the **irrigation scheduling** issue through the use of instrumentation and/or a water budgeting approach ensures that water uptake efficiency is being addressed. Proper irrigation scheduling will have a positive effect on nutrient uptake efficiency. Irrigation scheduling through the use of soil water content sensors is the best method to accurately promote water use and provide the optimal amount of water to citrus trees. Many instruments are available for growers to use in irrigation scheduling. These instruments range from tensiometers to neutron probes and are described in Bulletin 343 (Munoz-Carpena, 2004)

The second method of irrigation scheduling is the use of estimates from computer programs. Some programs can be used to estimate both evaporation from the soil and transpiration through the tree. These predictions are based upon local weather data. This estimated water use is called evapotranspiration or ET and can be found for various locations across Florida by visiting the Florida Automated Weather Network site at http://fawn.ifas.ufl.edu. Use of water budgets for irrigation schedules is explained in SS459 (Morgan and Hanlon, 2006).

Nutrient management plans should be developed annually, and should include soil and plant-tissue test results. It is advisable to maintain these records to build a history of nutrient management within the grove. Realistic **production yield goals** should be based upon past production or potential production for younger trees. Coupling the soil and plant-tissue test results and related fertilizer recommendations with production yield goals and tree growth information (Morgan and Hanlon, 2006), grove managers can create nutrient budgets for nitrogen, phosphorus, and potassium fertilization. Information such as fertilization rate, application methods including the number of split applications, fertilizer sources, and dates of application should be recorded. This information coupled with subsequent yield information at the end of the season completes the annual plan. Using information collected from the previous years to refine the plan for the coming year means that managers are working systematically toward the goals expressed in this document.

The next steps for improving management decision-making processes and citrus production areas will likely be the adoption of **precision agricultural methods**. A part of the precision agricultural concept includes modifying existing irrigation systems, variable-rate fertilizer application, and an integrated **decision-support system.** Such methods can customize water and fertilizer applications for specific site variations in soils or tree size within a grove.

Precision Agriculture

The components of a precision agricultural system must be by definition an information gathering and interpretation support system. Information collected from the grove should include soil and leaf nutrient concentrations, tree size (canopy volume), yields, and soil moisture availability. To be most effective, this information must be interpreted spatially. That is, information collected from the grove should be available to the decision maker through displays such as maps or computer graphics, showing where one or more of these measurements are placing constraints on realizing the goals established above. For example, soil moisture sensors may be indicating a dry region within the grove. Coupling this information with the soil survey map of the grove, this dry region may be a function of soil type.

In turn, this information can be used to design an effective irrigation management strategy; perhaps including this drier region in its own irrigation zone, if large enough to do so. If not, perhaps larger water emitters could be used in such a dry zone. This drier area could then be irrigated to appropriate soil moisture readings without over-irrigating the rest of the block or grove. In this example, the decision to create an irrigation zone addressing the dry area may save considerable irrigation pumping charges, and improve both the water and nutrient uptake efficiencies within the entire grove.

In another example, mapping of tree locations with related yields may identify considerable variation in production levels. In this case, another precision agricultural technique, variable-rate fertilizer applications, may prove beneficial. In research in citrus blocks that have different sized trees, variable-rate fertilizer applications can reduce fertilizer use by 20 to 40% relative to uniformly applied fertilizer (Schumann et al., 2006). Thus, such practices can pay for themselves very rapidly and reduce nutrient losses.

Decision-support systems are comprised of software programs that assist the manager with decisions concerning water and nutrient management as well as other grove operations. To use these systems, information on tree size and performance, are added to soil information to predict the need for irrigation and fertilizer applications in a site-specific manner. That is, schedules can be determined to improve both water and nutrient uptake efficiencies.

Summary

Links between water uptake efficiency and nutrient uptake efficiency were discussed in light of selected management goals. By pursuing these goals, grove managers will promote healthy trees that produce commercially viable and high quality citrus products. At the same time, demands for scarce resources will be minimized and negative impacts on the environment will be reduced. Using both water and nutrients efficiently within grove operations can potentially decrease the costs of production. In turn, managers are contributing to the sustainability of the citrus industry within Florida.

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