Keeping Water and Nutrients in the Citrus Tree Root Zone

(Focusing on Nitrogen and Phosphorus)

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1. Typical nutrient management practices used in Florida citrus production

a. *Fertilizer sources.*

Water soluble fertilizers are typically bulk-blended into $N\text{-}K_2O$ or complete $N\text{-}P_2O_5\text{-}K_2O$ fertilizers, often including micronutrients, for spreading in citrus groves. They are rapidly available for tree uptake. Solid fertilizers are applied with conventional spreading equipment and are sometimes applied by hand to young trees.

The most common solid water soluble N sources applied to citrus are ammonium nitrate and ammonium sulfate. Urea is often included in combination with ammonium nitrate to make fluid fertilizers that are applied with irrigation water (fertigation). Other less-common N sources include potassium nitrate and calcium nitrate.

Phosphorus fertilizer is applied to citrus at much lower rates compared with N, and in many cases is not applied at all if soil testing shows sufficient residual P. When P fertilizer is applied, the solid water-soluble forms used are concentrated superphosphate, mono-ammonium phosphate, and di-ammonium phosphate. Fluid forms of P include ammonium polyphosphate and phosphoric acid.

Slow-release sources are materials of limited water solubility that release plant-available nutrients as they decompose or degrade in the soil following application. Almost all slow-release fertilizers are N sources. Slow-release fertilizers applied to citrus include urea-formaldehyde (ureaform, methylene urea), isobutylidene diurea (IBDU), and organiform.

Controlled-release fertilizers are made by surrounding water-soluble fertilizer with a coating made of polymers, plastic, wax, or sulfur. The standard or "reference" release rate of a particular fertilizer is controlled by varying the coating thickness or physical characteristics during manufacture, but nutrient release is also typically influenced by soil temperature or water content.

Natural organic fertilizers include materials like animal manures, meals, and non-hazardous municipal wastes and composts. Nutrient release from these materials occurs during biological degradation. The speed at which nutrients become available varies widely depending on composition, age, application method, and climatic conditions.

b. *Fertilizer rates and timing.* Annual recommended N fertilizer rates applied to citrus depend on tree age and fruit type (Table 1), while recommended P fertilizer rates depend on soil and leaf tissue test results (Table 2). See UF-IFAS publication SL-253, "Nutrition of Florida Citrus Trees, 2nd Edition, for details.

A basic dry fertilizer application timing schedule for citrus divides the total annual requirement into three equal increments applied in March, May, and September. Applying fertilizer during the summer rainy season is typically avoided. A basic fertigation schedule divides the annual fertilizer rate into 10 to 20 doses per year.

Table 1. Summary of recommended N fertilizer rates for application to citrus based on tree age.

Tree age	Fruit type	Annual N fertilizer rate ranges
1 through 3 years	All	0.15 to 0.90 lbs N/tree
4 through 7 years	Oranges	120 – 200 lbs/acre
	Grapefruit	120 – 160 lbs/acre
8 years and older	Oranges	140 – 250 lbs/acre, yield-based
	Grapefruit	120 – 160 lbs/acre
	Orlando Tangelos	140 – 250 lbs/acre
	Honey Tangerines	140 – 300 lbs/acre

Table 2. Summary of recommended P fertilizer rates for application to citrus based on leaf and soil test analysis results.

If leaf tissue P is...	...and soil test P is...	...the recommendation for P fertilization is:
Excessive or High	Soil test P value is not applicable	Do not apply P fertilizer to the soil for 12 months following leaf and soil sampling, then sample again and re-evaluate.
Optimum	Sufficient	
Optimum	Less than sufficient	Apply 8 lbs P_2O_5/acre to the soil for every 100 boxes/acre of fruit produced during the current year. Sample leaves and soil again in 12 months and re-evaluate.
Low	Less than sufficient	Apply 12 lbs P_2O_5/acre to the soil for every 100 boxes/acre of fruit produced during the current year. Sample leaves and soil again in 12 months and re-evaluate.
Deficient	Less than sufficient	Apply 16 lbs P_2O_5/acre to the soil for every 100 boxes/acre of fruit produced during the current year. Sample leaves and soil again in 12 months and re-evaluate.

c. *Fertilizer application methods and placement.*

Solid fertilizer spreaders apply dry materials directly over the root zone, avoiding the row middle. For small trees, manual or electronic spreader adaptations can be made that deliver fertilizer rates accurately to the root zone while leaving out the non-rooted area between trees. It is essential that spreaders be calibrated to apply the exact amount of fertilizer per acre.

Fertigation with microsprinklers or drippers places nutrients in the wetted area where the most active roots are located. Fertilizer may be applied more frequently in small amounts. Doing so can increase fertilizer use efficiency and reduce leaching. Application cost is lower than that of dry or foliar fertilizer application since fertilization is incorporated into the normal irrigation schedule. To effectively fertigate citrus trees, the microirrigation system must be properly maintained such that water and fertilizer are applied uniformly.

Suspension fertilizers are applied with a standard herbicide boom that places the fertilizer directly over the root zone.

Foliar fertilizers are applied to citrus trees with a conventional grove airblast sprayer, typically in 100 to 250 gal of water per acre. The goal of airblast spraying is to replace the air contained within the tree canopy with spray-laden air. Foliar application is not intended to replace soil-applied fertilizers, but it can provide N and P to the tree on a timely basis during critical stages of growth, flowering, and fruit development.

d. *Variable rate fertilization* solves the problem of fertilizer waste that occurs when nutrients are uniformly-applied to a grove with varying tree sizes. With variable rate fertilization, dry fertilizer is accurately placed in independent left and right bands under the trees. Variable rate fertilization is most effective in groves with high spatial variability because the technology is designed to exploit variability. A grove containing a mixture of mature trees, young trees, and/or resets benefits the most from using this technology to apply fertilizers.

e. *Citrus response to N fertilization application* is strong because N has more influence on tree growth, appearance, fruit production, and fruit quality than any other nutrient. When N is in short supply, growth and yield are limited and the foliage becomes pale green or yellow. The typical yield response curve to N (Fig. 1) shows that a rather large decrease in N supply is required before yield is greatly decreased.

In contrast to N, a positive tree response to P fertilizer is rarely observed. Most mature Florida citrus groves contain sufficient residual P that accumulated from previous fertilizer applications, so regular P fertilizer application is usually not necessary.

2. Typical water management practices used in Florida citrus production

a. *Type of irrigation.* Most Florida citrus groves are irrigated by micro-sprinkler systems that apply water efficiently and precisely. A small minority of groves are irrigated by drip systems or seepage irrigation (water table control on flatwoods soils only).

b. *Irrigation volume.* The annual irrigation requirement for citrus is about 15 to 17 inches depending on rainfall amount and distribution. These values do not consider irrigation system efficiency. Annual citrus potential evapotranspiration is around 45 inches.

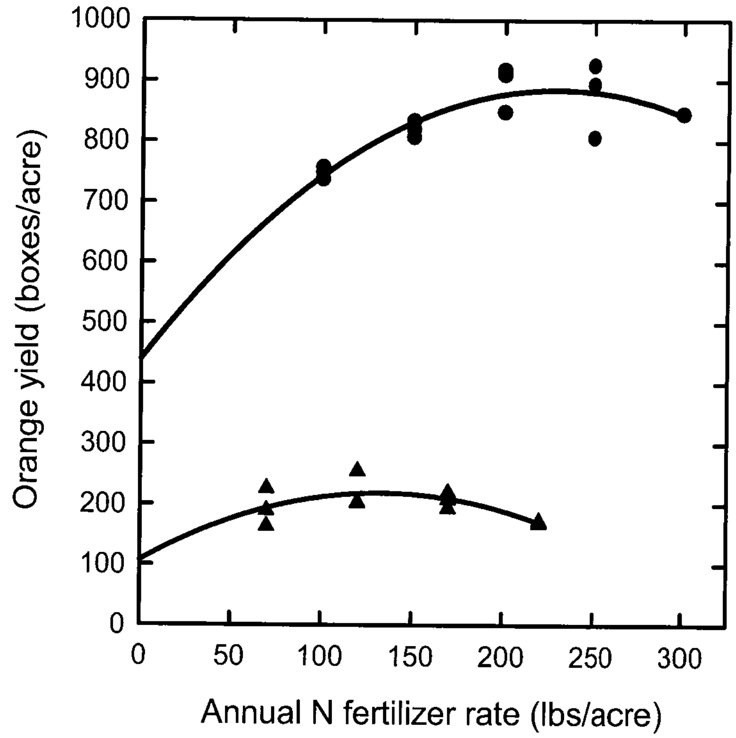

Fig. 1. Orange fruit yield response to N fertilizer in low-producing and high-producing groves.

c. *Irrigation scheduling.* Proper irrigation scheduling applies an appropriate volume of water to a citrus grove at the appropriate time based on tree need, soil properties and weather conditions. Scheduling methods include experience, the calendar method (e.g. 0.8 inches every 4th day during the dry season), monitoring soil water status, and calculating a water budget.

   Measuring soil moisture change with modern sensing equipment is probably the most accurate irrigation scheduling method. These devices may be fixed in one location, portable, or hand-held. They measure soil moisture at one depth or at multiple depths. General categories include tensiometers, electrical resistance blocks, time domain reflectometry (TDR) probes, and capacitance probes.

d. *Drainage management.* Central ridge groves are naturally well-drained, but flatwoods groves must be artificially drained to lower the shallow water table following heavy rain. There are two drainage management philosophies – uncontrolled and controlled. With uncontrolled drainage, water flow control points in the drainage network are opened as wide as possible to drain the grove quickly. With controlled drainage, flow points are opened only partially, which allows the grove to drain more slowly. This philosophy keeps a base water table closer to the citrus root zone for a longer period of time and may delay the onset of irrigation. The potential for nutrient loss is considerably lower with controlled drainage.

3. Nutrient budgets

a. *Quantity of nutrients removed by the fruit crop.* In the Florida citrus production system, the major component of the annual nutrient removal from the tree-soil system is that in the harvested fruits (Table 3). Nitrogen and potassium are removed in much greater quantities compared with other nutrients.

Table 3. Average total amounts of various nutrients in 100 boxes of orange fruits (1 box = 90 lbs).

N	P	K	Ca	Mg	S	Fe	B	Zn	Mn	Cu
------------------------------------ lbs nutrient/100 boxes of fruit ------------------------------------										
12.1	1.7	14.5	4.4	1.2	1.0	0.036	0.023	0.027	0.017	0.006

b. *Nitrogen budgets* for mature, high-producing Florida citrus groves have been estimated using the "checkbook" method (comparing inputs vs. outputs) and simulated using the LEACHM model (Tables 4 and 5). The production system described in Table 4 was evaluated for an entire year. Nitrogen fertilizer application constituted about 70% of the total N input. Tree N uptake was also equal to about 70% of total N input. About 63% of tree N uptake was allocated to fruit production. The amount of N lost from the system was around 55 lbs N/acre/year, or about 16% of the total N input.

Table 4. Citrus N budget estimation and simulation by the LEACHM model for a 20+ year-old, very high-producing orange grove on deep sandy soil with optimum irrigation.

	N budget	Simulation
	---------- lbs N/acre/year ----------	
Input		
Fertilizer N applied	250	250
Mineralization	80	70
Atmospheric deposition	10	-----
Non-symbiotic N fixation	5	-----
Initial soil profile N	18	22
Total	363	342
Plant uptake		
Total N in fruits (1140 boxes/acre)	160	LEACHM does not partition N by tree component
Spring growth	30	
Fibrous roots	40	
Storage	25	
Total	255	251
Estimated losses/residual soil N		
Gaseous loss	38	21
Drainage (leaching) below the root zone	-----	**53**
Soil residual N	13	17
Total	51	91
Unaccounted N (likely to be leached)	**57**	

Table 5. Nitrogen balance at the end of a 6-week period for a single application of soluble N fertilizer as simulated by LEACHM.

N inputs		N outputs					
From N fertilizer application	From organic matter	Plant uptake	Leaching	Volatili-zation	To microbial biomass	Soil storage	% of N fertilizer that leached
---------- lbs/acre ----------							
25	13	18	13	9	2	-4	36
50	13	29	13	13	2	6	21
75	13	35	25	17	2	9	29
100	13	46	27	26	2	12	24

c. *Nitrogen cycling in a citrus grove.*

Nitrogen mass and distribution throughout an orange tree has been measured for trees of varying size. The mature fruit crop contains about one-fourth of the total N in a large tree, while the leaf canopy contains slightly more (Table 6). The remaining N is distributed between the wood and roots.

As a small orange tree grows into a large tree, the proportion of total N in the branches increases, while the proportions in the leaf canopy and trunk decrease (Fig. 2).

* P - index → P in runoff

Table 6. Example of the biomass and nitrogen distribution in a mature orange tree.

Total tree dry wt. = 273 lbs **Total N in tree = 2.3 lbs (includes 4.8 box/tree mature fruit crop; 1 box = 90 lbs)**		
	% of total tree dry biomass	**% of total N in tree**
Leaves	10	28
Twigs and branches	40	24
Trunk	3	2
Roots	23	20
Fruit	24	26

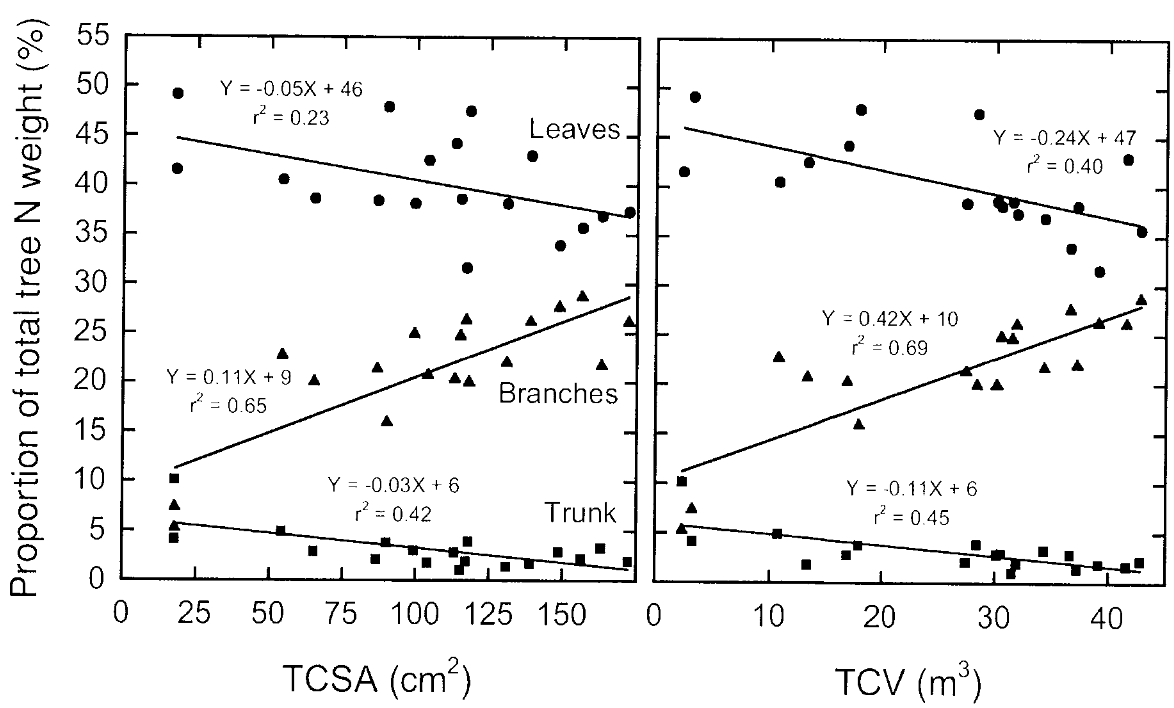

Fig. 2. How citrus tree size as measured by trunk cross-sectional area (TCSA) and tree canopy volume (TCV) affect N weight allocation between leaves, branches, and trunk.

Soil organic matter concentration in a citrus tree root zone typically varies between 0.5 and 1.5%, with lower values in central Florida ridge soils and higher values in flatwoods soils. The stable form of organic matter (humus) contains about 5% N by weight. Mineralization of humus releases around 50 lbs N/acre/year in most citrus groves.

Citrus tree residues (leaves, twigs, fibrous roots) decompose quickly (mostly within 1 to 2 years after deposition) due to Florida's warm and humid climate. The mineralized nutrients return to the soil and become available for plant uptake. In a residue mineralization study, the amount of N released from grove floor residue and dead roots during a 1-year time period varied from 35 to 75 lbs/acre in a young (4-year-old) grove and from 110 to 135 lbs/acre in a mature (20-year-old) grove.

N leaching losses from a mature orange grove were calculated by analyzing soil solution N concentration and estimating the water flux that moved below the root zone for a 2-year period (Table 7). Nitrogen leaching estimates ranged between almost none to around 30 lbs N/acre depending on fertilizer source and rate. Fertilizer source had the greatest effect on N leaching, with the order of fertigation > dry granular > controlled release. The relative amount of N leached as a percentage of N rate applied varied between 1 and 16%. The authors of this study explained that more N leaching occurred with fertigation compared with dry granular application "purely because of unexpected prolonged irrigation or unexpected high rainfall following certain fertigation events in both years."

Table 7. How N source and rate affect estimated NO_3-N leached below the root zone of a mature citrus grove on an Entisol with optimal irrigation scheduling in 1994 and 1995.

N source	N rate	Estimated NO_3-N leached			
		1994	1995	1994	1995
	lbs/acre/year	----- lbs/acre NO_3-N -----		----- % of N applied -----	
Dry granular	100	9	11	9	11
	150	10	12	7	8
	200	13	12	7	6
	250	20	19	8	8
Fertigation	100	15	16	15	16
	150	16	22	11	15
	200	21	27	11	14
	250	26	31	10	12
Controlled-release	50	1	1	2	2
	100	1	3	1	3
	150	3	7	2	5

Nitrogen use efficiency (NUE) is defined as the amount of N fertilizer taken up by citrus trees divided by the amount applied. NUE has been measured for young orange trees using labeled N fertilizer (Table 8). Ammonium nitrate had a substantially higher NUE (40%) compared with urea (28%), probably because N was lost from urea by volatilization before it could be absorbed by the roots. Under the same environmental conditions, ammonium nitrate applied to mature trees would probably have higher NUE higher due to a larger root system.

Table 8. Recovery of labeled N fertilizer by 6-year old orange trees 280 days after it was applied on 15 Feb 1999. The N rate of 0.13 lbs/tree was equivalent to 15 lbs/acre.

Tree component	Nitrogen fertilizer source	
	Ammonium nitrate	**Urea**
	--------------- % of N applied ---------------	
Leaves	9	5
Twigs	5	3
Trunk	1	1
Roots (fibrous + woody + tap)	7	5
Fruit (9-month-old)	18	10
Total	**40**	**24**

d. *Citrus P nutrition and cycling.* Citrus trees take up much less P than N. On an atomic basis, the N:P ratio in a citrus tree is around 20:1. Unlike N, applied P fertilizer can be retained to some extent by most Florida citrus soils. A survey of 122 Florida citrus production blocks planted on poorly-drained Spodosols and Alfisols found that Mehlich 1 soil test P averaged 55 ppm in the top 6 inches of soil. (The "high" range starts at 31 ppm.) In another study, the mean Mehlich 1-extractable P of 118 soil samples from a wide range of Florida citrus groves was 103 ppm.

Since most mature Florida citrus groves contain sufficient residual P from previous fertilizer applications, regular P fertilizer application is not necessary. The need for P fertilizer in established groves is determined by soil and leaf analysis. Most previously non-cultivated soils used for new citrus plantings are naturally low in P, so fertilizer application may be needed for the first few years until P accumulates in the root zone.

e. *Benchmark data describing nutrient leaching and runoff losses.*

Nitrogen leaching

A 7-year study was conducted in Highlands county to evaluate the effect of N fertilization BMPs on groundwater quality beneath five citrus groves. The NO_3-N concentration was monitored in the surficial portion of the aquifer for 2 years prior and 5 years after BMP implementation. The BMPs included appropriate N rates, conversion from dry fertilizer application to fertigation (three groves), inclusion of slow-release fertilizer (one grove), and optimum irrigation scheduling.

Groundwater NO_3-N concentration beneath the grove that was planted on flatwoods soil was below 2 ppm at the start of the study. No change was made to the N fertilization program, and groundwater NO_3-N actually decreased slightly 6 years later (Table 9). Groundwater NO_3-N concentration beneath the groves on ridge soils steadily decreased with time following BMP implementation. Grove B showed the most improvement, where groundwater NO_3-N decreased by more than two-thirds in 6 years (Table 9).

Phosphorus runoff

A 2-year study was conducted in the Indian River area to evaluate annual loads of various P forms in runoff water from seven citrus groves. Phosphorus fertilizer was applied to all groves regardless of soil test P. The amount of total P runoff that occurred in a 2-year period varied between 0.7 and 7.4 lbs/acre (Table 10). For all groves, more than half of the total P in runoff was in a dissolved form. No clear relationship was found between the amount of P in runoff and citrus grove characteristics like P fertilizer rate, water-extractable soil P, or Mehlich 1-P. This result emphasizes that the factors affecting off-site P movement are numerous and complex.

4. Monitoring the grove and tree nutrition

a. Useful *soil analysis* for citrus includes measurement of organic matter, pH, and extractable P, Ca, and Mg, which help to formulate and improve a fertilization program. Soil analysis is particularly useful when trends across several consecutive years are observed, but soil analysis should not be relied upon alone to formulate a fertilizer program or diagnose a nutritional problem.

Table 9. Nitrate-N concentrations in surficial groundwater beneath five Highlands county citrus groves 2 years prior and 5 years after implementing a nitrogen fertilizer BMP program that included optimum irrigation scheduling.

Pre-BMP (1993 – 1994)		**Post-BMP (1995 – 1999)**	
Grove N fertilizer management	N concentration in groundwater, 1993 (ppm NO_3-N)	Grove N fertilizer management	N concentration in groundwater, 1999 (ppm NO_3-N)
Grove A (flatwoods)			
Soluble N fertilizer; 125 lbs N/acre/year in 2 dry applications.	1.5	Soluble N fertilizer; 125 lbs N/acre/year; 2 dry applications.	0.5
Grove B (ridge)			
Soluble N fertilizer; 190 lbs N/acre/year in 3 dry applications.	30.0	Soluble N fertilizer; 130 lbs N/acre/year in three urea sprays + 18 fertigations.	7.5
Grove C (ridge)			
Soluble N fertilizer; 180 lbs N/acre/year in 2–3 dry applications	7.5	Soluble N fertilizer; 154 lbs N/acre/year in 18 fertigations.	2.5
Grove D (ridge)			
Soluble N fertilizer; 180 lbs N/acre/year in 3 dry applications.	11.0	50:50 mix of soluble and slow-release N; 165 lbs N/acre/year; 3 dry applications.	8.5
Grove E (ridge)			
Soluble N fertilizer; 180 lbs N/acre/year in 3 dry applications.	12.0	Soluble N fertilizer; 160 lbs N/acre/year; 18 fertigations.	9.0

Table 10. Total P (TP), total dissolved P (TDP), and ortho P (OP) loads in runoff water from seven Indian River area citrus groves during a 2-year period.

Grove	P fertilizer application	Soil analysis method		P load in runoff water, 2001+2002		
		Water-P	Mehlich 1-P	TP	TDP	OP
	lbs/acre/year	---------- ppm ----------		--------------- lbs/acre ---------------		
1	33	4	38	1.2	0.8	0.2
2	34	5	34	0.7	0.5	0.2
3	34	3	15	3.4	1.6	1.3
4	34	2	13	4.1	2.5	1.3
5	33	8	60	7.4	6.4	5.4
6	21	1	9	2.7	1.8	0.8
7	14	7	57	4.5	3.4	2.4

UF-IFAS soil test interpretations for P (Table 10) were established from experiments with annual field and vegetable crops conducted for many years. Soil test calibration work with Florida citrus trees suggests that the interpretations in Table 10 are suitable for citrus. Values for extractants other than Mehlich 1 were obtained from correlation data with that extractant.

Table 11. Soil test P interpretations for Florida citrus.

Extractant	Soil test interpretation				
	Very Low	Low	Medium	High	Very High
	(Less than sufficient)			(Sufficient)	
Mehlich 1	< 10	10 – 15	16 – 30	31 – 60	> 60
Mehlich 3	< 11	11 – 16	17 – 29	30 – 56	> 56
Ammonium acetate pH 4.8	≤ 11			> 11	
Bray P1	≤ 40			> 40	
Bray P2	≤ 65			> 65	

b. Citrus *leaf analysis* is used to detect problems and adjust fertilizer programs for any nutrient because leaf concentrations are the most accurate indicator of fruit crop nutritional status. Because citrus is a perennial plant, it is its own best indicator of appropriate fertilization. Sampling guidelines should be followed precisely to insure that analytical results are meaningful.

   Laboratory results are interpreted by comparing values with the leaf analysis standards in Table 12. These standards are based on long-term field observations and experiments, and are used to gauge citrus tree nutrition throughout the world.

Table 12. Guidelines for interpretation of orange tree leaf N and P analysis based on 4 to 6-month-old spring flush leaves from non-fruiting twigs.

Element	Deficient	Low	Optimum	High	Excess
	------------------	------------------	%	------------------	------------------
N	< 2.2	2.2 – 2.4	2.5 – 2.7	2.8 – 3.0	> 3.0
P	< 0.09	0.09 – 0.11	0.12 – 0.16	0.17 – 0.30	> 0.30

c. Citrus *tree size* (canopy height and volume) can be measured remotely using an ultrasonic sensor system, while tree position within the grove can be pinpointed with a differential global positioning satellite system (DGPS). These data are processed by a computer program to create a canopy volume map. Since citrus yield is directly related to canopy volume, this map helps growers make decisions about long-term management. For example, a grove with a wide range of canopy volumes can be expected to have a considerable range in yield. Managing for canopy volume variability could improve yields and reduce environmental impacts of fertilizers.

   Citrus *yield maps* can be produced by combining automatic harvest tub position logger data with GPS technology. The number of tubs per unit grove area can be used to identify both high and low production sites. Fertilizer savings can be realized by applying the rate of fertilizer needed by the trees based on their yield with a variable rate fertilizer applicator.

d. *Monitoring water table depth in the flatwoods.* Most flatwoods citrus soils have a restrictive layer that can perch the water table and significantly affect tree water relations. To avoid off-site movement of nutrients, the level of this water table should be monitored and maintained within an optimal zone.

   A water table observation well is a perforated pipe buried vertically in the ground that permits groundwater to rise and fall inside it just as it does in the adjacent soil. An observation well with a simple float indicator provides rapid evaluation of shallow water table depths. This well is an excellent tool for determining when to irrigate or when the water table is too high. The goal of water table management is to maintain the water table at a level just below the root zone but not high enough to cause root damage. Upward water flux from a shallow water table due to capillary action opposes leaching by moving soluble nutrients in a upward direction against gravity.

5. Opportunities to improve water and nutrient use efficiency

a. *Best Management Practices* (BMPs). Most nutrient BMPs are simple, common-sense, "good housekeeping" practices that many grove managers already use in their normal caretaking. In abbreviated form, they involve:

- Educating and training field operators about BMPs.
- Developing a nutrient management plan.
- Using tissue and soil analysis to make fertilization decisions.
- Using appropriate application equipment.
- Properly calibrating and maintaining application equipment.
- Applying fertilizers to target sites.
- Avoiding high risk fertilizer applications (such as during the rainy season).
- Storing fertilizer to prevent contamination of nearby water sources.
- Collecting spilled fertilizer and applying it as normal.
- Using caution when loading near ditches, canals, and wells.
- Using multiple fertilizer loading and transfer sites
- Using backflow prevention devices on water filling systems.
- Splitting fertilizer applications throughout the growing season.
- Using erosion-control practices to minimize soil loss and runoff.
- Trying to wet only the root zone when irrigating.
- Adding organic matter to the soil whenever possible.
- Plugging wells that are not in use.
- Using appropriate fertilizer sources and formulations.

b. *Using high-tech soil moisture monitoring devices.* A multi-level capacitance probe can be used to adjust an irrigation schedule to minimize nutrient leaching. The four graphed lines in Fig. 3 represent soil moisture content at 4-inch (red), 8-inch (blue), 12-inch (purple), and 20-inch (green) depths in the soil. The x-axis shows a 16-day time period separated into 2-day increments.

The effect of irrigation is easily observed as sharp increases in soil moisture at the 4, 8, and 12-inch depths. However, note that the first irrigation increased soil moisture at the 20-inch depth as well, which is below the zone of highest root density. Since the goal here was to keep the irrigation water in the top 18 inches of soil, the grower reduced the duration of subsequent irrigations. The steadily decreasing water content at the 20-inch depth during the following 2-week period showed that the grower had attained optimum irrigation water management.

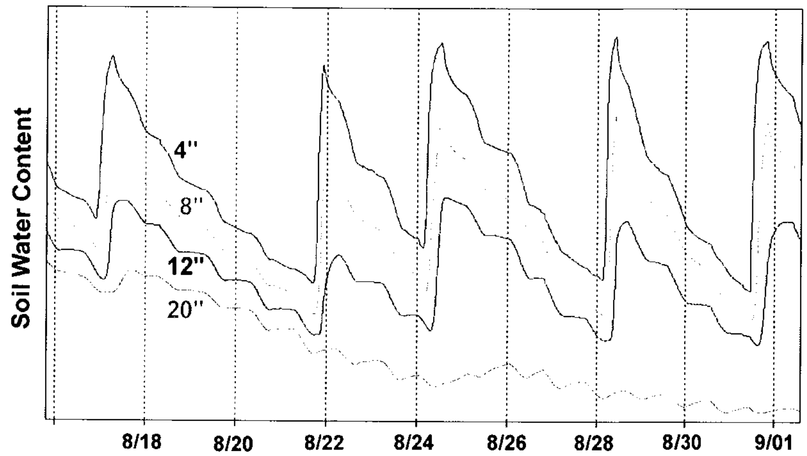

Fig. 3. Continuous monitoring of soil moisture at 4, 8, 12, and 20-inch depths in the soil by a multi-level capacitance probe installed in the root zone of a mature citrus tree.

c. *Irrigation scheduling* considering rainfall and daily ET can be accomplished by using the Citrus MicroSprinkler Irrigation Scheduler found at http://fawn.ifas.ufl.edu/tools/irrigation/citrus/scheduler/

d. *Precision nutrient application based on tree size.* Immature trees or resets should not receive the same fertilization as mature trees, and gaps in the grove should not receive any fertilizer. Prior to using precision application, the grove must be mapped either in real time or by post-processing to characterize the spatial distribution of canopy volume and yield. This map is then used to apply fertilizer with a variable rate spreader, which can reduce fertilizer use in citrus groves by as much as 40%. In addition to reducing production costs, risk of nutrient movement from the grove is minimized.

e. An *"open hydroponics"* system (OHS) is based on the theory that citrus tree performance can be maximized by providing water and nutrients at a rate that closely matches the daily needs of the trees. The delivery of water and fertilizer is by drip irrigation to concentrated portions of the root system formed in direct response to the drip emitters. OHS systems are more expensive to install than microsprinklers, but cost less to operate. Experience with OHS in other countries indicates that a 30% savings in both water and fertilizer may be possible.

6. Focus for future research efforts

a. Controlled-release fertilizer use – Evaluate citrus yield and fruit quality response.
b. Precision nutrient application – Continue development of new application technology.
c. Variable rate irrigation – Link variable rate fertilization with fertigation.
d. Irrigation scheduling – Improve capabilities and performance of automated irrigation systems, including on-line rain forecasts, to permit more accurate scheduling.
e. Open hydroponics system – Continue developing a new integrated system of growing citrus trees in Florida.

7. Summary

Table 13. Summary of current BMP research areas for citrus, level of knowledge, and gaps.

BMP research area	Level of knowledge*	Gaps
Nutrient management plan	4	
Tissue/soil analysis	4	Confirm initial soil test P calibration.
Fertilizer application method (conv.)	5	
Variable rate application	3	Field performance under a wide variety of conditions.
Fertilizer sources	4	Horticultural performance of controlled-release fertilizers.
Fertilizer rates	5	
Fertilization timing	5	
Erosion control	5	
Irrigation method	3	Variable rate irrigation.
Irrigation scheduling	4	Automated irrigation.
Amendments to improve soil properties	2	Effect of long-term organic matter addition.
Open hydroponics	1	Performance in sandy Florida soils.

*Rating scale: 0 = None; 1 = Very low; 2 = Low; 3 = Medium; 4 = High; 5 = Very high.

Table 14. Questions to and summary of vision statements by key UF/IFAS state and county faculty with active programs in BMPs for citrus.

Questions	Answers
1. What is your opinion/vision for the next 5 years on what the citrus industry needs to do to improve their irrigation management?	1. Accurate irrigation scheduling. 2. Sensor or ET-based automated irrigation.
2. What is your opinion/vision for the next 5 years on what the industry needs to do to improve their fertilizer management?	1. Use controlled-release fertilizer if it is affordable. 2. Sensor-based variable-rate fertilization.
3. What educational programs are needed?	1. How to use available technology.
4. What are the critical issues on the horizon (5 to 10 years) that may affect the industry?	1. Long-term effect of citrus greening and canker diseases on water and nutrient management. 2. Effect of continued urban growth on the citrus industry.

Table 15. Strategic areas of future research involving citrus for improving the quality of Florida waters, their respective approaches and estimated chances of success.

Approach used to improve water quality	**Possible areas of research**	**Estimated relative chance of success**	**Why?**
Precision nutrient application.	Sensor-based fertilizer application.	Very good.	Technology exists but needs refinement and testing.
Controlled-release fertilizer.	Verify release curves for new materials.	Very good.	A sound method is being established.
Irrigation scheduling.	Link soil moisture sensors or ET to irrigation systems.	Fair to good.	Reliability of technology.
Open hydroponics.	Investigate its use in Florida.	Unknown.	System is only in the initial testing stage in Florida.

8. References

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