Update on advanced citrus production system research in Florida

By Arnold Schumann, Kevin Hostler, Laura Waldo and Kirandeep Mann

In an August 2009 *Citrus Industry* magazine article, we introduced the concepts of the Advanced Citrus Production System (ACPS) and its overarching goals of early high fruit yields and return on investment to help offset the devastating effects of citrus greening and other diseases. There are now multiple field experiments in progress to test and develop these ACPS concepts for Florida conditions. In this article, we will update the results from the main Gapway Grove Corporation / University of Florida ACPS experiment on the Ridge in Auburndale.

This ACPS experiment was planted with Hamlin on Swingle or C-35 rootstocks in the second half of December 2008. Other treatment comparisons include three different planting densities (218, 303, 363 trees per acre) and three different water / nutrient management methods (conventional granular fertilizer 6 times in year 1 with grower-operated microsprinkler irrigation; intensively-managed microsprinkler fertigation with inverted emitters; and intensive drip fertigation). Such drip fertigation operating at a nearly daily frequency is often called "open hydroponics" (OH) because it diminishes the role of soil storage while increasing the dependence of the trees on the dilute nutrient solution being supplied frequently by the irrigation system. Successful root "training" by OH fertigation promotes a proliferation of healthy active fibrous roots with a large surface area for efficient absorption of nutrients close to the drip emitters.

HOW DOES ACPS IMPROVE NUTRIENT AND WATER USE EFFICIENCY?

The description "open hydroponics" sounds like an inefficient cultural system with the potential for indiscriminate nutrient leakage to the environment. We therefore chose the name ACPS instead. In reality, at the Auburndale experiment, ACPS has already proved by year 2 to be the most efficient citriculture technique from a nutrient, water and energy conservation perspective.

With traditional agriculture, soil must be used as a temporary reservoir for water and nutrients because irrigation and fertilizer are applied relatively infrequently. During the storage of water and nutrients in soil, physical, chemical and biological processes are systems to avoid any excesses, thus minimizing leaching, runoff, volatilization and evaporation losses.

PRACTICAL ACPS – WHAT WE HAVE LEARNED IN THE FIRST 1.5 YEARS

In the Auburndale experiment, soil water sensors, flow meters and a rain gauge are the primary tools used to establish correct dosing of water and nutrients throughout the season. To date, a 100 ppm nitrogen concentration in the total volume of nutrient solution delivered to the trees has proved to be very effective; the other nutrients are then proportionately balanced according to the complete hydroponics nutrient mixture in the fertilizer tanks.

In year 1, only one nutrient solution pulse per day from 8 a.m. to 9 p.m. was adequate, but in year 2, we added six small pulses of only water from 12 p.m. to 5 p.m. (Figure 1). Notice in the figure that during the daytime we try to maintain the soil moisture in the 0-inch to 4-inch depth at near field capacity. This minimizes drought stress while maximizing stomatal opening, gas exchange and photosynthesis. Nutrient applications were targeted for the morning hours because transpiration and photosynthesis usually peak in the morning. Also, in the case of a typical summer afternoon thunderstorm in Florida, much of the nutrients delivered in the morning would be absorbed into the plant by the afternoon, thus avoiding leaching losses. If soil moisture stays high due to rainfall, the fertigation is paused until the soil is dry enough. A second soil moisture sensor was installed horizontally at 18 inches depth to monitor the movement of excessive water past the root zone and allows any necessary corrective action to be taken quickly.

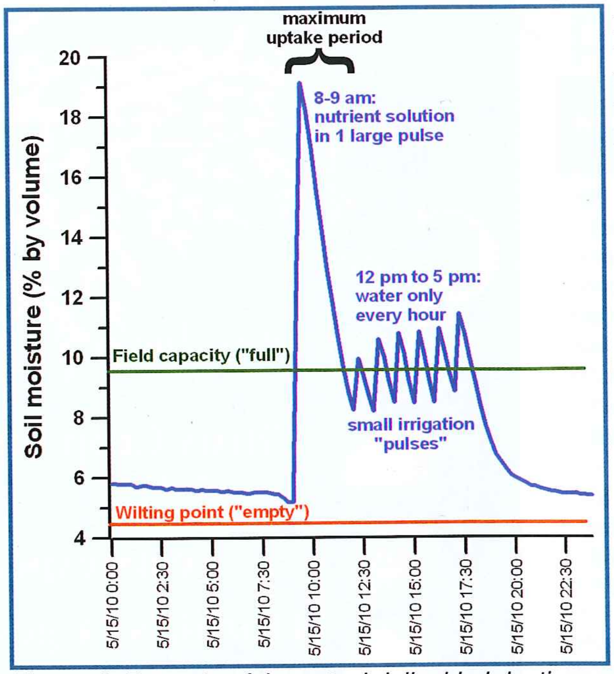

***Figure 1.** Example of the actual daily drip irrigation cycle used in the spring of year 2.*

AMOUNTS OF WATER AND NUTRIENTS APPLIED AND THEIR EFFICIENCIES IN THE FIRST YEAR

Current UF/IFAS nitrogen fertilizer recommendations for citrus trees in the first year are 0.15 to 0.30 lb/tree/year (= 33 to 65 lb/acre/year). The conventional treatment in the Auburndale experiment therefore received 0.22 lb/tree/year (48 lb/acre/year @ 218 tpa).

During the first year of growth under the ACPS, trees grew larger and needed less water and nutrients than under conventional cultural practices (Table 1). Trees grown with drip OH received only 0.4 times the water and 0.17 times the nitrogen amounts compared to conventionally grown trees at the same planting density of 218 trees per acre. Even at the high density of 363 trees per acre, the drip OH method required only 0.67 times the water and 0.28 times the nitrogen of the conventionally grown trees. Canopy height and volume growth was consistently improved by ACPS, with the drip OH treatment at 363 trees per acre growing 2.74 times more canopy volume than under conventional practices. Because fruit yield is strongly correlated to canopy volume, the improvement of 2.74 times in canopy growth per acre bodes well for achieving an economic yield in half the time and/or twice the yield at a given age. In fact, the trees in drip OH treatments have already set a crop of fruit in their second year, suggesting that juvenility traits may also disappear more quickly with ACPS (Figure 2).

By 17.5 months age, the drip OH tree heights averaged 4.5 feet, well on their way to reaching 6 feet by year 3, which was the original objective of the ACPS experiment. It is noteworthy that only 0.8 percent to 1.3 percent of the soil surface area is wetted by the drippers in the ACPS to reduce water losses by evaporation.

For comparing water or nutrient efficiencies, we divided tree canopy volume produced in year 1 by the amount of water or nitrogen applied in the same year. Efficiencies for the drip OH method were impressive, ranging from 4 times more efficient for water, to nearly 10 times more efficient for nitrogen, compared to the conventional practice. The microsprinkler OH method operating at a frequency of about every two to three days was intermediate in water and nitrogen efficiency (1.64 times and 4.45 times, respectively) at the standard 218 trees per acre density. However if microsprinkler OH was to be used in higher density plantings, the water requirement could possibly be higher than the conventional practice because microsprinklers are high-volume devices and are not as efficient as drip devices, especially in the rainy summer months. We therefore propose to use a single application of high-grade (e.g. "nursery" grade), controlled-release fertilizer in the microsprinkler OH treatment during the summer period from mid-June to mid-September of 2010. The trees will then receive the necessary nutrients without needing to fertigate during rainy days. We estimate that the microsprinkler OH water efficiency could then be improved to 0.64 times, thus offsetting the additional water required for higher densities such as 363 trees per acre.

Table 1. Water and fertilizer N applied and tree canopy growth in year 1. Water for freeze protection was not included.

	Conventional* (218 tpa)¥	Microsprinkler OH§ (218 tpa)	Drip OH¶ (218 tpa)	Drip OH (363 tpa)
Irrigation water (gal/acre)	49,177 (1x)	45,997 (0.94x)	19,684 (0.40x)	32,777 (0.67x)
Fertilizer nitrogen (lb/acre)	48.0 (1x)	16.5 (0.34x)	8.0 (0.17x)	13.4 (0.28x)
Tree height (feet)	3.18 (1x)	3.67 (1.15x)	3.92 (1.23x)	3.92 (1.23x)
Tree canopy volume (feet^3/acre)	2,507 (1x)	3,837 (1.53x)	4,129 (1.65x)	6,875 (2.74x)
Water efficiency (feet^3/1000 gal)	51.0 (1x)	83.4 (1.64x)	209.8 (4.11x)	209.8 (4.11x)
Nutrient efficiency (feet^3/lb N)	52.2 (1x)	232.5 (4.45x)	516.1 (9.89x)	516.1 (9.89x)

*Conventional = granular fertilize and Tr in six split applications
¥ tpa = trees per acre
§ Microsprinkler OH = open hydroponics through inverted microsprinklers (1/tree)
¶ Drip OH = open hydroponics through drip emitters

EFFECTS OF ACPS ON ENVIRONMENTAL PROTECTION, CONSERVATION OF RESOURCES, ENERGY AND THE CARBON FOOTPRINT OF CITRUS PRODUCTION

The benefits of ACPS in conserving renewable and non-renewable input resources in the first year are self-evident. In general, gains of efficiency in any production system lead to conservation of resources, reduction of pollution and byproducts (environmental protection), lower energy requirements from fossil fuels and other non-renewable sources, and hence a dramatic reduction in carbon footprint.

Historically, we know from the citrus nitrogen BMP studies that the most important factors which regulate nitrate leaching to groundwater on the Ridge soils are the fertilizer rate, and the vigor and productivity of the crop. We installed vacuum lysimeters in each of the main treatments in the Auburndale experiment to sample soil water leached to below 5 feet. The sampled water was analyzed for nitrate-N concentrations after major leaching events from rain or freeze protection. The results illustrate graphically the strong reduction of nitrate concentrations in soil leachates destined for the groundwater when nutrient and water efficiencies are improved by ACPS (Figure 3). The lowest nitrate concentrations were measured in the drip OH lysimeters, where levels remained below 2 ppm for most of the samples except for the one taken immediately after the January freezes (5.92 ppm). In contrast, for the conventional treatment, nearly half of the samples were above 10 ppm nitrate-N, with a maximum of 26.5 ppm. The microsprinkler OH lysimeters showed intermediate nitrate concentrations as expected. Nitrate leaching was therefore inversely proportional to the nutrient efficiencies, which in turn were determined by fertilizer application rates and tree growth rates.

Figure 2. *Hamlin orange fruit during May 2010 on trees growing with ACPS drip fertigation. The trees were planted 17 months earlier.*

The conservation of mainly water and fertilizer inputs by the ACPS is already clear. Linked to these input reductions are other synergies, especially those which reduce energy requirements. For example, less diesel or electricity is used for pumping water, less fuel is consumed for hauling and applying fertilizer, etc. However, the single largest reduction in energy requirement is due to the much lower nitrogen requirement by drip OH in year 1 (0.17 times) because nitrogen-fertilizer manufacturing is the most energy-intensive operation in the whole citrus production cycle. We can, therefore, tentatively conclude that the carbon footprint of citrus production through year 1 has been reduced by at least 6 times from using drip OH in an ACPS.

REFINING THE ACPS FOR FLORIDA: FUTURE OUTLOOK IN YEARS 2-3

The Auburndale experiment is already showing that a version of the ACPS may be very successfully deployed in Florida citrus. New questions and challenges remain, including the more aggressive pest control required for protecting the rapidly flushing trees. By the beginning of year 2, a survey of the 15-acre experiment by trained scouts revealed that there were no symptoms of citrus greening yet, despite known greening-infected trees with no psyllid control being less than one mile away. The interaction of the ACPS with greening and other diseases and pests will be increasingly important in subsequent years.

One of the fundamental difficulties in adopting drip fertigation for new citrus plantings on the Ridge is the lack of freeze protection from drip emitters. For that reason, the Auburndale experiment was "dual plumbed" at additional cost with microsprinkler emitters in drip OH plots. An important outcome of the first 1.5 years is the good performance of the microsprinkler OH method. Its efficiencies lagged behind the drip OH method, but it produced nearly the same tree growth. Therefore, new groves with microsprinkler OH would benefit from ACPS without the need to invest in expensive additional freeze protection.

Another option which we will start to explore in the Auburndale ACPS and other replant experiments is to use high-quality, controlled-release fertilizer instead of liquid fertilizer. That approach will reduce the complexity (and possibly cost) of the ACPS, but might compromise the necessary control over nutrient delivery and balance that is possible with liquid-injection systems.

SUMMARY

In summary, ACPS can minimize water and nutrient use with high-frequency drip fertigation targeting high-root densities in small soil volumes while maintaining very high tree growth under Florida conditions. The much greater efficiencies of ACPS than conventional production practices are remarkable. Other refinements for achieving greater efficiency, which we are already using, are variable rate technologies such as the hoop sprayer. The hoop sprayer used in the Auburndale experiment sprays only the tree canopies and turns the spray off between trees, thus saving agrochemicals. It also economizes by only treating the row and not broadcasting sprays over the whole acreage. Later, as the inevitable greening-infected trees will be removed, we plan to integrate granular fertilization into the ACPS, using a variable rate fertilizer spreader for higher efficiencies.

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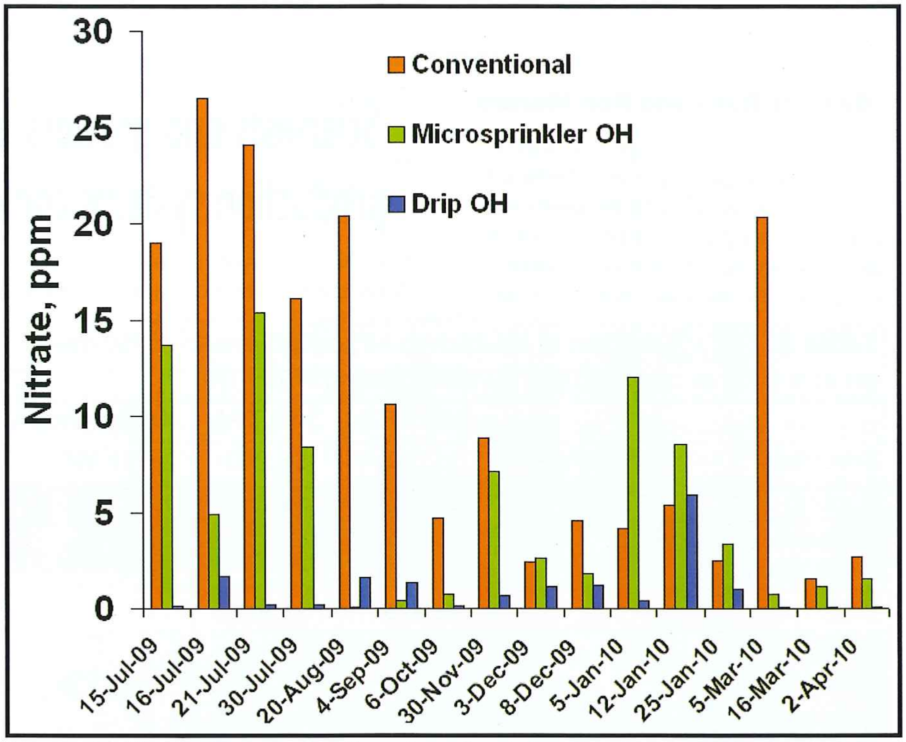

Figure 3. *Nitrate-N concentrations in soil solution leached to a depth of >5 feet below citrus trees.*