Water and Fertilizer Monitoring System for tree growth in Pot-in Pot Production

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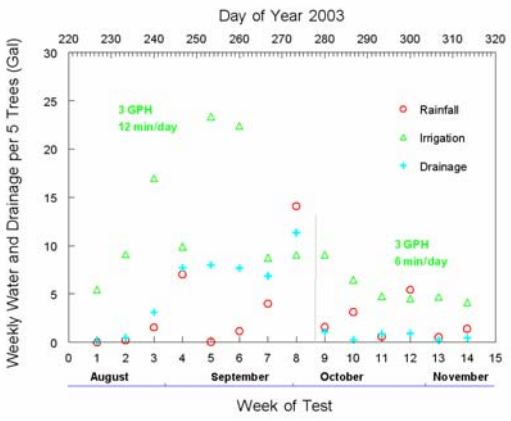
What will you expect if you can apply water and nutrition to your container-grown plants at the time when they need without waste while still maintain a proper nutrient level and water to air ratio? Research by the USDA- ARS Application Technology Research Unit (ATRU) has started to provide answers to these questions. A water and fertilizer monitoring system at Willoway Nurseries in Avon, Ohio was developed to study patterns that typical nurseries should use to irrigate plants. Research showed that a large amount of water lost through drainage with the current irrigation practices in pot-in-pot nursery production because of over applying water to container-grown plants during a short period of time. The study showed that water either moves down the side of the pot due to medium shrinkage or moves through large pores and never has enough time to be absorbed into small pores. Also, the current irrigation practices not only cause a large portion of water wasted but also cause a problem that the excess water carries nutrients and other chemical elements back to the water sources. Trees grown in soilless media with large porosity in pot-in-pot systems expose the experience with either wet or dry situation since there is no proficient method to monitor the medium moisture. The wet-and-dry cycle can cause problems for plant roots with shortage of nutrients, high soluble salt levels, and low air to water ratio. Once the plants start showing adverse symptoms caused by these problems, it is usually too late to make rescue treatments. Along with the fact that many container growers are having a difficult time to find dependable water sources, these issues have brought researchers to look for

Figure 1. An experimental field with three plots containing 150 pot-in-pot container trees and a plot containing 50 above-ground container trees to determine water use, nutrient management, drainage and leachate, and medium moisture and temperature during four seasons in nursery pot-in-pot container production

answers to optimize water and fertilizer use in nursery container production.

In 2003, the experimental monitoring system was established in a 0.5 acre field site to investigate water use efficiency, drainage and chemical leachate from pot-in-pot nursery production. Results from 2003 and 2004 studies illustrated that only 3 minutes are required with a 3 gallon per hour spray stake to apply enough water for a #15 container tree during each irrigation cycle, and only twice irrigation cycles are required each day during the growing season (Figures 1). However, growers normally apply irrigation to pot-in-pot production 20 to 30 minutes every day, which causes large amount of water lost through drainage. Some growers have already used the scientific data from this research to improve their irrigation practices. Reducing drainage water from the pot-in-pot production could also greatly reduce the amount of chemical elements leached through drainage. Because the total amount of water lost through drainage in the 2004 growing season was much less than the 2003 growing season, the total amount of N, P and K lost though drainage in 2004 was almost four times less than in 2003 (Figures 2 and 3) while tree caliper growth was maintained

equally (Figure 4). During the winter time, the medium temperature close to the tree root zones were about 32°F even the ambient air temperature was lower than 0°F (Figure 5). Also, the medium temperature at the bottom of containers was about 4°F higher than the temperature the root zone in the pot-in-pot system (Figure 6).



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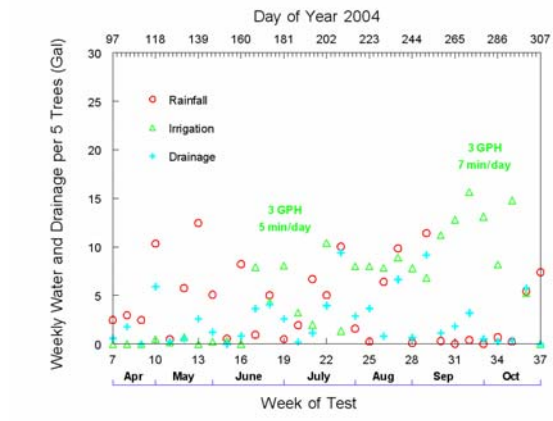
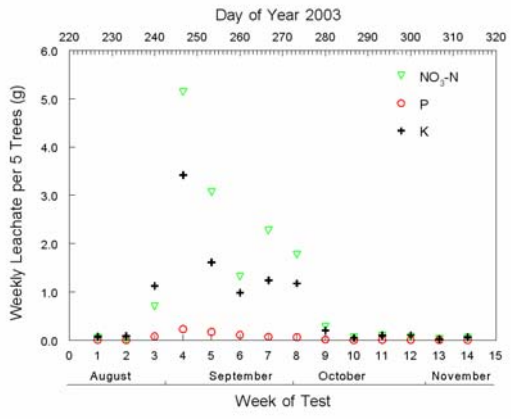


(b)

Figure 2. Amounts of weekly rainfall, irrigation and drainage from 5 trees in #15 pot-in-pot containers during 2003 and 2004 growing seasons



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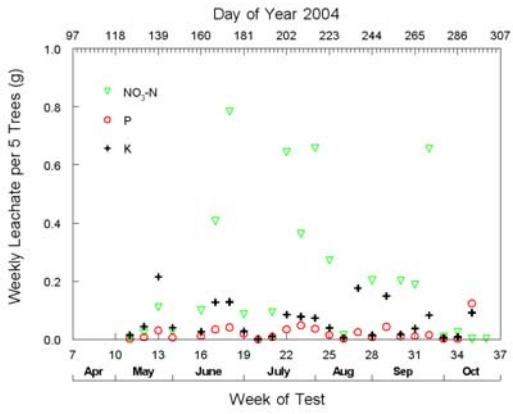


(b)

Figure 3. Amounts of weekly NO3-N, P, and K leachate from 5 trees in #15 pot-in-pot containers during 2003 and 2004 growing seasons

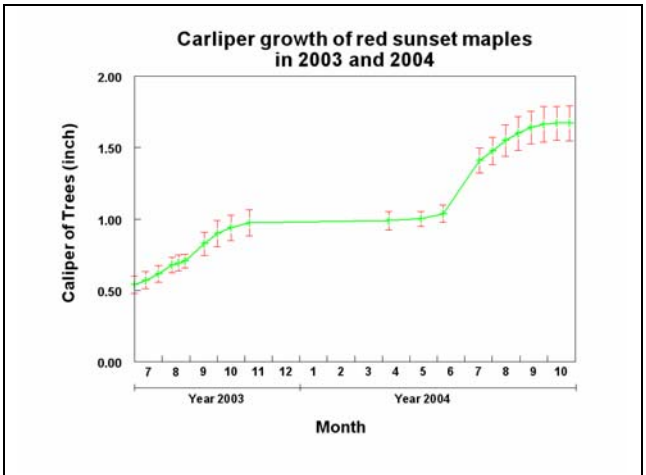


Figure 4. The red maple tree caliper growth during 2003 and 2004 growing seasons.

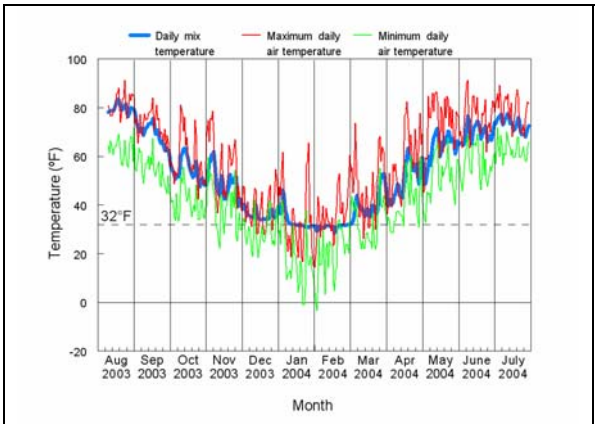


Figure 5. Average daily medium temperatures in 10 rows and daily minimum and maximum ambient air temperatures between August 2003 and July 2004

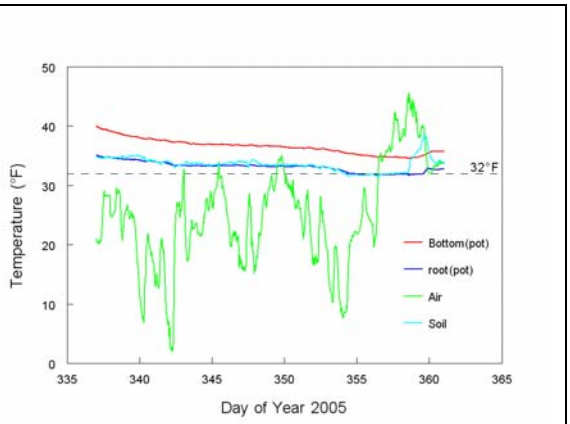


Figure 6. The medium temperatures at the bottom of containers and near the root zone in pot-in-pot system, and ambient air temperature as well as soil temperature in December, 2005

Because of the 2003 discoveries that changed irrigation practices, the nursery industry and scientific collaborators strongly demanded the expansion of research activities. In 2005, the system was expanded to have three separate pot-in-pot plots containing 150 pot-in-pot container trees (Figure 1) and another plot containing 50 above ground container trees. Each plot is equipped with 10 drainage water measurement

devices, 10 medium moisture probes, 10 thermocouples, and a weather station and a data logger. This research has emphasized on: (1) investigating the irrigation schedule, irrigation frequency, and the amount of water required for a tree to grow properly under the varied rainfall and climate conditions; (2) investigating water loss due to runoff and drainage, methods to minimize the water loss, and water resource managements; (3) investigating the level and timing of N, P, and K application and loss through the runoff and drainage to optimize fertility management practices, and protect water resources by decisions that the drainage water should be recycled or disposed from the nursery; (4) investigating the amount of pesticide leachate through water runoff and drainage following chemigation or spray application in pot-in-pot system production; (5) investigating the influence of temperature on medium moisture content, prevention of possible winter injury of plants and the best irrigation time for plants in spring. The corresponding information from this research will help growers apply water and nutrients only when needed by plants. The outcome from this research will have great impact on the nursery industry as it seeks newer production methods, which will include (1) improved water/nutrient usage management with most beneficial to nursery crops for higher crop quality; (2) optimal production practices to reduce waste water and nutrient use to lower production cost, and (3) improved environmental stewardship by minimizing excess nutrients released into off-farm land.

In addition to the water and fertilizer monitoring system, researchers at ATRU have developed their own automatic irrigation control technique based on the medium moisture level for the container production. To obtain an optimal growing condition for plants, water should be applied at the time when plants need water. The medium moisture

was monitored on a regular basis to trigger automatic irrigation control system to apply water as needed. The ATRU experimental system is unique because it links medium moisture monitoring function and irrigation application together. Another unique function of this system is that during irrigation process it applies a short burst of water 5 to 10 seconds every minute until medium moisture reaches the desired level. Slowly applying water can allow water having time to diffuse uniformly through the medium before next application of water occurs. Because container media usually have large porosity, applying a large amount of water at one time can cause water drained away quickly. This irrigation technique is expected to drastically reduce the amount of water applied to the container-grown trees, and it is expected to be very useful for field and landscape operations using either drip or micro irrigation technology although the technique is still in the testing stage.

In 2005, three studies were conducted in the three pot-in-pot plots and the above-ground plot (Figure 1). For the three pot-in-pot plots (Plots #1, #2, and #3) once a row of five trees required irrigation, the automatic control system was used to provide a cycle of 5-second irrigation during every minute until the medium water content reached the stop point. For the above-ground plot (Plot #4), irrigation was controlled manually and water was applied 3 minutes each time and twice a day unless a sufficient amount of rainfall was received to wet the medium on that day. A spray stake at a 3 gallon per hour flow rate was used for each tree for all four plots.

The first study in 2005 was conducted in Plot #1 to determine water and nutrient use, and water drainage and nutrient leachate with three different container mixes. Irrigation schedules were managed with our automatic control system based on the

medium moisture level at 30% for start and 40% for stop. Trees used in Plot #1 were red maple and were bare-root transplanted to #15 containers containing Mix #1. The Mix #1 was an experimental bio-solid mix mainly composted with coal ash. Trees with Mix #1 were not applied with any fertilizer and nitrogen after transplanted into the containers. Mix #2 and Mix #3 are two different tree mixes used by commercial nurseries while Mix #3 contained much higher initial NH3-N and NO3-N than Mix #2. Trees with Mix #2 and Mix #3 were equally applied with Scott's slow release granular 20-5-8 fertilizer at a rate of 119 grams per tree at the first week after trees were transplanted into #15 containers, and then they were applied with 28% nitrogen at a rate of 0.112 mL per tree every week during the growing season.

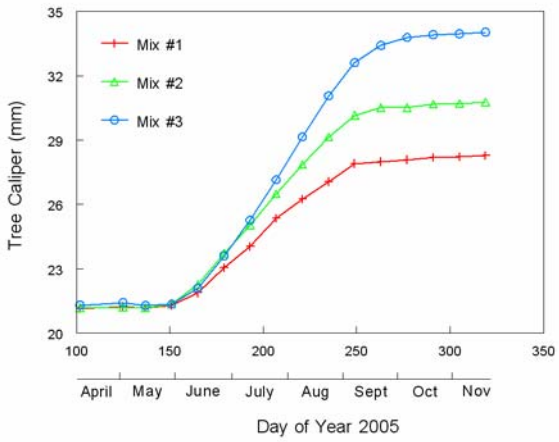
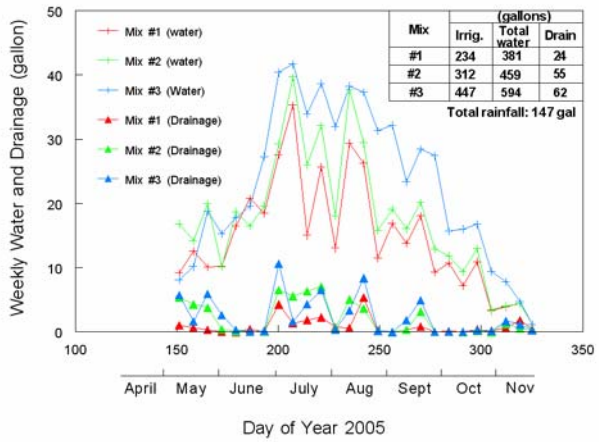


Figure 7. Comparison of red maple tree calipers among three different mixes used in Plot #1.

The second study in 2005 was conducted in Plot #2 and #3 to determine water and nutrient use, and water drainage and nutrient leachate for different moisture levels with granular and liquid fertilizer applications. Pear trees in Plot #2 and eastern red bud trees in Plot #3 were tested with Mix #2.

The third study in 2005 was conducted in Plots #2, #3, and #4 with 50 above-ground pots to compare water use between automated and manual controlled irrigation practices. Half Plot #4 was planted with pear trees and another half was planted with eastern red bud trees.

Tree caliper growth rate varied with the type of container mixes (Figure 7). Mix #3 produced the largest tree caliper growth while Mix #1 produced the smallest caliper growth. However, Trees with Mix #3 used the highest amount of water while trees with Mix #1 used the least amount of water among the three treatments (Figure 8). Also, Mix #1 had the lowest drainage and Mix #3 had the highest drainage among the three mixes. During the 2005 growing season, about 147 gallons of rainfall reached 5 tree containers. Most portion of drainage from the three mixes was directly caused by uncontrolled rainfall.



Mix	(gallons) Irrig.	Total water	Drain
#1	234	381	24
#2	312	459	55
#3	447	594	62

Figure 8. Amounts of weekly water (irrigation + rainfall) applied and drainage loss from 5 red maple trees with three different mixes used in Plot #1.

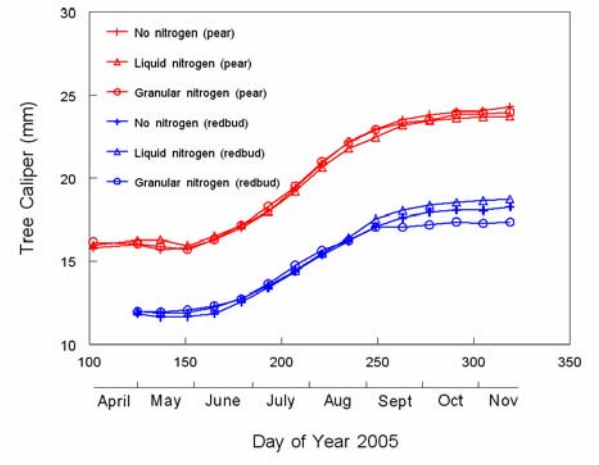


Figure 9. Comparison of pear and redbud tree calipers among three different nitrogen treatments during growing season.

For either redbud or pear, there was no difference in caliper growth among the liquid, granular and no nitrogen application treatments during the first year of growing season (Figure 9).

Therefore, just one time application of top dressed, slow release granular 20-5-8 fertilizer

after the trees were transplanted might provide enough nitrogen for pears and redbuds to grow during the first year. With the automatic irrigation control system to maintain the medium moisture content between 30 and 48%, 5 redbud trees took 168 gallons of irrigation water and 5 pear trees took 114 gallons of irrigation water during the entire growing season (Figure 10). However, during the entire growing season each 5 trees in Plot # 4 took 383 gallons of irrigation water with the method of manually applying water twice a day and three minutes.

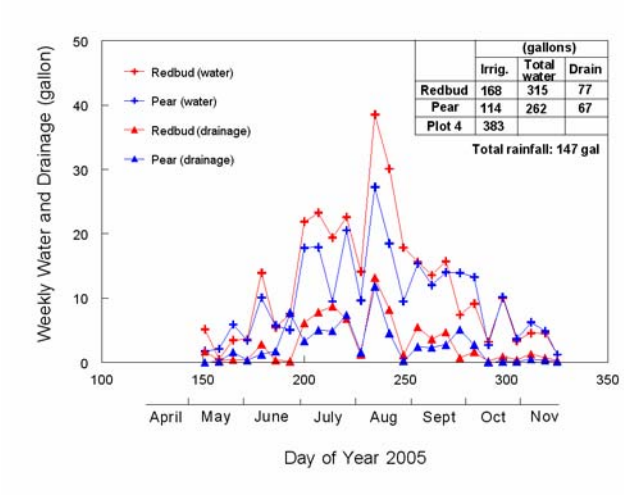


Figure 10. Amounts of weekly water (irrigation + rainfall) applied and drainage loss from 5 redbud and 5 pear trees in Plot #2 and #3.

Discussion

Using the water and fertilizer monitoring system resulted in dramatic water use reduction. Before the system was established, water was applied 20 to 30 minutes every day if rainfall was not enough to wet the medium. After the system was used to monitor irrigation practice, irrigation time was reduced to about six minutes every day. The automatic irrigation control system, as plants called for water, could even greatly reduce water use. What growers have to remember is that water and fertilizer uses should be monitored for different medium types and plant species because their requirements and planting circumstances are different. For example, red maples used a significantly larger amount of water than redbuds or pears during the first growing

season.

The tree caliper growth was most noticeable between day 100 and 250 in the growing season. A major impact was made on red maple tree caliper by changing the amount of water and the nutrient level in the medium. Applying the top dressed, slow release, granular fertilizer to trees at the beginning of the growing season might be enough to support healthy growth for redbuds and pears for the first year. There will be more research needed to determine how much and when water and fertilizer should be applied to achieve optimal growth without adverse damages to plants.

During the growing season, the medium temperature in pot-in-pot system did not vary the medium moisture content level. In winter and summer, even the daily ambient air temperature had great fluctuations, the medium temperature in pot-in-pot system remained very steady and much better than the temperature of soil surrounding the pot-in-pot containers. Moreover, the medium temperature at the bottom of the pot-in-pot containers was always about 4 °F higher than the medium temperature at four inches below the medium top surface. The steady warm medium temperature in pot-in-pot system could prevent the roots from cold winter injury and summer heat damage. We highly suspected that the drain tile under the pot-in-pot system had brought some geothermal energy into the system.

The final question is how much it will cost growers to install this system to monitor water, fertilizer, drainage, leachate and tree growth in their production fields. Although a few nurseries can setup a system similar to our experimental system for research use, many nurseries can install a scaled down system for their own production practices. Plants should be divided in different zones by species and pot sizes, assuring

uniform readings and water application. Pots should be mounted on a drain tile to carry excess water away, especially for rainfalls. Spray sticks or pressure compensated nozzles are recommended for irrigation to achieve even water distribution across the growing zone. Since nurseries have large varieties of plants, medium moisture probes are suggested for use to monitor moisture level in the medium to control irrigation schedule which is predetermined by the grower. The beauty of this system is its ability to change moisture levels as needed at any time during the growing season. In the future growers may be able to monitor nutrient levels in the foliage of plants to determine if fertilizer is needed, which is similar to soil tests normally used for other crops for fertilizer application.

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