Comparison of Irrigation, Leachate and Tree Growth between Soilless and Coal Ash Based Media

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Abstract

In nursery production, knowledge of water quality and quantity is needed to improve irrigation and fertilizer application efficiency as it relates to potential for soil and groundwater contamination. Water and fertilizer use and loss as well as tree growth were investigated for Red Sunset maple (*Acer rubrum* 'Franksred') trees in a pot-in-pot system with two different potting media and one coal ash based medium. The coal ash based medium (Mix #1) was mainly composed of biosolids, flue gas desulfurization gypsum, and coal combustion bottom ash. The two potting media mainly composed of aged pine bark and steamed composted nursery trimmings as well as left-over potting medium from commercial nurseries, but one with low initial amendments (Mix #2) and the other one with high initial amendments (Mix #3). Trickle irrigation was applied to each tree with an automatic control system. Watering trees started when the medium moisture was below 30%, and stopped when the moisture was 42%. During two-year tests, the amount of water including irrigation and rainfall applied to each tree with Mix #1, #2 and #3 was 741, 910 and 950 L, respectively. The amount of water loss through drainage for each tree with Mix #1, #2 and #3 was 107, 147 and 112 L, respectively. Among the tree media, Medium #3 produced the highest tree growth rate, followed by the Mix #2. The coal ash based medium had great potentials to be used for nursery production.

INTRODUCTION

Pot-in-pot production system has been expanded rapidly during the past decade to produce higher quality crops at reduced labor costs. However, the expectations are unclear to growers when they apply water and nutrition to the container-grown plants at the time as needed without waste while still maintain a proper nutrient level and water to air ratio. A water and fertilizer monitoring system (Fig. 1) at Willoway Nurseries in Avon, Ohio was developed to study patterns that typical nurseries should use to irrigate plants (Zhu et al., 2004, 2005). 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 answers to optimize water and fertilizer use in nursery container production.

In 2003, the experimental monitoring system was established in a 0.2 ha 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 min. are required with an 11.3 L/h spray stake to apply enough water for a #15 container (57 L) tree during each irrigation cycle, and only twice irrigation cycles are required each day during the growing season. However, growers normally apply irrigation to pot-in-pot production 20 to 30 min. everyday, 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 although tree caliper growth was maintained equally (Fig. 2), the total amount of N, P and K lost though drainage in 2004 was almost four times less than in 2003 (Figs. 3 and 4). During the winter time, the medium temperature close to the tree root zones were about 0°C even the ambient air temperature was lower than -18°C (Fig. 5). Also, the medium temperature at the bottom of containers was about 2°C higher than the temperature the root zone in the pot-in-pot system (Fig. 6).

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 and another plot containing 50 above ground container trees (Fig. 1). 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; and (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 s 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.

The specific objective of this research was to compare amounts of irrigation, leachate and tree growth among two soilless media and one coal ash based medium.

MATERIALS AND METHODS

In 2005 and 2006, one study was conducted in a plot to determine water and nutrient use, and water drainage and nutrient leachate with three different container media. Major nutrients initially existing in medium in a #15 (57 L) container are listed in Table 1. The Mix #1 was an experimental bio-solid medium mainly composted with coal ash. Mix #2 and Mix #3 were two different soilless tree media used by commercial nurseries while Mix #3 contained much higher initial NH_3-N and NO_3-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 g/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/tree every week during the growing season. Trees with Mix #1 were not applied with any fertilizer and nitrogen after transplanted into the containers during 2005 growing season while they were treated equally as trees with Mix #2 and #3 in the 2006 growing season. A spray stake at a 11.3 L/h flow rate was used for each tree. Irrigation schedules were managed with our automatic control system based on the medium moisture level at 30% for start and 40% for stop. Trees were red maple and were bare-root transplanted to #15 containers.

RESULTS

Tree caliper growth rate varied with the type of container mixes (Fig. 8). Mix #3 produced the largest tree caliper growth while Mix #1 produced the smallest caliper growth. However, during the second growing season the growth rate of trees in Mix #3 was slower that those in Mix #1 and #2. During the first growing season, 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 (Fig. 7). The amounts of water applied to 5 trees and lost through drainage during the second growing season were different from the first growing season due to changes in tree growth. Mix #1 used the least amount of water and produced the lowest drainage among the three mixes. About 997 L of rainfall reached 5 tree containers during the two growing seasons. Most portion of drainage from the three mixes was directly caused by uncontrolled rainfall. During two-year tests, the amount of water including irrigation and rainfall applied to each tree with Mix #1, #2 and #3 was 741, 910 and 950 L, respectively. The amount of water loss through drainage for each tree with Mix #1, #2 and #3 was 107, 147 and 112 L, respectively.

Figure 9 shows the weekly leachate of NO_3-N from five trees with three different mixes during the two growing season. The leachate from Mix #1 and #2 in the first growing season was much greater than in the second growing season. Mix #3 had very high initial NO_3-N at the beginning of the first growing season. The leachate from Mix #3 in the second growing season was higher than in the first growing season because no fertilizers were applied into Mix #3 during the first growing season. The leaching amount of P and K for all three mixes in the first growing season was higher than in the second growing season (Figs. 10 and 11).

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 min. everyday if rainfall was not enough to wet the medium. After the system was used to monitor irrigation practice, irrigation time was reduced to about 6 min. everyday. 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. High initial nitrogen in the mix might accelerate tree growth in the first growing season but might not help tree growth in the second growing season. 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 with the medium moisture content level. In winter and summer, even the daily ambient air temperature had a great variation, the mix 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.

CONCLUSIONS

During the first growing season, higher initial nutrition resulted in higher tree growth and higher amounts of leaching in water and fertilizer. Most leaching was caused by rainfall because of using the automatic intermittent irrigation control. Mix #1 (coal ash potting medium) reduced water and fertilizer use, but was very heavy. Long term observation of tree growth is needed.

Amounts of NO_3-N, P and K loss in the first growing season was much higher than the second growing season for the Mix #2 and #3. Mix #1 had higher NO_3-N leachate in the second growing season than the first growing season because of different fertilizer application practices.

ACKNOWLEDGEMENTS

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Tables

Table 1. Major nutrients initially existing in medium in a 57 L container.

Mix #	Initial nutrient weight (g)				Porosity
	NH_3-N	NO_3-N	P	K	(%)
1	0.18	16.76	11.63	61.15	9
2	0.05	0.07	140.29	86.24	28
3	6.05	16.99	23.37	44.46	25

Figures

Fig. 1. A system to determine water quantity and quality for pot-in-pot production.

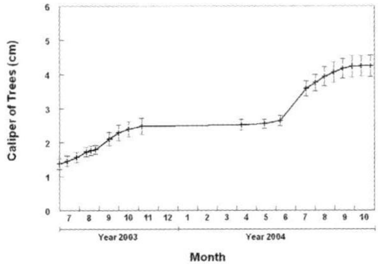

Fig. 2. The red maple tree caliper growth during 2003 and 2004 growing seasons.

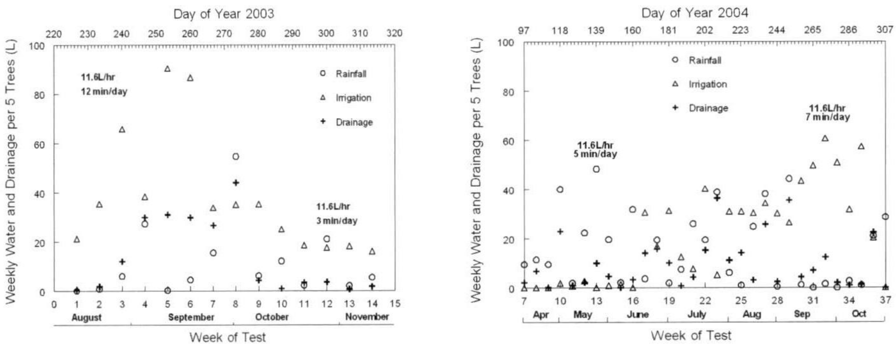

Fig. 3. Amounts of weekly rainfall, irrigation and drainage from 5 trees in #15 pot-in-pot containers during 2003 and 2004 growing seasons.

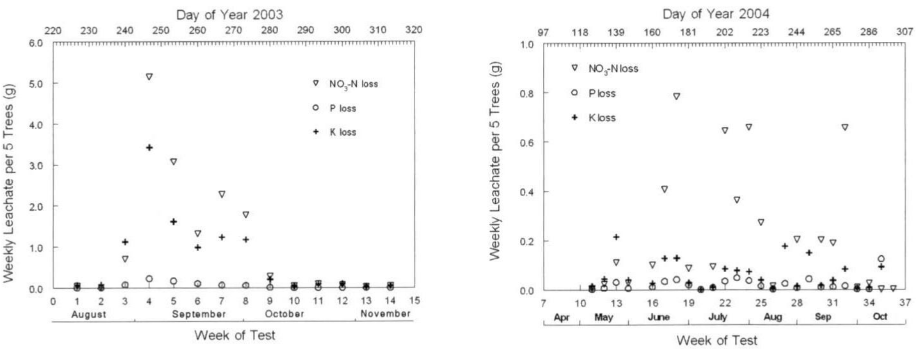

Fig. 4. Amounts of weekly NO_3-N, P, and K leachate from 5 trees in #15 pot-in-pot containers during 2003 and 2004 growing seasons.

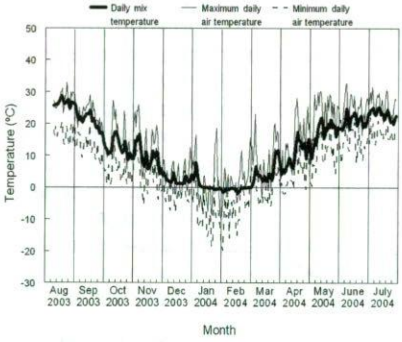

Fig. 5. Average daily medium temperatures in 10 rows and daily minimum and maximum ambient air temperatures between August 2003 and July 2004.

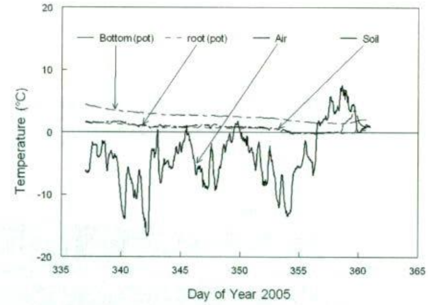

Fig. 6. The medium temperatures at the bottom of containers and near the root zone in pot-in-pot system, and ambient air temperature as well as soil temperature in December 2005.

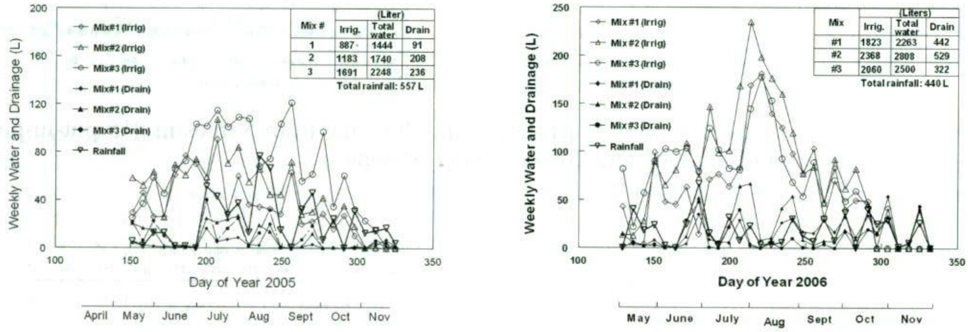

Fig. 7. Amounts of weekly water (irrigation + rainfall) applied and drainage loss from five maple trees with three different mixes during 2005 and 2006 growing seasons.

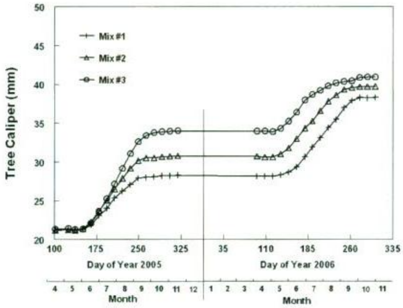

Fig. 8. Comparison of red maple tree calipers among three different potting media.

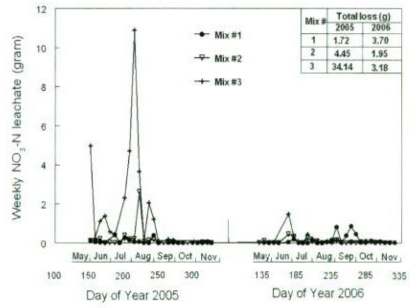

Fig. 9. Amounts of weekly Nitrate nitrogen (NO_3-N) leachate from five red maple trees with three different mixes during 2005 and 2006 growing seasons.

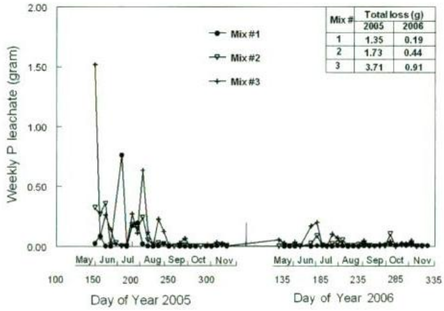

Fig. 10. Amounts of weekly phosphate (P) leachate from five red maple trees with three different mixes during 2005 and 2006 growing seasons.

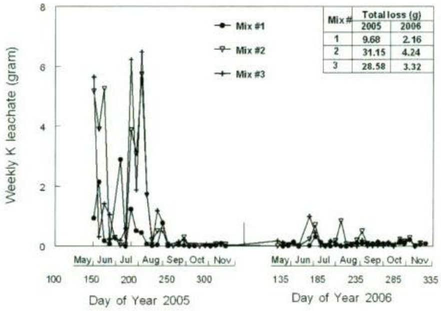

Fig. 11. Amounts of weekly potassium (K) leachate from five red maple trees with three different mixes during 2005 and 2006 growing seasons.