Research Reports

The Use of Suction Cup Lysimeters for Monitoring the Nutritional Status of Container Substrate for Optimum Growth of Willow Oak[1]

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Abstract

As container size and subsequent weight increase, extracting substrate solution for mineral nutrient analysis becomes difficult. Therefore, the objective of this research was to determine, using suction cup lysimeters (SCLs) to obtain the substrate solution, the electrical conductivity (EC) level associated with optimal growth of containerized willow oak (*Quercus phellos* L.). Two-year-old trees were grown in 56.8 liter (#15) containers and fertilized with either 0, 50, 100, 150, 200, 250, or 300 g (0, 1.8, 3.5, 5.3, 7.0, 8.8, or 10.5 oz) Osmocote Plus Northern 15N–3.9P–9.8K per container. Plant height and trunk diameter were measured at the beginning and end of the growing season. Leaf samples were taken at the conclusion of the study for mineral nutrient analysis. Growth was optimal at 200 g (7 oz) Osmocote per container and corresponded with a seasonal mean EC level of 0.5 dS/m. SCLs were an effective method of extracting solution for EC monitoring from large containers.

Index words: electrical conductivity, controlled release fertilizer, container-grown.

Significance to the Nursery Industry

This study demonstrated that suction cup lysimeters (SCLs) are valuable tools for extracting and monitoring the mineral nutrient levels of substrate solutions of large nursery containers. The level of nutrients in the extracted solution correlated well with the growth of container-grown willow oak (*Quecus phellos*) and that approximately 200 g (7 oz) per container of a controlled-release fertilizer (Osmocote 15–9–12) resulted in optimal growth. The electrical conductivity (EC) associated with optimal growth was 0.5 dS/m.

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Introduction

The production of woody nursery crops in containers has become the predominant method of production in the United States. Because soilless media regularly used in container production have relatively low water-holding capacities and ability to retain mineral nutrients, the medium solution is continually being depleted of nutrients through leaching or plant uptake (13). Therefore, intensive management of fertilizer, substrate, and irrigation regimes is needed to maintain container fertility for optimum plant growth. Concerns about potential environmental contamination caused by nutrient-laden runoff from woody plant nurseries have also led

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to the need for careful monitoring of the nutritional status of containerized plants (3).

The two methods generally used to supply mineral nutrients to containerized crops are liquid feed (LF) fertilizers, in which water-soluble fertilizers are added to irrigation water, and controlled release fertilizers (CRFs) in which dry products are either incorporated into the growth substrate or top dressed following planting. Previous studies have shown that high quality plants can be produced using either LF or CRFs as long as adequate nutritional levels are maintained in the medium solution (1, 2, 3). However, maintaining adequate levels of nutrients within containers can be difficult, especially in outdoor growing conditions in which rainfall, in addition to irrigation, facilitates leaching of highly soluble nutrients, reducing fertilizer use efficiency and possibly leading to nutrient deficiencies that in turn limit plant growth (3). Alternatively, plants grown under high fertility levels show an increase in the shoot:root ratio of the plant potentially leading to poor performance after being transplanted to more stressful environments outside the nursery setting (5). In addition, applying high rates of nitrogen (N) and other nutrients to increase nursery productivity results in detrimental environmental consequences if leachate is not managed carefully.

CRFs supply mineral nutrients to the plant by releasing them at relatively low levels over an extended period of time. Using CRFs allows for increased nutrient use efficiency (1) and lower labor costs because reapplication of the fertilizer is reduced compared to using LF fertilizers (7). Use of a CRF can therefore significantly reduce the amount of nutrients that are leached from containers, thus reducing the potential for groundwater pollution (1, 3).

One problem with CRFs is that during the early part of the growing season larger amounts of nutrients are released from CRFs than can be utilized by the plants, whereas during the latter part of the season, nutrient release may be limiting (1, 13). The grower must then decide if and when to reapply CRFs during the growing season (1, 10).

CRF products are categorized by the length of time needed for the prill to release ~80% of its contents at a given temperature with the release rate of most popular CRF products being affected directly by temperature and not by the moisture content of the substrate (4). However, the adequacy of these longevity ratings has been questioned. When comparing the longevity rating of an 8 to 9 month and a 12 to 14 month CRF, Meadows and Fuller (7) found that after 4 months, N levels in the substrate solution had dropped below 10 ppm, limiting growth. A study by Shiflett et al. (10) determined that plants of Helleri holly (*Ilex crenata* 'Helleri') that received reapplications of CRFs after an initial application at the start of the season were larger than plants receiving just one application of CRF at the beginning of the season. However, mid-season reapplication of CRF increased the amount of N leached from the container by as much as 42%. Therefore, growers should base their decision to reapply CRF upon whether or not the extra growth that results will offset the reapplication costs as well as the impact that reapplication could have on the environment (10).

Nutritional analysis of container substrate solution is, therefore, an integral part of maintaining fertility in container systems. Lucas et al. (6) have shown that substrate solution sampling methods based on water extraction of nutrients most accurately represent the actual level of nutrients in the substrate solution. Several methods exist for obtaining substrate solution for analysis from containers. As container size and consequently weight increase, obtaining substrate solution for analysis via methods such as the pour-through extract method (PT) (13) becomes more difficult. SCLs have demonstrated potential for extracting substrate solution for analysis from the large containers [≥18.9 liter (#5)] commonly used in nursery production of woody plants (11, 12). Therefore, the objective of this study was to determine the EC levels of substrate solution extracted by SCLs that are associated with optimal growth of willow oak, a popular landscape shade tree fertilized with a CRF.

Materials and Methods

This research was conducted at the Virginia Polytechnic Institute and State University's Urban Horticulture Center, Blacksburg. Fifty-six container-grown willow oak trees, seeded in January 1999, were potted individually from 18.9 liter (#5) containers into 56.8 liter (#15) plastic containers with unamended pine bark medium as substrate in September 2000. The pot-in-pot method of production was used with sunken containers spaced approximately 1.5 m (5 ft) on center. Seven different application levels [0, 50, 100, 150, 200, 250, and 300 g (0, 1.8, 3.5, 5.3, 7.0, 8.3, 10.5 oz)/container] of Osmocote Plus Northern 15N–3.9P–9.8K (15N–$9P_2O_5$–$12K_2O$), a polymeric resin coated CRF with an 8 to 9 month longevity rating at 21.1C (70F) (Scotts-Sierra Hort. Products Co., Marysville, OH) were surface applied on April 26, 2001. This product also contained micronutrients in the amount of 0.02% boron, 0.05% copper, 0.45% iron, 0.06% manganese, 0.02% molybdenum, and 0.05% zinc. Treatments were replicated eight times and arranged in a completely randomized design. Four containers from each treatment were randomly chosen to receive a 4.8 cm × 61 cm (1.9 × 24 in) ½-bar (50 kPa) lysimeter (SoilMoisture Corp., Santa Barbara, CA) for removal of substrate solution for EC analysis throughout the experiment. Each SCL was installed approximately 20 cm (7.9 in) from the base of the trunk and inserted to the bottom of the container via a previously augered hole with a diameter of approximately 5.0 cm (2 in). After lysimeters were installed, the CRF was surface applied and additional pine bark was then distributed evenly over container surfaces to lightly cover the CRF. When EC levels began to decline, a reapplication rate of 20% of the original amount was applied to each container via top dressing on July 26, 2001, in an attempt to keep EC levels from decreasing. The containers were spray-stake irrigated for 10 to 15 min daily to receive approximately 7.6 liters (~2 gallons) of water each day during the study. Substrate temperatures ranged from 16C to 27C (60 to 80F) during the investigation.

Initial plant height and trunk diameter measurements were taken on April 30, 2001. Trunk diameter measurements were taken 15 cm (6 in) above substrate surface and marked with a painted line so final measurements could be taken from the same point. Twice weekly, May 7 through September 5, 2001, substrate solution samples were removed from the containers using SCLs one to two hours after irrigation. For extraction of substrate solution, approximately 40 kPa of vacuum were created within each lysimeter using a vacuum hand pump (Model 2005G2, SoilMoisture Corp. Santa Barbara, CA) and extraction time ranged from 5 to 10 min to obtain sufficient solution for EC testing [≥ 10 ml (0.34 oz)]. Solution was then removed from the lysimeter using a 50-ml (1.7

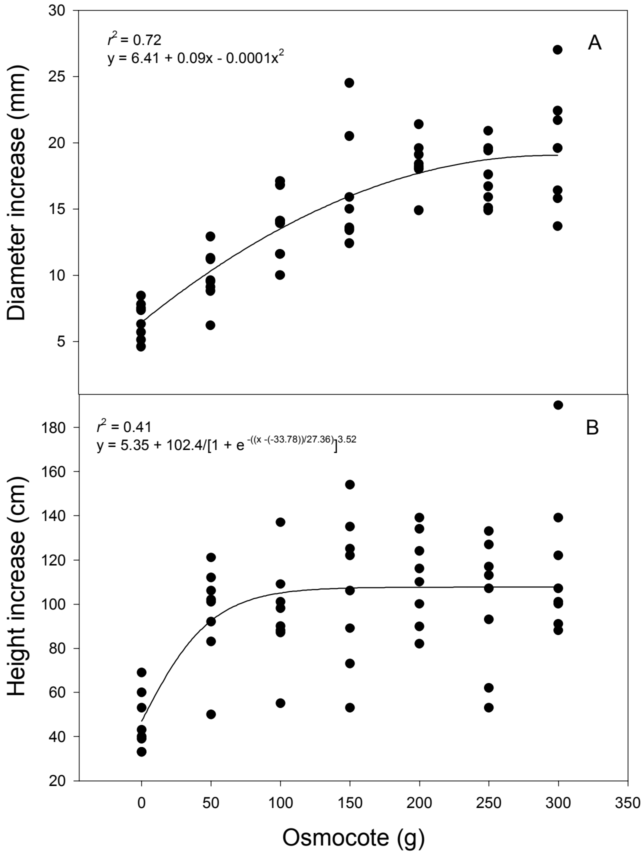

Fig. 1. Effect of Osmocote application rate on trunk diameter increase (A) and height increase (B) of two-year-old container-grown willow oak trees. n = 8 per treatment level. (p_{reg} = <0.001 for A and B)

oz) syringe with plastic tubing. The solution was then tested for EC level using an Agrimeter (Myron L Company, Carlsbad, CA) and EC levels were recorded over time throughout the experiment.

Final height and diameter measurements were taken on September 18, 2001. On September 21 approximately four 2 g (0.07 oz) samples of the most recently fully expanded leaf tissue were removed and dried at 66C (150F) for 5 days. Dried leaf tissue was ground in a Cyclone Sample Mill (UD Corp., Boulder, CO) and weighed. Tissue was digested as described by the Kjeldahl Block Digestor Method (9) and analyzed for total N by colorimetric flow injection analysis or ashed in a muffle furnace for 4 hours for total P, K, Ca, Mg, Fe, Mn, and Zn levels by inductively coupled plasma (ICP) spectrometry. All data obtained during the study were subjected to regression analysis using SigmaPlot (version 5.0, SPSS, Inc., Chicago, IL).

Results and Discussion

Optimal growth (trunk diameter increase) was achieved with an initial application rate of 200 g (7 oz) of Osmocote 15N–3.9P–9.8K at the beginning of the growing season and a 40 g (1.4 oz) reapplication rate on July 26 (Fig. 1). Application rates >200 g (7 oz) resulted in only marginal increases in growth of willow oak. Lower rates of Osmocote (50 to 100 g) gave optimal height, but trunk diameter is a better indicator for economic value than height. Also the relationship between fertilizer rate and height was weak. Gouin and Link (2) found that a wide range of Osmocote rates can be used successfully for woody crops such as Loboy pyracantha (*Pyracantha* X 'Loboy'), Japanese holly (*Ilex crenata)*, common cherry laurel (*Prunus laurocerasus*), creeping juniper (*Juniperus horizontalis*), and old fashion weigela (*Weigela florida)*.

Substrate solution EC levels increased as the fertilizer rate increased. Levels were relatively high from May 30 to July 19 and then began to decrease over time (Fig. 2). The pattern of nutrient release demonstrated in this study was typical for Osmocote, whose release rate is temperature dependent but generally releases a higher amount of nutrients initially, with EC levels decreasing over time (1, 10). After EC levels began to decrease, a reapplication rate that was 20% of the original amount was applied to prevent further decline and to

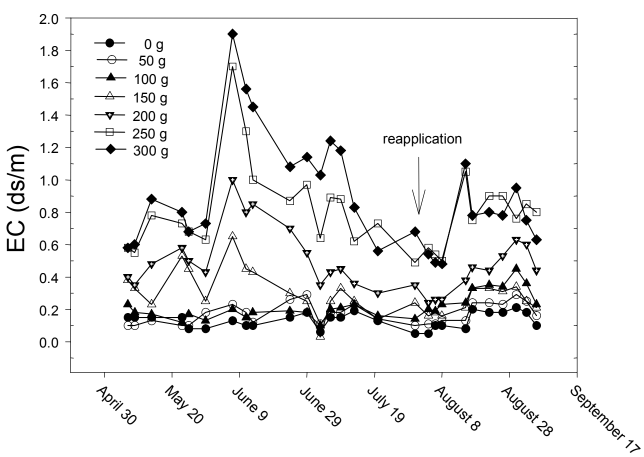

Fig. 2. Effect of Osmocote rate on mean electrical conductivity (EC) levels of substrate solution May 7–September 5, 2001. A reapplication rate, 20% of the original treatment level, was applied on July 26, 2001. See Fig. 3 for growing-season SE of means.

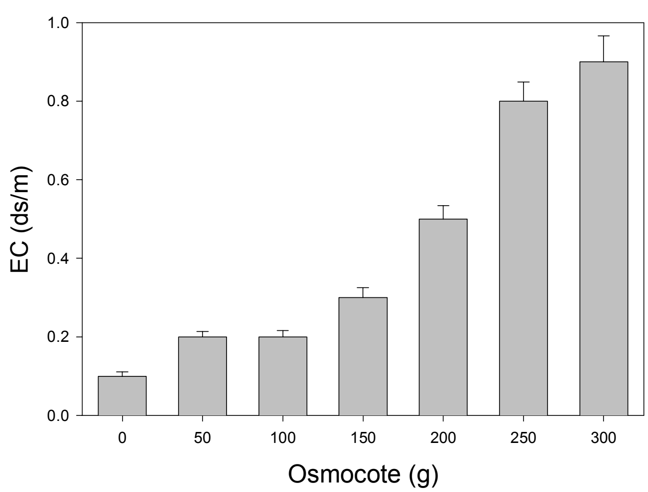

Fig. 3. Electrical conductivity (EC) levels averaged over the growing season of substrate solution as affected by different fertilizer rates. Vertical bars represent ± 1 standard error of the mean (n = 28).

Table 1. **Mean foliar nutrient levels of willow oak at the end of the experiment as affected by fertilizer rate. Samples taken September 21, 2001 (N = 4).**

Osmocote (g)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)
0	1	0.07	0.57	0.66	0.16	29.2	184	19.9
50	1.4	0.1	0.64	0.73	0.18	27.8	175.3	34.4
100	1.8	0.12	0.65	0.76	0.18	35.3	179.5	42.7
150	2.2	0.14	0.61	0.66	0.16	38.3	164	54.1
200	2.3	0.15	0.62	0.65	0.17	42.3	134.7	61.9
250	2.4	0.17	0.66	0.54	0.17	43.4	132.2	59.5
300	2.4	0.17	0.68	0.49	0.15	40.3	116.1	50.5
P-value								
Linear	0.0001	0.0001	0.6574	0.1261	0.5646	0.1142	0.4661	0.0001
Quadratic	0.0001	0.0067	0.8734	0.0046	0.3862	0.3922	0.2822	0.0009
r^2	0.92	0.79	0.08	0.36	0.03	0.14	0.44	0.45

maintain a more even release of nutrients from the CRF. Fertilizer reapplication resulted in a subsequent increase in substrate solution EC for all treatments that received fertilizer (Fig. 2).

Growing season average EC levels for all treatments (Fig. 3) were calculated after the last reading was taken on September 5, 2001, (n = 28 per treatment) and ranged from 0.1 dS/m for the control to 0.9 dS/m for the 300 g (10.6 oz) treatment. The seasonal average EC level associated with the 200 g (7 oz) treatment was approximately 0.5 dS/m (Fig. 3). Substrate solution EC correlated well with trunk diameter increase (Fig. 4). Although EC levels for the 200 g (7 oz) treatment dropped below 0.5 dS/m, maintaining this level with reapplications of the CRF during the growing season would help to assure optimum growth. EC levels for treatments below 200 g (7 oz) were rather steady and relatively low, about the same as the irrigation water (0.1 dS/m). These low EC levels indicate that most mineral nutrients were being used by the plant or leached from the container during irrigation or rainfall events. The EC level at which optimal growth is produced may vary depending upon irrigation water EC, the type of fertilizer used, and irrigation scheduling (10).

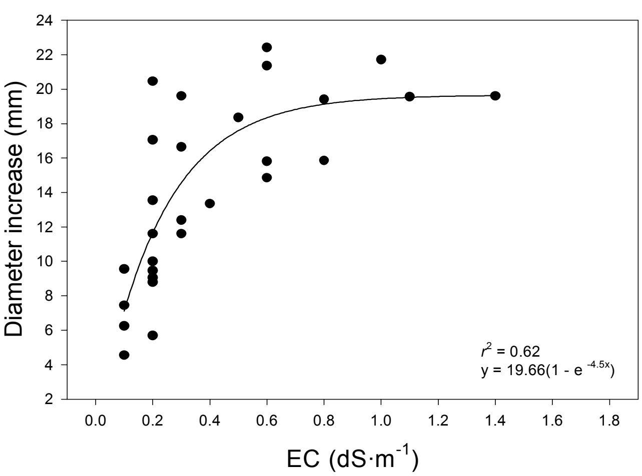

Fig. 4. **Relationship between seasonal average electrical conductivity (EC) level and trunk diameter increase of two-year-old container-grown willow oak trees (n = 28).**

Foliar mineral nutrient levels associated with the 200 g (7 oz) treatment were 2.3% N, 0.15% P, 0.62% K, 0.65% Ca, 0.17% Mg, 42.3 ppm Fe, 134.7 ppm Mn and 61.9 ppm Zn (Table 1). These are comparable to the sufficiency range for willow oak as reported by Mills and Jones (8).

In summary, suction cup lysimeters successfully obtained substrate solution from containers with pine bark substrate for EC analysis throughout this study. The SCLs permitted monitoring of EC levels, which could be assessed so that optimal growth of willow oak could be maintained. We demonstrated that optimal growth of willow oak trees could be produced with an initial application of 200 g (7 oz) of Osmocote at the beginning of the growing season in climates similar to Blacksburg, VA (USDA Hardiness Zone 6A). By applying 200 g (7 oz) Osmocote, as compared to larger amounts, the chance for potential environmental contamination from nutrient-rich runoff is decreased. Subsequent CRF applications may be needed to maintain EC levels of 0.5 dS/m depending upon fluctuations in nutrient release throughout the growth period.

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