Accelerated Pot-in-Pot using Double Cropped Retractable Roof Greenhouse Grown Tree Liners

DISSERTATION

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By

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ABSTRACT

A liner refers to a small plant that is transplanted and grown to become larger. Tree liners are typically produced in the Pacific Northwest of the United States. Even though the Midwestern US has a shorter growing season, many advantages of producing tree liners in retractable roof greenhouses (RRG) in the US Midwest have been previously found. A production system at The Ohio State University (OSU), Columbus, Ohio, using a RRG (Cravo Equipment, Ltd., Bradford, ON, Canada) and containerized tree liner production with or without out planting to pot in pot (PIP) was evaluated in this dissertation.

Bottom heat (BH) mats (Olson Products Inc., Medina, Ohio) used for Fall 2007 plantings at 40°F did not affect the growth of trees when compared to plants at ambient temperature (AT). BH treatment for Fall 2008 plantings at 70°F used during winter promoted the height and caliper of red maple (*Acer rubrum* L. 'October Glory'®) and Avondale red bud (*Cercis chinensis* L. 'Avondale'). Avondale redbud continued to show benefits of BH even 20 months after application in the RRG. Littleleaf linden (*Tilia cordata* Mill. 'Greenspine'®) had a better growth in AT than BH. Red maples and littleleaf linden, planted in Fall, showed larger heights and calipers than those planted in Summer due to better acclimation.

Fertilizer treatments were used on the first year with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks (CR+LF treatment). Fall 2007 plantings with CR+LF produced larger caliper for red maple and taller Avondale redbuds. Littleleaf lindens were not affected by the fertilizer treatments in Fall 2007. Summer 2008 plantings had bigger height and caliper with CR for red maple and Avondale redbud. Littleleaf linden, had a larger caliper with CR 16 months of the treatment.

Geohumus (Geohumus International Gmbh, Frankfurt am Main, Germany) was used as an amendment on the media on the second year of the experiment, where 1% was incorporated at planting. Geohumus promoted caliper growth of littleleaf linden during the early stages of growth in 3 gal. pots in the RRG and 7 gal PIP. Avondale redbuds were the only species that had an interaction between the addition of Geohumus and BH increasing of shoot dry weight. Red maples grew better without the Geohumus amendment.

The PIP system did not significantly impact the growth of littleleaf linden in either 7 gallon or 15 gallon pots. Red maple, in 15 gallon pots produced larger plants when fertilized with CR+LF.

The RRG produced taller plants in 3 gal pots with larger calipers than those plants transplanted to the PIP in the same period of time. Treatments like BH

could be used for red maples and Avondale redbuds to accelerate production. Fertilizer combinations of CR and LF and Geohumus amendments should be further studied on these species. The production of tree liners in a double crop system could be achieved with the combination of methods that could accelerate the growth of each species. The construction of a PIP system may not be necessary if plants are transplanted to 7 and 15 gallon pots and kept inside of the RRG.

DEDICATION

This document is dedicated to my husband, Ausberto José Ramos.

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FIELDS OF STUDY

Major Field: Horticulture and Crop Science

TABLE OF CONTENTS

LIST OF FIGURES

Figure Number Page

LIST OF TABLES

Chapter 1: Introduction

The total forest area in 2005 was estimated to be around 30% of the Planet's land area, just under 40 million km^2 (FAO, 2006). It is estimated that by 2030 there will only be ten percent remaining, with another ten percent in a degraded condition (Wilson, 2002). The benefits of trees are well known but deforestation and urban development continues without measuring the consequences. A single mature tree can release enough oxygen back into the atmosphere to support two human beings (McAliney, 1993; McDonald et al., 2009). However, to counter balance the amount of pollutants a person produces during a lifetime, an estimated amount of 300 trees are needed (McAliney, 1993). Carbon emissions are an increasing issue, climate change and public awareness of protecting the planet including planting of trees has become more important. Methods to accelerate tree production and increasing their survival in the landscape have become an important issue especially in urban areas were the average tree survival is 7 years.

The United States (US) and Canadian nursery/ landscape industries are exhibiting characteristics of a maturing market and the input of innovative production methods to rejuvenate and advance the industry are becoming critical (Hall et al., 2005). In an industry where over 40% of production costs and 20 to

39% of gross sales go to labor, it would follow that the innovations with the greatest gain would occur in increased plant production efficiencies and reduced production times to increase labor utilization. The increasing restrictions being placed on natural resources, especially on watering in landscape sites, also create additional strains on the industry and augment the need for reduced input production practices that ease landscape transplant survival. Systems that improve root growth would be logical choices for increasing labor efficiency and transplant survival. Although 80% of a plant is the above-ground portion (60% trunk, 15% branches, 5% leaves) and only 20% is below ground (5% feeder roots, 15% transport roots) (Perry, 1982), the influence of the roots on plant survival far surpasses their contribution in mass. More than 50% of the $26 Bn wholesale production of woody nursery crops in the US is produced in containers (Mathers et al., 2007a). Part of container popularity results from increased root growth and survival versus field production.

In recent years, increased interest in retractable roof greenhouses (RRG's) and pot-in-pot (PIP) systems to accelerate tree liner/caliper production has occurred (Mathers, 2006; Mathers et al., 2007a). PIP and RRG's as *production systems* to manipulate the growing environment have been shown to increase root mass (Ruter, 1995; Stoven et al., 2006) and improve plant adaptation to stress (Mathers et al., 2007a) versus conventional container or bare-root grown plants. Root dormancy as a *physiological process* to manipulate plant growth is unexplored in ornamentals.

Geohumus is a mineral that is formed from volcanic rock flour, clay minerals and silicates. This material stores waters that can be available to the plants. Geohumus can store at least 40 times its own weight in water and releases it back to the roots as needed. Geohumus increases the heat storage capacity of the soil in the immediate vicinity along with it. As a result, frost damage from temperature fluctuations are near the freezing point is buffered. Media Geohumus amendments that increase plant water use efficiency during production and could potentially carry through production to increase transplant survival in landscapes has also not been explored (Hummel et al. 2007) nor has the impact on multiple container transplants or varying times of media amending.

Although RRG's, PIP, root dormancy and Geohumus media amendments offer opportunities to manipulate root growth for maximum production gains, limited information is available regarding root morphology, anatomy and growth subsequent to the manipulations they afford.

Chapter 2: Acceleration of Containerized Tree Liners Using Bottom Heat

Introduction

There is no consensus regarding root dormancy in woody plants. Romberger (1963) states that dormancy does not occur in roots (Romberger, 1963). In some plants, the roots continue to grow in the fall and throughout the winter-whenever soil temperatures are above 40 °F (5 °C) (Crider, 1928; Hammerle, 1901; Ladefoged, 1939). This is the case in peach (*Prunus persica*), where roots can apparently grow anytime during the winter that soil temperatures and moisture are adequate (Okie and Nyczepir, 2004). Other examples of temperate zone woody plants that have *no* root dormancy are *Magnolia virginiana* (Mathers, 2008) Arizona cypress (*Cupressus arizonica*) and apricot (*Prunus armeniaca*) (Crider, 1928).

Optimum root temperatures seem to exist and it is tree species specific and has a significant effect on stress tolerance (Lyr, 1996). Trees from which an optimum root temperature have been reported are *Tilia cordata* (Lyr and Garbe, 1995); *Pinus sylvestris* (Lyr, 1996), *Picea abies* (Lyr, 1996; Vapaavuori et al., 1992), *Acer rubrum* (Graves et al., 1989), *Gleditsia triacanthos inermis* (Graves, 1988),

Pseudotsuga menziesii (Heninger and White, 1974; Lyr, 1996), *Quercus robur*, *Larix decidua*, *Pinus nigra*, *Carpinus betulus*, *Betula verrucosa* and *Acer pseudoplatanus* (Lyr, 1996).

Acer rubrum and *Tilia cordata* have an optimum root zone temperature of 86ºF (30ºC) and 68ºF (20ºC), respectively (Graves et al., 1989; Lyr and Garbe, 1995). No experiment has been done where the root temperature is above 40ºF (5ºC) during winter to see if these species have true root dormancy or if the increase in temperature can promote root growth when the shoot is dormant.

The objectives of this study are: 1) evaluate the growth of landscape trees from cell (plugs) to 3 gal black rounded pot and 2) explore root dormancy using bottom heat temperatures as means of manipulating plant growth to significantly reduce production times.

Materials and Methods

Plants were grown inside the peaked Retractable Roof Greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, Ontario, Canada) at The Ohio State University (OSU), Columbus, Ohio. A MicroGrow controller (MicroGrow Systems, Temecula, California) operated the RRG roof and sidewalls according to external ambient temperature settings, closing roof and sidewalls at outdoor temperatures of 70° F during the day and 50° F at night from April to December. The RRG was covered with a clear woven-polyethylene film with a glazing of 35% shade covering (RC02; Cravo Equipment). From December to April, the roof and sides

of the RRG remained closed and a propane heater was activated at 28°F to protect the plants from freezing temperatures. Plants were grown in 3-gallon, black round containers (Nursery Supplies Inc., Fairless Hills, PA) in a soilless mix (Kurtz Brothers Inc.) of 60% pine bark, 20% rice hulls, 10% sand, 5% composted sewage sludge (Com-Til, Lockbourne, Ohio) and 5% stone aggregate by volume.

Plantings were started in October of 2007 and 2008. From December to March plants were separated into two groups: one with bottom heat (BH) using low watt propagation mats applied (Olson products Inc., Medina, Ohio) and a control group at ambient temperature (AT). October 2007 plantings were grown with a BH of 40ºF. October 2008 plantings started with a BH of 40ºF and were increased to 70ºF in January 2009.

For each crop, three landscapes species grown from tissue culture (North American Plants, LLC, Lafayette, Oregon) were planted in the RRG, red maple (*Acer rubrum* L.'October Glory®'), littleleaf linden (*Tilia cordata* Mill. 'Greenspire®') and Avondale redbud (*Cercis chinensis* L. 'Avondale'). All plants were trained to a 5 or 6' bamboo stakes (A.M. Leonard, Inc.) of half an inch in diameter and attached to the stakes with grafting tape (A.M. Leonard, Inc.).

Year one, Fall 2007

All the trees species had a starting height of 7.62 cm. The October 2007 plantings either receive bottom heat (BH) or remained at ambient temperature (AT). Beginning in April 2008, plants either received a top dressing of controlled

release (CR) fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. The same total nitrogen was calculated to be delivered in the CR and the CR+LF treatments. Plants were arranged in a split plot design (main plot-temperature, subplot – fertilizer) with 4 replications. Thirty four plants per species per treatment were assigned per four treatments AT CR, AT CR+LF, BH CR, and BH CR+LF.

From October 2007 to December 2007 plants were irrigated using sprinkler head irrigation 3 times per day (7:00am, 11:00am and 3:00pm) for 5 minutes applying approximately 1.7mm of total water per pot. During winter, plants were watered as needed. From April 2008 to August 2008 plants received 500 ml of water in 3 events: 7:00am, 10:00am and 2:00pm, per day, per pot, using spaghetti tubing of one eight of an inch (Roberts Irrigation Products, Inc., San Marcos, California) with Orange Mini Flow emitters with a 160° Spray pattern (SS-AG160LGN-100, Roberts Irrigation Products, Inc., San Marcos, California).

On November 2, 2007, 70 dead red maples were replaced with new plants (North American Plants, LLC, Lafayette, Oregon) of the same size (7.62cm) as planted in October 2007. A random sample of plants was evaluated in December 2007 and April 2008 and measures of root volume were taken. Root volume was measured by calculating the water displaced by the roots in a volumetric cylinder.

Many Avondale redbud trees died during overwintering and only the fertilizer treatment could be evaluated.

Plants grew slowly so destructive sampling evaluation was delayed from the original time of June 2008 to August 2008. In August 2008 plants were 11 months old when evaluated for height and caliper, taken at 2.4 cm above the soil. Three plants per treatment were randomly selected to evaluate leaf area using a model Li-3100 leaf area meter (LI-COR, Inc. Lincoln, Nebraska). The substrate was washed from the root system and the plants were pruned at the root collar. The shoot and leaf tissues were combined in paper bags. Roots were placed in separate paper bags. Roots and shoots were oven dried for one week at 54°C (Blue M Electric Forced-Air Drying Ovens, Williamsport, Virginia). Shoot and root dry weights were measured. All measures were analyzed using PROC GLM with SAS software (SAS Institute, Inc., Cary, NC). Treatments were compared using least significant differences (LSD) with $\alpha = 0.05$.

Year two, Fall 2008

The same cultivars as Fall 2007 were used and received in different sizes (North American Plants, LLC, Lafayette, Oregon): red maples were 7.62cm tall as in Fall 2007, Avondale redbuds and littleleaf lindens were 15.64cm and 25.4cm tall, respectively. A total of 34 plants per species per treatment were planted in the same soilless media as in Fall 2007 with either 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without

amendment (0G) on October 1, 2008. Plants were arranged in four randomized blocks. All plants were top dressed at potting with CR fertilizer, 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.). Irrigation was the same as Fall 2007. From December 2008 to March 2009 plants received either BH or AT as in Fall 2007. BH was increased to 70°F in January 2009. Treatments consisted of 0G AT (as a control), 0G BH, 1G AT and 1G BH.

One sub-sample of each of the four replications was randomly selected and substrate was washed from the root system in April 2009. Root and shoot dry weights were measured as in Fall 2007 (August 2008 evaluation). No destructive sampling was made to red maples to leave a complete set of plants to be evaluated later. On June 2009 and October 2009 height and caliper of all plants were measured and destructive samples were taken as for Fall 2007 planting.

Results and Discussion

Year one, Fall 2007

April 2008 Evaluation

Root volume of red maples and littleleaf lindens, measured in April 2008, were similar between BH and AT (Table 2.1). No difference was observed in the time of bud break.

August 2008 Evaluation

Red maple trees still showed no difference in growth between BH and AT for all measures (Table 2.2) in the August 2008 evaluation. There were no treatment differences on littleleaf linden trees in height, caliper and leaf area (Table 2.2). However, root (Table 2.2) and shoot (Table 2.2) dry weights were larger when grown in AT. These results demonstrate that these species react differently to root temperatures. Red maples being non-affected could indicate that they have root hardiness or 40ºF was not a sufficient temperature to stimulate growth. The reduced shoot and root mass at 40ºF for littleleaf linden could indicate root dormancy does exist for this species. In an 2007 experiment plants with true root dormancy showed root deterioration when growing in heat mats (Mathers, 2008).

Romberger (1963) indicates that a temperature above 40ºF (5ºC) is needed in order to continue root growth through winter. The plants used for this experiment were very small with roots in the top quartile of the pot. The sensor for the bottom heat was placed in the middle of the pot. The sensor should have been placed near the roots in order to ensure that the temperature set was what the roots received. The temperature was increased on the next experiment (Fall 2008) so higher temperatures were reached in the top quartile, again to see if higher temperatures could promote root growth in these species. The optimum growth of red maple and littleleaf linden is obtained when root temperature is 86°F (30°C) (Graves et al., 1989), and 68°F (20°C) (Lyr and Garbe, 1995), respectively. This indicates that littleleaf linden has a preference for colder root

temperature than red maple. Perhaps, the protection of the RRG to extreme temperatures in the pot media during winter was sufficient for littleleaf linden root and shoot mass growth and the addition of BH was not necessary.

Species	Temperature treatment	Root volume (ml)
Red maple	AT	1 a
	BH	1 a
	Significance	NS
Littleleaf linden	AT	2 a
	BH	2 a
	Significance	NS

Table 2.1. Root volume (ml) evaluated in April 2008 on the trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red maples (*Acer rubrum* L. 'October Glory'®) and littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Different letters signify least significant differences (LSD) P=0.05, NS non-significant.

Species	Temperature treatment	Average Growth Parameters				
		Height (cm)	Caliper (mm)	Leaf area (mm^2)	Root dry weight (gr)	Shoot dry weight (gr)
Red maple	AT	93 a	7.7 a	1762.3 a	15.1 a	25.6a
	BH	98 a	7.9 a	2263.0 a	18.5 a	33.6 a
	Significance	NS	NS	NS	NS	NS
	AT CR	91 a	7.3 a	2272.3 a	14.9 a	28.4 a
	AT CR+LF	95 a	8.0 a	1252.2 a	15.2 a	22.8 a
	BH CR	97 a	7.3 a	2526.9 a	18.6 a	36.4 a
	BH CR+LF	98 a	8.3 a	1999.1 a	18.5 a	30.7 a
	Significance	NS	NS	NS	NS	NS
Littleleaf linden	AT	106 a	8.5 a	1791.5 a	19.2 a	29.7 a
	BH	109 a	8.7 a	1352.9 a	12.4 b	19.4 b
	Significance	NS	NS	NS	*	*
	AT CR	106 a	8.5 a	1927.4 a	20.0 a	32.5 a
	AT CR+LF	107 a	8.5 a	1655.6 a	18.4 a	26.9 a
	BH CR	107 a	8.3 a	1208.4 a	10.1 a	17.5 a
	BH CR+LF	110 a	9.1 a	1497.3 a	14.8 a	21.3 a
	Significance	NS	NS	NS	NS	NS

Table 2.2. Growth measures evaluated in August 2008 for the trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Different letters signify least significant differences (LSD) P=0.05, NS non-significant.

Year two, Fall 2008

April 2009

Root dry weight of 7 months old littleleaf linden and Avondale redbud trees were not affected by BH (Table 2.3) when measured in April 2009. However, littleleaf linden trees had a higher shoot dry weight with BH than AT (Table 2.3). This was contrary to the Fall 2007 results where there were no difference in shoot growth (visual observation) in April 2008 evaluation. This increase in growth could be associated with the increase in BH temperature to 70°F. Another difference was that Fall 2007 plants started at 7.62cm versus Fall 2008 25.4cm. Larger plants could have been able to benefit from BH versus smaller plants.

Avondale redbuds had a significant interaction with Geohumus (Figure 2.1), where the combination of Geohumus and bottom heat (1G BH) provided the largest weights (Table 2.3). According to the Missouri Botanical Garden, Avondale redbud growth is inhibited by dry soils (Stentz, 2010). The increase of water content in the media by the addition of Geohumus could have maintained the right amount of water to improve the shoot growth of this species. Avondale redbud is USDA zone a 6 to 9 plant for cold hardiness; warmer temperatures during the production of this tree may increase its growth. Not enough plants of red maple were available for April 2009 random sampling to evaluate BH effects.

The plants received in Fall 2008 were larger than for Fall 2007 and dry weights could be evaluated. Fall 2007 plants were very small and only root volumes could be evaluated. As in Fall 2007, it appeared that littleleaf linden showed a true root

dormancy. Avondale redbud may also have true dormancy; however in combination with Geohumus shoot growth was promoted. The shoot dry weight increase of these species could be related to a difference in bud break. Plants with BH had an earler bud break than AT by at least one week (Figure 2.2). Avondale redbuds had an average bud break date of March 29 in China (Luo et al., 2007). Littleleaf linden in a Mediterranean type of climate have a mean bud break in Aprill 11 and could be as early as March 3 (Santanen and Simola, 2007). The bud break in this experiment was before April 2, 2009 for all the species (Figure 2.2). Others have found that bud break is initiated by increasing air temperature (Lyr and Garbe, 1995).

June 2009

Red maple trees evaluated in June 2009 at 11 months old showed no difference between BH and AT for the measures of leaf area, root and shoot dry weights (Table 2.4). However, caliper measures were larger in plants grown in BH (Table 2.4). Heights were also larger with BH (Table 2.4). A significant interaction with Geohumus also existed for height with maple (Figure 2.3). No Geohumus (0G) with BH promoted the largest plant heights. Perhaps the Geohumus was holding more water in the media and higher temperatures in the BH may have been needed to increase the temperature due to extra water in the media. The plants with 1% Geohumus may have experienced colder temperatures than plants without the Geohumus. *Acer rubrum* has its optimum growth at 86ºF (30ºC) (Graves et al., 1989), so this species prefers higher temperatures in the root.

These results demonstrate that root temperatures of 40ºF (5ºC) used in Fall 2007 do not promote red maple root or shoot; however, 70ºF used in Fall 2008 promotes shoot extension and diameter growth. *Acer rubrum* may have true root dormancy but shoot growth can be promoted by increased root temperatures.

Littleleaf linden leaf area and shoot and root dry weight (Table 2.4) were non-significant for BH and AT. However, height and caliper growth were significantly improved for littleleaf linden with AT (Table 2.4). As with the Fall 2007 experiment, Fall 2008 littleleaf linden plants had significantly better shoot growth with AT evaluated in June 2009 versus BH plants (Table 2.4). Shoot dry weight increases observed in April 2009 with BH did not continue to June 2009. Littleleaf linden has its optimum growth when the root temperature is at 68ºF (20ºC) (Lyr and Garbe, 1995). The optimum growth was determined with one-year-old trees and the temperature was controlled between March (started at bud break) and July (Lyr and Garbe, 1995). In contrast, the root temperature in our study was controlled from December to March and stopped at bud break. Perhaps continuation of the bottom heat treatment could have been beneficial for this species. Littleleaf linden may have true root dormancy; however, an increase of root temperature was beneficial in early spring for shoot growth.

Avondale redbud tree results were similar to those of red maples as shoot and root dry weights (Table 2.4) were not significantly different. Height and caliper, as with Avondale redbud were greater with BH (Table 2.4). Leaf areas (Table 2.4) were also significantly larger for Avondale redbuds with BH treatment. This is the

only species where leaf areas were significantly increased. Leaves of Avondale redbuds are larger than those at either littleleaf linden or red maple. The early bud break of the Avondale redbuds resulted in significantly larger leaves with BH treatment. The larger leaf area could also be achieved by the addition of 1G treatment (Figure 2.1).

Species	Treatment	Growth Parameters	
		Shoot dry weight (gr)	Root dry weight (gr)
Littleleaf linden	AT	0.8 b	1.7 a
	BH	1.2 a	1.5 a
	Significance	*	NS
Avondale redbud	AT	0.4 b	0.5 a
	BH	1.1 a	0.5 a
	Significance	*[z]	NS

Table 2.3. Shoot and root dry weight (gr) evaluated in April 2009 to the trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Means are over Geohumus treatments. Different letters signify least significant differences (LSD) P=0.05, NS non-significant. [z] Interaction with Geohumus *P* = 0.0538

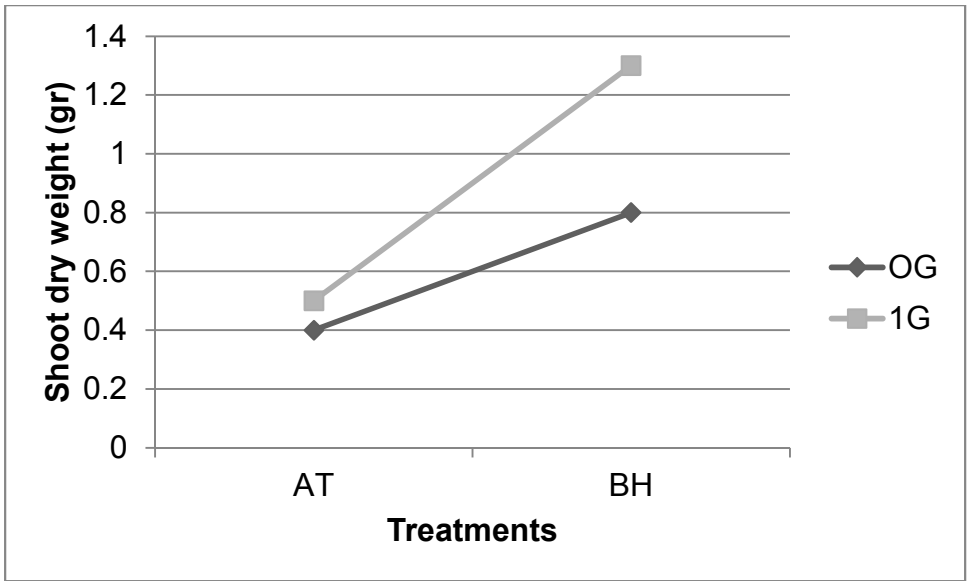

Figure 2.1. Interaction of treatments on shoot dry weight (gr) evaluated in April 2009 to Avondale redbuds (*Cercis chinensis* L. 'Avondale') trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Avondale redbuds were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Interaction *P* = 0.0538.

Figure 2.2. Red maple (*Acer rubrum* L. 'October Glory'®) (furthest in the background), Avondale redbuds (*Cercis chinensis* L. 'Avondale') (center) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) (foreground) from Fall 2008 planting at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) (left) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) (right) from December 2008 to March 2009. Plants in BH had an early bud break than plants in AT, showing more plants with open and expanded leaves for all three species. Avondale redbud was the most obvious and the first to bud break. Picture was taken on 4/2/2009 by Dania Rivera.

Species	Treatment	Growth Parameters				
		Height (cm)	Caliper (mm)	Leaf area (mm^2)	Root dry weight (gr)	Shoot dry weight (gr)
Red maple	AT	103 b	5.6 b	2837.9 a	24.7 a	4.1 a
	BH	115 a	7.0 a	2373.7 a	20.9 a	3.4 a
	Significance	*	*	NS	NS	NS
	Temp*Geohumus	**	NS	NS	NS	NS
Littleleaf linden	AT	119 a	7.3 a	1260.2 a	10.6 a	5.8 a
	BH	108 b	7.0 b	1167.3 a	10.4 a	4.0 a
	Temperature	*	*	NS	NS	NS
Avondale redbud	AT	47 b	3.7 b	1000.3 b	6.4 a	2.0 a
	BH	56 a	4.4 a	1367.6 a	8.6 a	2.6 a
	Temperature	***	***	*	NS	NS

Table 2.4. Growth parameters evaluated in June 2009 on trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany) or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Means are over Geohumus treatments. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

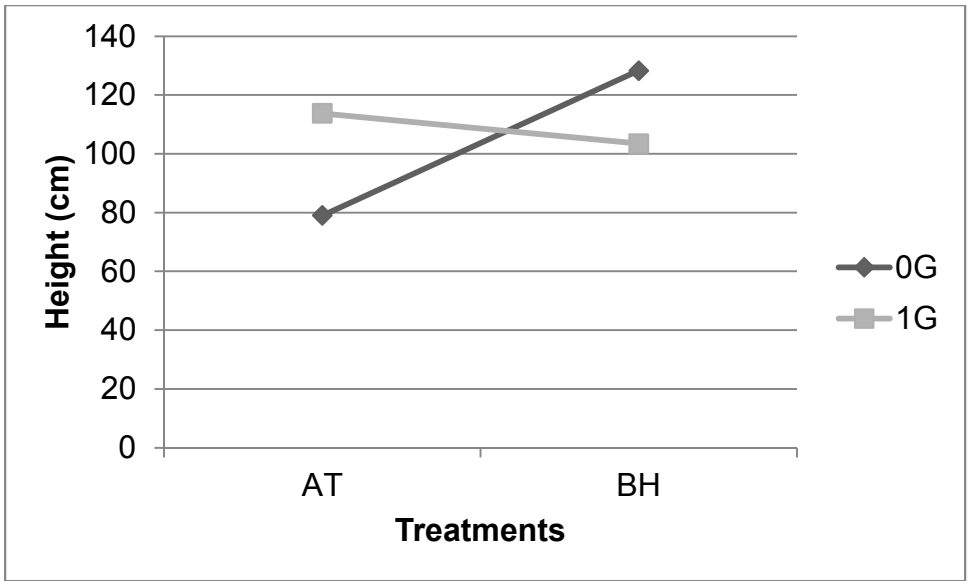

Figure 2.3. Interaction of height (cm) evaluated in April 2009 to red maples (*Acer rubrum* L. 'October Glory'®) trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red maples were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009.

Conclusion

Bottom heat treatment affected the growth of the trees in this experiment. Red maples and Avondale redbuds had an increase in height and caliper when the temperature in the media during winter was increased to 70ºF but not with a temperature of 40ºF. Red maples have an optimum root temperature for maximum growth at 86ºF (30ºC) (Graves et al., 1989). These trees could benefit from receiving a BH treatment with an extension past bud break. This difference in height and caliper could mean larger trees in marketable sizes grown during the winter months in the Midwest.

Not all species responded equally to BH. Littleleaf linden had a larger shoot mass with BH when measure in April 2009 but two month later plants shoot growth was higher in AT and shoot mass was not different. The optimum root temperature for maximum growth of littleleaf linden is 68ºF (20ºC) and extension growth responds strongly to root temperatures (Lyr and Garbe, 1995). As the RRG protect the plants from extreme temperatures, the addition of BH may not be necessary for littleleaf linden.

Higher root temperatures for red maples and Avondale redbuds during winter and extending bottom heat temperatures after bud break could be the focus of future experiments. Additionally, a cost analysis of the additional growth versus the energy used for bottom heat and the examination of the possible moisture

content interaction of Geohumus and shoot growth in Avondale redbud should be conducted.

Chapter 3: Double Crop System

Introduction

A tree liner is a small tree with a height and caliper ranging from 120 to 240cm and 12.7 to 19.1mm, respectively. Many growers import liners from the West Coast due to the larger growing season (Case and Mathers, 2006; Mathers et al., 2004). One way to extend the growing season in the Midwest is using protective structures like the retractable roof greenhouse (RRG). Many advantages of using the RRG have been reported including: nitrogen use efficiency, increased growth, reduced heat stress, extended growing season (Stoven et al., 2006) and shorter production times (Mathers, 2003). Previous studies in the OSU RRG suggest that time of production could be reduced for red maple and Eastern redbud (Stoven et al., 2006) and that even difficult-to-grow species can be produced in Ohio with good results (Mathers et al., 2006; Mathers et al., 2007b). There is no previous experiment where the RRG is use for a double crop system. Double crop system consists in the completion of two crops, from seedling to liner, in one year, doubling the crop production in the same space.

Double cropping in the Midwestern US would add value and make construction more affordable to the RRG (Mathers, 2003). Prices for flat-roof houses typically

run about @8.82/ft^2 and peaked-roof houses are $10.00/ft^2 (Cravo Equipment, Brantfort, ON, Canada, 2010, personal communication). Double crop could be possible in a peaked roof greenhouse because the roof can be closed and supplemental heat added in the winter (Mathers, 2003). Double cropping could also help growers distribute labor over the entire year and reduce labor demands in spring. Other methods to increase growth during winter such as bottom heat mats, media amendments and fertilization regimens could be explored in conjunction with double cropping. Bottom heat during winter could increase growth of some plant organs depending on the tree species and temperature (see Chapter 2). Media amendments like Geohumus could promote root growth by adding available water in the media and by increase heat storage capacity (Personal communication, Christian Bruns, 2009).

This study has three objectives: 1) evaluate the growth of landscape trees from cell (plugs) to 3 gal black rounded pot when grown double cropped (6-month) versus a twelve- month-cycle in a RRG; 2) evaluate the time of planting (fall versus summer) on the plant growth; and 3) explore root dormancy and Geohumus media amendments as means of manipulating plant growth to significantly reduce production times.

Materials and Methods

Plants were grown inside the peaked Retractable Roof Greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, Ontario, Canada) at The Ohio State University

(OSU), Columbus, Ohio. A MicroGrow controller (MicroGrow Systems, Temecula, California) operated the RRG roof and sidewalls according to external ambient temperature settings, closing roof and sidewalls at 70° F during the day and 50° F at night between April to December. The RRG was covered with a clear woven-polyethylene covering (RC02; Cravo Equipment Ltd., Brantford, ON, Canada). From December to April, the roof and sides of the RRG remained closed and a propane heater was activated at 28°F to protect the plants from freezing temperatures. Plants were grown in 3-gallon, black round containers (Nursery Supply Co.) in a soilless mix (Kurtz Brothers Inc.) of 60% pine bark, 20% rice hulls, 10% sand, 5% composted sewage sludge (Com-Til, Lockbourne, Ohio) and 5% stone aggregate.

In order to double crop, trees were started in October 2007 and 2008 and in June 2008 and 2009. Some plants were grown either October to June, June to October or for one year, October to October or June to June, before planting into a pot in pot (PIP) system. October plantings either received bottom heat (see Chapter 2) from December to March or remained at ambient temperature (AT) as the control. June plantings were grown only at AT. For each crop, three landscapes species grown from tissue culture (North American Plants, LLC, Lafayette, Oregon) were planted in the RRG. All plants were trained to a 5 or 6' bamboo stakes (A.M. Leonard, Inc.) of half an inch in diameter and attached to the stakes with grafting tape (A.M. Leonard, Inc.).

Year one, Fall 2007

Red maple (*Acer rubrum* L. 'October Glory®'), littleleaf linden (*Tilia cordata* Mill. 'Greenspire®') and Avondale redbud (*Cercis chinensis* L.) were planted in the RRG in October 2007 (Table 3.1). All the trees species had a starting height of 3 inches. October plantings either receive bottom heat (BH) or remained at ambient temperature. Beginning in April 2008, plants either received a top dressing of controlled release (CR) fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scotts Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. The same total nitrogen was delivered in the CR and the CR + LF treatments. Plants were arranged in a split plot design (main plot- temperature, subplot – fertilizer) with 4 replications. Thirty four plants per species per treatment were assigned per four treatments AT CR, AT CR+LF, BH CR, and BH CR+LF.

From October 2007 to December 2007 plants were irrigated using sprinkler head irrigation 3 times per day (7:00am, 11:00am and 3:00pm) for 5 minutes applying approximately 1.7mm of total water per pot. During winter plants were watered as needed. From April 2008 to August 2008 plants received 500 ml of water (per pot) in 3 events, 7:00 am, 10:00 am and 2:00 pm per day, using spaghetti tubing

of one eight of an inch (Roberts Irrigation Products, Inc., San Marcos, California) with Orange Mini Flow emitters with a 160° Spray pattern(SS-AG160LGN-100, Roberts Irrigation Products, Inc., San Marcos, California).

In November 2, 2007, 70 dead red maples were replaced with new plants (North American Plants, LLC, Lafayette, Oregon). A random sample of plants was evaluated in December and April and measures of root volume were taken. Many Avondale redbud trees died during overwintering and only the fertilizer treatment could be evaluated.

Plants grew slowly so destructive sampling evaluation was delayed by one more month from June 2008 to August 2008. In August 2008 at 11 months height and caliper (taken at 2.4 cm above the soil) of all plants were evaluated. Three plants per treatment were randomly selected to evaluate leaf area using a model Li-3100 leaf area meter (LI-COR, Inc. Lincoln, Nebraska). The substrate was washed from the root system and the plants were pruned at the root collar. The shoots and leaf tissues of each plant were combined in paper bags. Roots were placed in separate paper bags. Roots and shoots were oven dried for one week at 54°C (Blue M Electric Forced-Air Drying Ovens, Williamsport, Virginia). Shoot and root dry weights were measured.

Electrical conductivity (EC), pH and nitrate nitrogen (NO^3) were also measured using a pour through procedure (Ruter and Garber, 1998) from April to August. The measures were analyzed using PROC GLM with SAS software (SAS Institute, Inc., Cary, NC). Treatments were compared using least significant

differences (LSD) with $\alpha = 0.05$. Unfortunately, due to plant loss during the experiment, there were not enough plants for a whole set of replications per treatment to be left in the RRG to grow on for a full year as originally planned.

Planting	Oct. 07	June 08	Aug. 08	Oct. 08	June 09	Oct. 09	June 10
Fall 2007	P		M/D				
Summer 2008		P		M	M/D		
Fall 2008				P	M/D	M/D	
Summer 2009					P	M/D	M/D

Table 3.1. Double crop timeline. Four crops, Fall 2007, Summer 2008, Fall 2008 and Summer 2009, were double cropped The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Planting (P) occurred either in October or June for Fall and Summer crops respectively. Measurements (M) evaluation of height and caliper of all plants were taken. Destructive samples (D) to evaluate leaf area, shoot and root dry weights were made for all crops before moving to a PIP system.

Year one, Summer 2008

Summer planting occurred in June 18, 2008, using the same species and fertilizer treatments as in the Fall 2007 planting (Table 3.1). Fertilizer was applied at potting. Plants were arranged in a split plot design (main plot fertilizer) with 4 replications. Irrigation was similar to Fall 2007. The destructive sampling was scheduled for October 2008. Only height and caliper were taken at this time. The plants were not yet of commercial size so the experiment was extended to June 17, 2009. Four plants per treatment of each specie were destructively evaluated for the same growth plant and media characteristics as measured and analyzed for the Fall 2007 planting.

Year two, Fall 2008

The same cultivars as the Fall 2007 and Summer 2008 plantings were used but received in different sizes (North American Plants, LLC, Lafayette, Oregon): red maples (7.62cm tall), Avondale redbuds (15.24cm tall) and littleleaf lindens (25.4cm tall). A total of 34 plants per species per treatment were planted in the same soilless media as in 2007 with either 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) on October 1, 2008 (Table 3.1). Plants were arranged in four randomized blocks. All plants were top dressed at potting with CR fertilizer, 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scotts). From December 2008 to March 2009 plants were separated in two groups: one with

bottom heat (BH) using low watt propagation mats (Olson products Inc., Medina, Ohio) and a control group at ambient temperature (AT). Bottom heat started at 40ºF and was increased to 70ºF in January 2009. Treatments consisted of 0G AT (as a control), 0G BH, 1G AT and 1G BH. The RRG was maintained at 28°F during winter cropping. Harvest occurred in June 2009 and October 2009. Measurements consisted of height, caliper (taken at 2.4 cm), leaf area, and shoot and root dry weights similar to Fall 2007 and Summer 2008. The measures were analyzed using PROC GLM at a least significant differences with $\alpha = 0.05$ using SAS software (SAS Institute, Inc., Cary, NC).

Year two, Summer 2009

The landscape tree species, red maple, littleleaf linden were the same species as Fall 2007, Summer 2008 and Fall 2008 plantings. Signature ™ Japanese tree lilac (*Syringa reticulate* 'Sigzam') (North American Plants, LLC, Lafayette, Oregon) was use to substitute Avondale redbud, which had proved non-hardy in Ohio winters. All trees were planted in June 18, 2009 (Table 3.1). Red maple (15.24 cm tall) and little leaf lindens (7.62 cm tall) were grown from tissue culture, Japanese tree lilac (7.62 cm tall) were obtained from cuttings. Plants were potted into soilless media with or without 1% of Geohumus by volume and fertilized as for the Fall 2008 planting. Measurements and destructive samples occurred during October 2009 and June 2010. Measurements and evaluations were the same as for the Fall 2008 planting.

Results and Discussion

Year one, Fall 2007

August 2008 Evaluation

Red maple trees showed no significant differences of the main effect of temperature for any of the measures (Table 3.2). The main effect of fertilizer treatment was significant for caliper with the combination treatment of CR+LF providing increased caliper measures (Table 3.2).

Littleleaf linden trees had a significantly larger root (Table 3.2) and shoot (Table 3.2) dry weights with AT when evaluated 10 months after planting. Height, caliper and leaf area were not significantly different for the main effect of temperature. Fertilizer treatment was also non-significant for any parameter evaluated (Table 3.2).

Avondale redbud trees, which were planted in June 16, 2008, were significantly taller with CR+LF fertilizer treatment (Table 3.2). Caliper, leaf area, root and shoot dry weights were not affected by fertilizer treatment (Table 3.2).

The EC of a substrate solution is indicative of the fertilizer level that is available to plant roots (Ruter and Garber, 1998). The EC measures done during this experiment with the pour through method (Ruter and Garber, 1998) were similar for CR and CR+LF treatments (Figure 3.1). The recommended pour through values for nursery containers are 0.5 to 1 mS/cm with a CR fertilizer for nursery crops (Florida container nursery best management practices guide, 2006) LF

should have an EC between 0.8 and 1.5 mS/cm (Florida container nursery best management practices guide, 2006). The values in this study were in the acceptable EC range. Environmentally, there are no federal guidelines or regulations regarding EC (as a measurement of all dissolved salts), other than that soluble salts (based on total chloride and sulfate) should not exceed 250 mg/L (Newman et al., 2006).

The recommended range for pH for nursery soilless media is 5.4 to 6.2. The pH values ranged from 3.7 to 5.2 (Figure 3.2). In June, pH declined sharply probably by the increase in temperature during summer that could promote an increase in release of CR fertilizer, but was back to normal values in July. Substrate pH can affect the availability of nutrients by the plants (Argo, 2003). Although our plants did not show any symptom of deficiency, it is possible nutrients were limiting in this period. The adequate amount of NO_3 using the pour through method should be between 15 to 25 ppm for a controlled release fertilizer and between 50 to 100 ppm for liquid fertilizers (Florida container nursery best management practices guide, 2006). In this study both fertilizer treatments provided supra-optima NO_3 (Figure 3.3). Previous studies in the OSU RRG used similar fertilization practices and also obtained higher nitrate readings ranging from 20 to 200 ppm (Stoven et al., 2006) as in this experiment. In an effort to improve nutrient use efficiency and reduce nutrient run off, controlled release fertilizers are been used (Newman et al., 2006). However, the fluctuation in nitrate during the experiment may be associated with physical or chemical reactions such as mineralization, binding

and denitrification in the media (Merhaut et al., 2006; Newman et al., 2006; Stoven et al., 2006). The maximum concentration level for NO_3 is 10mg/L for domestic water use (EPA, 1976). In plant production, probably could lecheates NO_3 higher than 10mg/L in the first few months of production when plants are small and do not have a sufficient root system to absorb all the nutrients supplied (Merhaut et al., 2006; Newman et al., 2006). Trees planted in Fall 2007 demonstrated a significant increase caliper with the combination of CR+LF.

For commercial purposes, the height and caliper of plants (after 10 months) started on Fall 2007 were smaller than the desired size of four feet (120 cm) and one-half of an inch (12.7mm), respectively. Red maple plants were in average around three feet tall (90 cm) with a caliper around one-third of an inch (7.8mm), littleleaf linden an average of three and a half feet (108cm) in height and around one-third of an inch (7.1 mm) in caliper. Avondale redbud trees were less than two feet (57cm) in height and (5.0mm) one-fifth of an inch in caliper, smaller than commercially desired in part due to their later planting and thus shorter growing season than the other trees.

Species	Treatment	Average Growth Parameters				
		Height (cm)	Caliper (mm)	Leaf area (mm^2)	Root dry weight (gr)	Shoot dry weight (gr)
Red maple	AT	93 a	7.7 a	1762.3 a	15.1 a	25.6 a
	BH	98 a	7.9 a	2263.0 a	18.5 a	33.6 a
	Significance	NS	NS	NS	NS	NS
	CR	94 a	7.3 b	2399.6 a	16.7 a	32.8 a
	CR+LF	97 a	8.2 a	1625.6 a	16.9 a	26.8 a
	Significance	NS	*	NS	NS	NS
	Interaction	NS	NS	NS	NS	NS
Littleleaf linden	AT	106 a	8.5 a	1791.5 a	19.2 a	29.7 a
	BH	109 a	8.7 a	1352.9 a	12.4 b	19.4 b
	Significance	NS	NS	NS	*	*
	CR	107 a	8.4 a	1567.9 a	15.0 a	25.0 a
	CR+LF	109 a	8.8 a	1576.5 a	16.6 a	24.1 a
	Significance	NS	NS	NS	NS	NS
	Interaction	NS	NS	NS	NS	NS
Avondale redbud	CR	55 b	4.9 a	2122.2 a	7.8 a	17.8 a
	CR+LF	59 a	5.1 a	2217.5 a	9.7 a	19.0 a
	Significance	*	NS	NS	NS	NS

Table 3.2. Growth measures evaluated in August 2008 for the trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Different letters signify least significant differences (LSD)), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

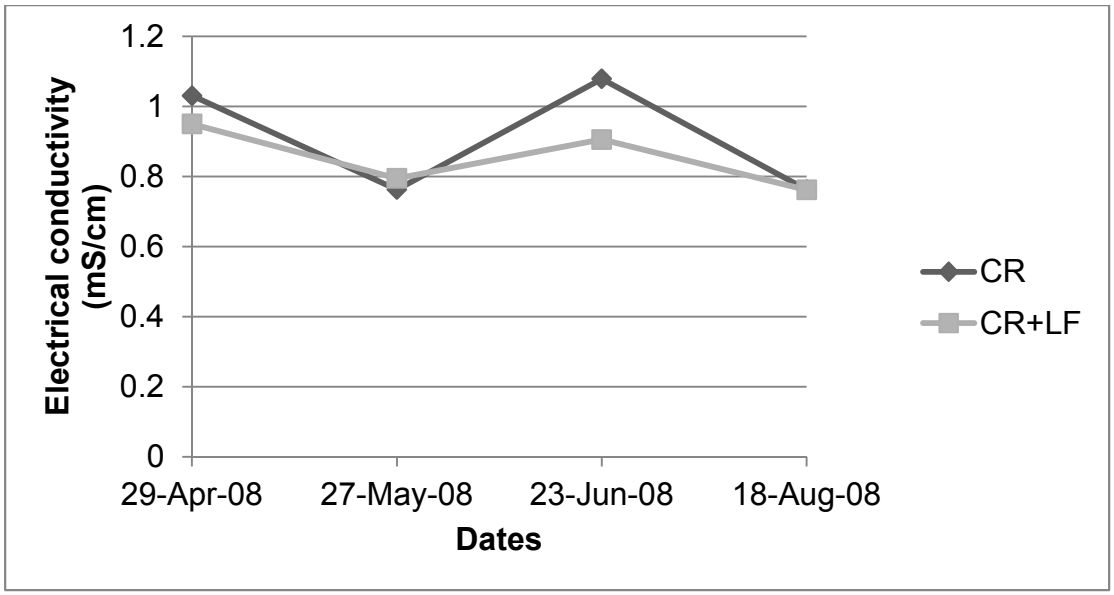

Figure 3.1. Electrical conductivity (mS/cm) measures evaluated for the trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Each value is the mean of four replications. Electrical conductivity was measured using the pour through method (Ruter and Garber, 1998).

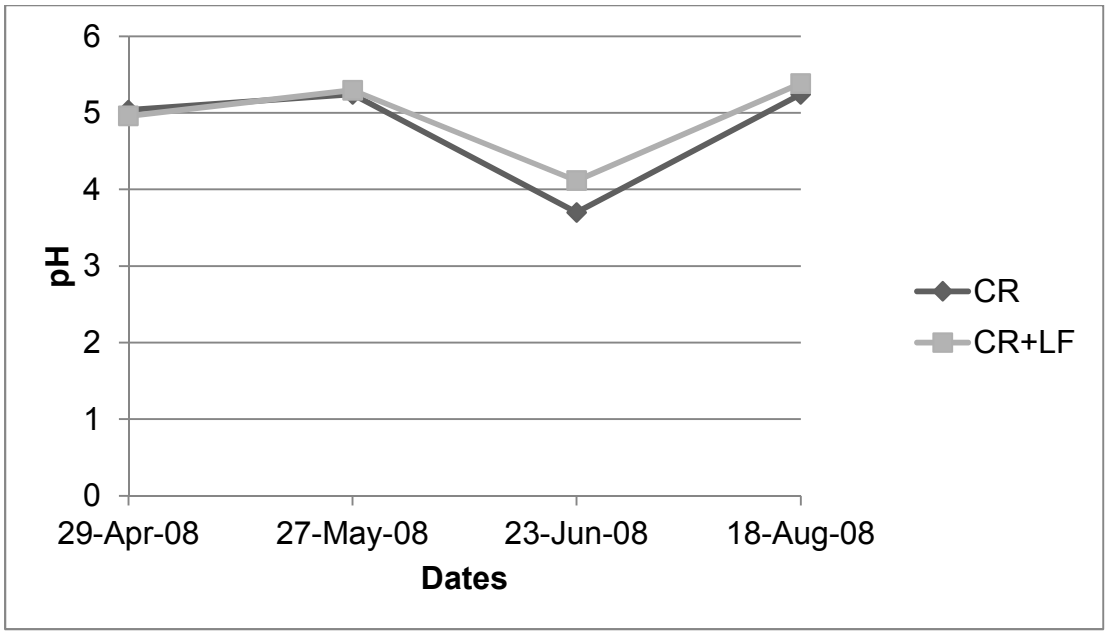

Figure 3.2. pH measures evaluated for the trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Each value is the mean of four replications. pH was measured using the pour through method (Ruter and Garber, 1998).

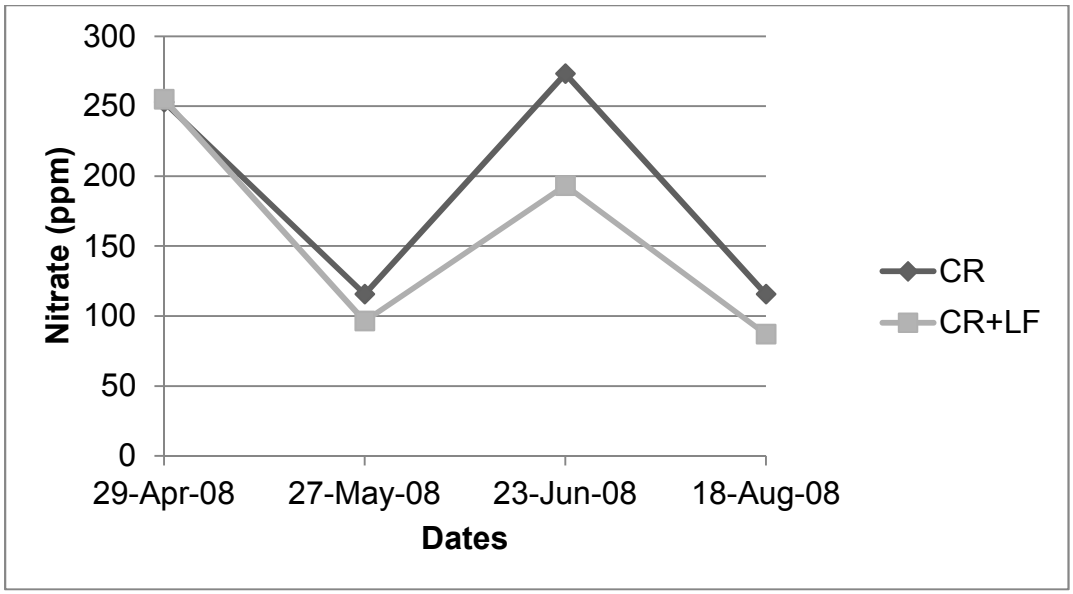

Figure 3.3.Nitrate (NO_3) (ppm) measures evaluated for the trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Each value is the mean of four replications. Nitrate was measured using the pour through method (Ruter and Garber, 1998).

Year one, Summer 2008

October 2008 Evaluation

For the Summer 2008 plants only height and caliper were evaluated in October 2008 due to reduced growth. Plants were allowed to grow one year (June 2008 to June 2009) instead of the original schedule of June 2008 to October 2008.

In October 2008, red maples were significantly taller when fertilized with CR compared to CR+LF (Table 3.3). The caliper measures were not significantly different (Table 3.3). Littleleaf linden trees were not significantly different for height or caliper (Table 3.3). Avondale redbud trees were significantly larger for height (Table 3.3) and caliper (Table 3.3) with CR fertilization (Table 3.3). In Fall 2007, there was an increase in growth with CR+LF for the caliper of red maple and the height of Avondale redbud (Table 2.2). However, for this summer crop red maple and Avondale redbud, CR improved height and calipers.

June 2009 Evaluation

When evaluated in June 2009 (a year after planting), red maple still exhibited improved height with CR (Table 3.4). Caliper, leaf area, root and shoot dry weight were not significantly different (Table 3.4). Littleleaf linden and Avondale redbud were not significantly different for any of the measures (Table 3.4).

Littleleaf linden demonstrated similar growth for Fall 2007 and Summer 2008 planting seasons regardless of fertilizer treatment. Red maples planted in Fall 2007 had a higher caliper with CR+LF; but those planted in Summer 2008 grew taller on CR. Fall plantings were fertilized right after bud break, while Summer

plantings were fertilized after planting. The grower practice of adding LF to CR applications is not supported by this research. From a grower perspective, applying CR one time reduces fertilizer use, expense equipment, labor and leaching potential of fertilizers.

Species	Treatment	Average Growth Parameters	
		Height (cm)	Caliper (mm)
Red maple	CR	43 a	5.7 a
	CR+LF	39 b	5.7 a
	Significance	*	NS
Littleleaf linden	CR	78 a	6.6 a
	CR+LF	65 a	5.8 a
	Significance	NS	NS
Avondale redbud	CR	67 a	5.9 a
	CR+LF	62 b	5.6 b
	Significance	***	*

Table 3.3. Growth measures evaluated in October 2008 for the trees from Summer 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Species	Treatment	Average Growth Parameters				
		Height (cm)	Caliper (mm)	Leaf area (mm^2)	Root dry weight (gr)	Shoot dry weight (gr)
Red maple	CR	150 a	8.3 a	3123.1 a	12.4 a	38.2 a
	CR+LF	130 b	8.0 a	2559.7 a	12.9 a	33.0 a
	Significance	***	NS	NS	NS	NS
Littleleaf linden	CR	196 a	11.2 a	2461.2 a	16.0 a	50.6 a
	CR+LF	193 a	11.3 a	1879.9 a	16.2 a	46.2 a
	Significance	NS	NS	NS	NS	NS
Avondale redbud	CR	110 a	8.6 a	3024.3 a	17.8 a	34.6 a
	CR+LF	108 a	8.5 a	2572.1 a	18.6 a	38.6 a
	Significance	NS	NS	NS	NS	NS

Table 3.4. Growth measures evaluated in June 2009 for the trees from Summer 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

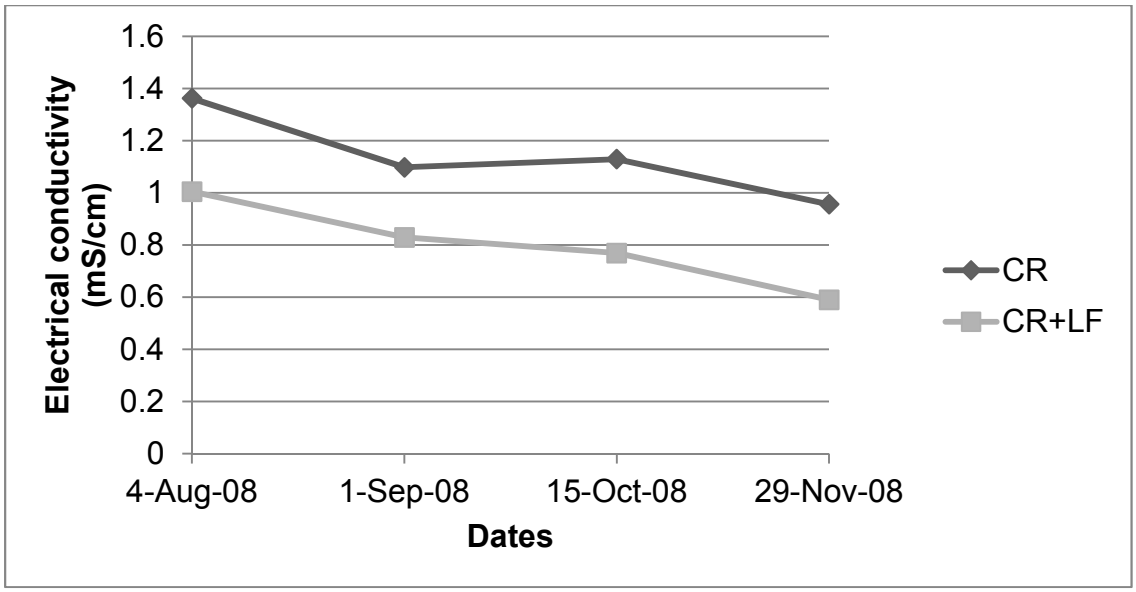

Figure 3.4. Electrical conductivity (mS/cm) measures evaluated for the trees from Summer 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Each value is the mean of four replications. Electrical conductivity was measured using the pour through method (Ruter and Garber, 1998).

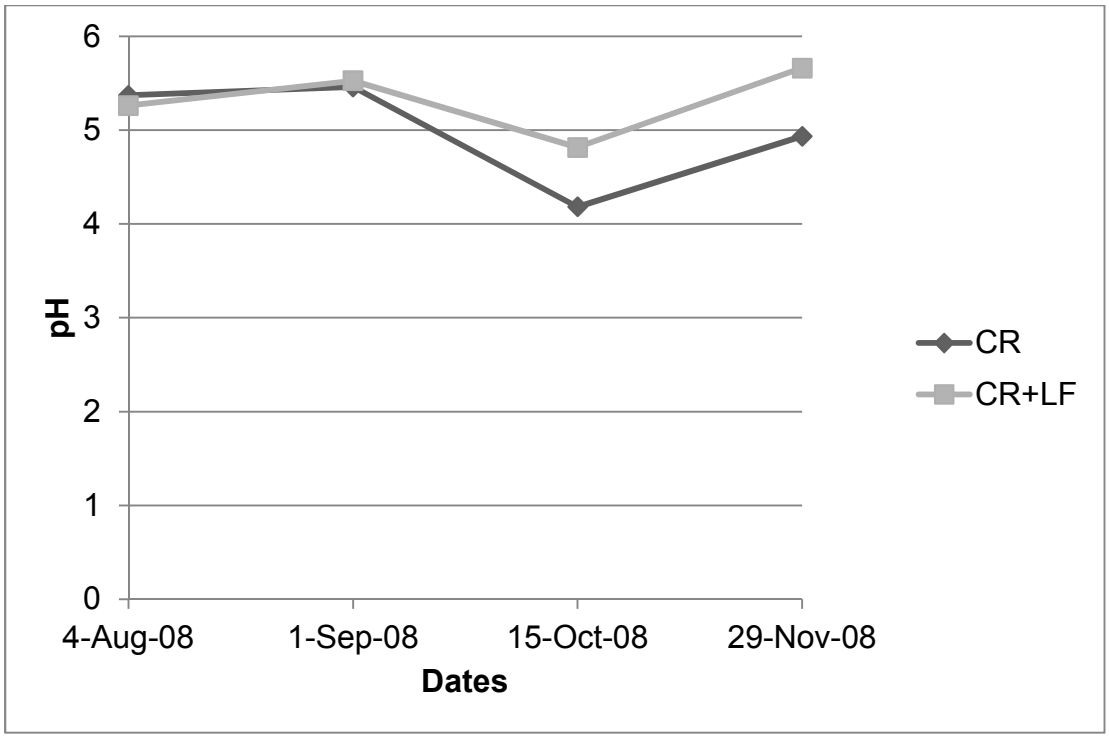

Figure 3.5. pH measures evaluated for the trees from Summer 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Each value is the mean of four replications. pH was measured using the pour through method (Ruter and Garber, 1998).

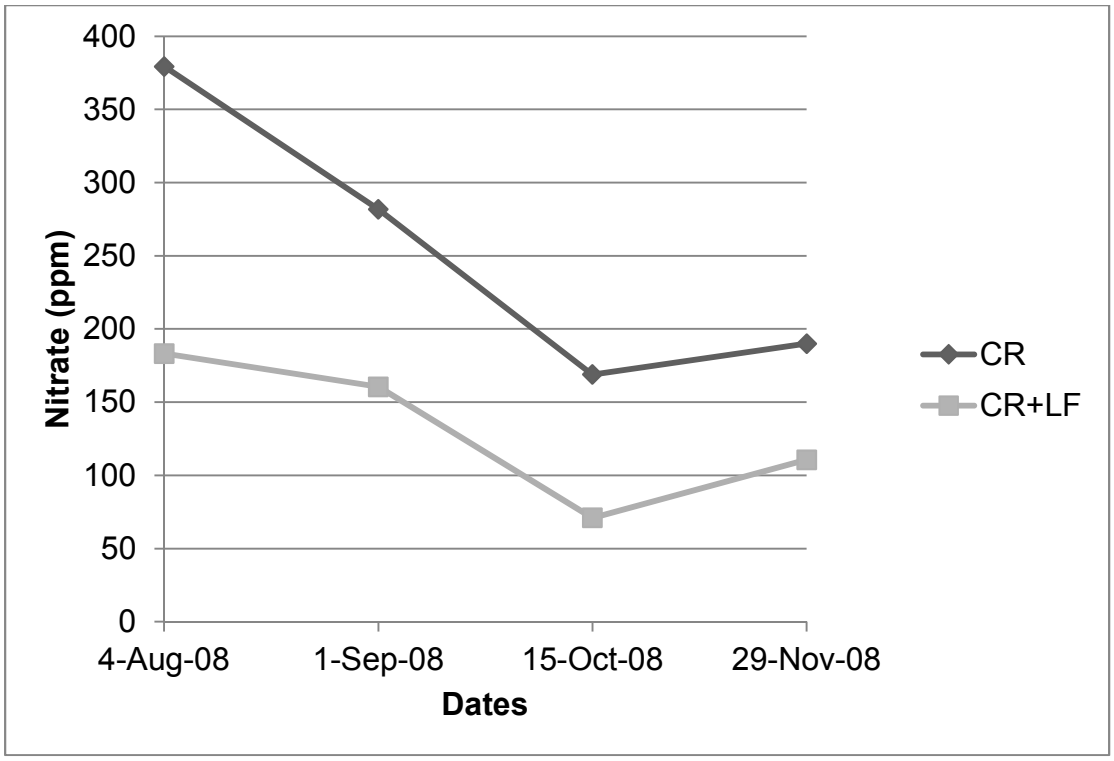

Figure 3.6. Nitrate (NO_3) (ppm) measures evaluated for the trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Each value is the mean of four replications. Nitrate was measured using the pour through method (Ruter and Garber, 1998).

Year two, Fall 2008

April 2009 Evaluation

Samples of plants were evaluated in April 2009 to primarily compare effects of the temperature treatment (see Chapter 2). At this point we also found differences in Avondale redbud growth attributable to Geohumus amendment (Table 3.5). There were not enough red maples to evaluate for April measures and carry on plants to their final evaluation. Littleleaf linden had a significant shoot dry weight increase (Table 3.5). Root dry weights were similar between Geohumus treatments and temperature treatments for littleleaf linden and Avondale redbuds (Table 3.5). There was also a significant interaction of the Geohumus and the BH on the shoot dry weight of Avondale redbud ($P \leq 0.0538$) was found (Figure 2.1). The higher shoot dry weight developed was with the Geohumus and bottom heat (1G+BH). The increased temperature of 70ºF promoted growth, suggested early bud break with exposure to warm temperatures and potential promote the increase in shoot growth.

June 2009 Evaluation

When plants were evaluated in June 2009, red maple did not exhibit differences for any measures with the Geohumus treatment (Table 3.6). Red maple was however, significantly larger in caliper with BH treatment (Table 3.6). Leaf area and root and shoot dry weight were not affected by temperature (Table 3.6). Red maple height was influenced by a significant interaction (Table 3.6) between

Geohumus and temperature (Figure 2.3). The combination of no Geohumus (0G) and bottom heat (BH) produced taller red maples (Figure 2.3) the higher height. This suggests that *Acer rubrum* may not have true root dormancy.

Littleleaf linden developed larger height and caliper in AT rather than with BH (Table 3.6). Leaf area and root and shoot dry weights were not significantly different between temperature treatments. Larger caliper was produced when Geohumus (1G) was present in the media.

Avondale redbud developed larger height, caliper and leaf area (Table 3.6) with the BH treatment (Table 3.6) but root and shoot dry weights were not affected by temperature treatment (Table 3.6). The addition of 1% Geohumus significantly increased shoot dry weight (Table 3.6). Height, caliper, leaf area and root dry weight were unaffected by Geohumus (Table 3.6).

As Geohumus maintains water available in the media and had an interaction with the temperature. If existed, future experiments with higher root zone temperatures (as suggested in Chapter 2) and with 1% Geohumus. The increase in plant growth found in this study was not differed by plant organ and species. Red maple trees increased in height, Avondale redbud trees increased in shoot dry weight and littleleaf linden trees increased in caliper. These differences could be due to susceptible timing with heat applications for example littleleaf linden caliper increase with BH in Fall, Avondale red bud shoot dry weight increase promoting early bud break in spring.

Species	Treatment	Average Growth Parameters	
		Shoot dry weight (gr)	Root dry weight (gr)
Littleleaf linden	0G	1.0 a	1.5 a
	1G	1.0 a	1.7 a
	Significance	NS	NS
	AT	0.8 b	1.7 a
	BH	1.2 a	1.5 a
	Significance	*	NS
	Interaction	NS	NS
Avondale redbud	0G	0.6 b	0.5 a
	1G	0.9 a	0.5 a
	Significance	*	NS
	AT	0.4 b	0.6 a
	BH	1.1 a	0.4 a
	Significance	*	NS
	Interaction [z]	*	NS

Table 3.5. Shoot and root dry weight (gr) evaluated in April 2009 to the trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Means are over Geohumus treatments. Different letters signify least significant differences (LSD) P=0.05, NS non-significant. [z] Interaction with Geohumus *P* = 0.0538.

Species	Treatment	Growth Parameters				
		Height (cm)	Caliper (mm)	Leaf area (mm^2)	Root dry weight (gr)	Shoot dry weight (gr)
Red maple	0G	118 a	6.7 a	2368.8 a	16.4 a	2.6 a
	1G	107 a	6.6 a	2765.4 a	25.7 a	4.6 a
	Significance	NS	NS	NS	NS	NS
	AT	103 b	5.6 b	2837.9 a	24.7 a	4.1 a
	BH	115 a	7.0 a	2373.7 a	21.0 a	3.4 a
	Significance	*	*	NS	NS	NS
	Interaction	**	NS	NS	NS	NS
Littleleaf linden	0G	112 a	6.9 b	1236.9 a	9.8 a	4.5 a
	1G	114 a	7.3 a	1190.6 a	11.4	5.3 a
	Significance	NS	*	NS	NS	NS
	AT	119 a	7.3 a	1260.2 a	10.6a	5.8 a
	BH	108 b	6.9 b	1167.3 a	10.4 a	4.0 a
	Significance	*	*	NS	NS	NS
	Interaction	NS	NS	NS	NS	NS
Avondale redbud	0G	51 a	4.1 a	1221.1 a	6.5 a	1.3 b
	1G	52 a	4.1 a	1146.8 a	8.3 a	3.2 a
	Significance	NS	NS	NS	NS	*
	AT	47 b	3.7 b	1000.3 b	6.4 a	2.0 a
	BH	56 a	4.5 a	1367.6 a	8.6 a	2.6 a
	Significance	***	***	*	NS	NS
	Interaction	NS	NS	NS	NS	NS

Table 3.6. Growth parameters evaluated in June 2009 to the trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Means are over Geohumus treatments. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Year two, Summer 2008

June 2010 Evaluation

Red maple, littleleaf lindens and Japanese tree lilac showed no difference for any growth parameter measured with Geohumus (Table 3.7). During the experiment many red maple trees died and a complete sample to compare treatments properly was not available. Tree lilac trees received in June 2009 went into a staled growth and dormant during the beginning of the season. All the Tree lilac started to grow later in the Fall thus the results with this species are inconclusive. Mathers, in a study in 2009, found that Birch and maple planted as cuttings in June were half the size of their counterparts planted in April or May (Mathers, 2009, unpublish).

Species	Treatment	Growth Parameters				
		Height (cm)	Caliper (mm)	Leaf area (mm^2)	Root dry weight (gr)	Shoot dry weight (gr)
Red maple	0G	57 a	9.0 a	.	77.6 a	.
	1G	113 a	9.0 a	2095.6	33.7 a	43.9
	Significance	NS	NS	.	NS	.
Littleleaf linden	0G	128 a	10.4 a	1081.7 a	13.0 a	25.8 a
	1G	108 a	9.1 a	2566.3 a	10.1 a	22.7 a
	Significance	NS	NS	NS	NS	NS
Japanese tree lilac	0G	42 a	3.5 a	1555.9 a	10.5 a	31.1 a
	1G	53 a	2.6 a	1227.8 a	3.2 a	9.3 a
	Significance	NS	NS	NS	NS	NS

Table 3.7. Growth parameters evaluated in June 2010 to the trees from Summer 2009 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) and Japanese tree lilacs (*Syringa reticulate* 'Sigzam') were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G). Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant, (.) not enough data to compare.

Double crop

Fall 2007 plants that were allowed to stay longer than the schedule, for a total of 11 months in the RRG. Fall 2008 plantings were grown from October to June, as planned for 8 months in the RRG. Both Summer plantings were grown in the RRG from June to October, for a total of 4 months each.

Red maple trees had a similar height of 90, 112 and 97cm when grown in Fall 2007, 2008 and Summer 2009 (Figure 3.7) respectively. Height of Summer 2008 was shorter (40.9 cm). The difference of the height in Summer 2008 versus Summer 2009 planting could be attributed to the start size of the plants, 7.62cm and 15.24cm respectively. None of the red maples trees reached the desired height from tissue cultured plugs. We established at the onset of the experiment of 120cm for height. However, Fall planted trees grew much better. Perhaps, plants that are grown through the winter are more adapted to the seasons and have the benefit of growing in early spring. Previous studies in RRG that protected plants from freezing, used bottom heat at 70°F (21°C) and placed the plants in the RRG from March 28, obtained red maples as high as 222cm in CR and 209cm in CR+LF (Stoven et al., 2006). Summer crops do not react to the warm weather as fast as Fall crops. The use of larger plants for the Summer crops may improve growth as observed in this study. Caliper was different between each planting and did not near reach our goal of 12.7mm (Figure 3.8). Calipers of 7.8, 8.1, 6.6, 8.7 were obtained in Fall 2007, Summer 2008, Fall 2008

and Summer 2009. More research needs to be done with this species to accelerate the growth to be able to double crop red maples.

Avondale redbuds heights (Figure 3.7) and calipers (Figure 3.8) also did not reach optimum size. However, the heights of these trees were benefited by the CR+LF treatment in Fall 2007 (57cm). In Fall 2008, bottom heat promoted the growth of this plant as early as April 2009 when combined with Geohumus. The increase in growth influenced by BH was observed also in height, caliper and leaf area in June 2009 evaluation. Geohumus promoted the shoot dry weight in June 2009 evaluation. Avondale redbuds are not hardy for zone 5. Plants that were grown during winter died back and re-grow from lower parts of the plants. Even under protection of the RRG this plant had difficulty in production in Columbus, Ohio. Avondale redbuds were not planted in Summer 2009). Eastern redbuds (*Cercis canadensis*) were the plants originally planned for this experiment. However due to a supplier error we received Avondale redbud instead.

Even that the littleleaf lindens used in the Fall 2008 and Fall 2007 had different initial heights, 25.4cm and 7.62cm respectively, height was similar at the time of evaluation 113 and 108cm respectively (Figure 3.7). Summer 2008 and 2009 were 71 and 51 cm tall and did not grow as height as plants from Fall plantings (Table 3.7). Calipers of littleleaf lindens were 7.1, 6.2, 7.9 and 4.6 for Fall 2007, Summer 2008, Fall 2008 and Summer 2009 (Figure 3.8). Height of Littleleaf linden Fall plantings was close to our desired size. Littleleaf linden was easy to grown in the RRG and grew larger than red maples which were considered “easy

to grow” trees (Nursery grower, personal communication). Littleleaf lindens may need to be started with larger plants in Summer to reach the desire size. This species has the potential to be double crop in the RRG.

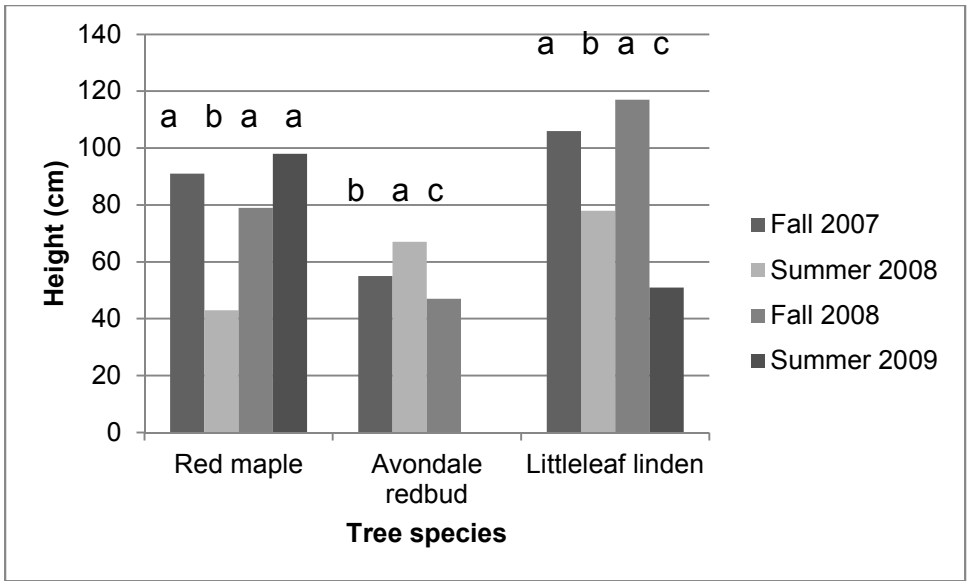

Figure 3.7. Height (cm) of tree species grown in the RRG. Fall 2007 plants were grown for 11 months. Fall 2008 plants were grown for 8 months. Summer 2008 and 2009 were grown for 4 months. Fall season were schedule to be grown from October to June and Summer season last from June to October. Means with different letters between each species are significantly different based on Fisher's protected least significant difference (α = 0.05).

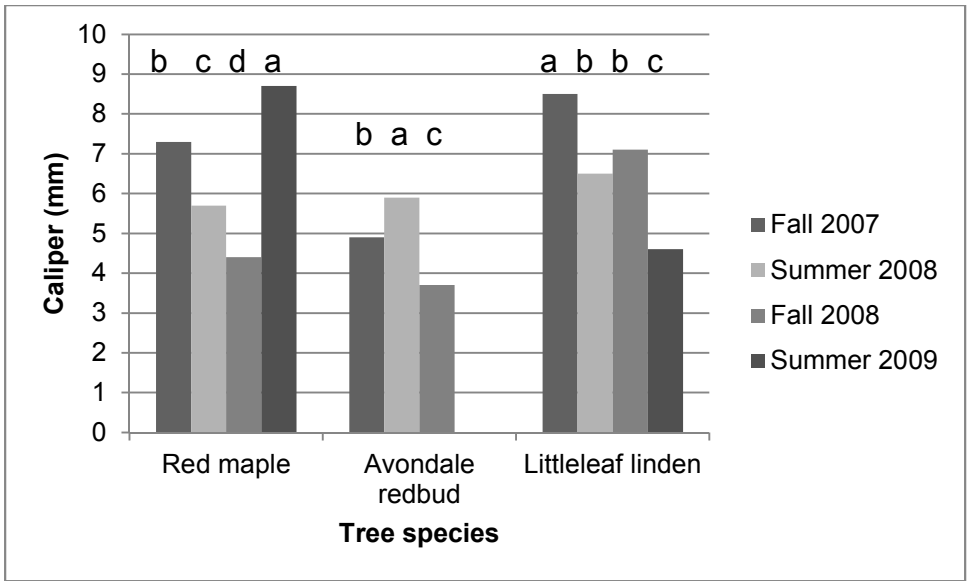

Figure 3.8. Caliper (mm) of tree species grown in the RRG. Fall 2007 plants were grown for 11 months. Fall 2008 plants were grown for 8 months. Summer 2008 and 2009 were grown for 4 months. Fall season were schedule to be grown from October to June and Summer season last from June to October. Means with different letters between each species are significantly different based on Fisher's protected least significant difference (α = 0.05).

Conclusion

Red maples trees were selected as easy to grow plants. The fertilization treatment in these trees produced better caliper with CR+LF in Fall 2007 but better height in Summer 2008 plantings. Temperature treatment produced taller plants with larger caliper when grown with BH at 70°F. Geohumus did not affect the growth of red maples. Trees did not reach our desirable size but trees planted in Fall 2007 (11 months), 2008 (8 months) and Summer 2009 (4 months) were similar in height.

This could mean that plants have the potential to be double cropped but smaller plants would be obtained. More research needs to be done to accelerate the growth of red maples.

Avondale redbuds were easy to grow but not hardy in Columbus, Ohio (zone 5) and is recommended for zone 6. The plants were growing inside the RRG but during the winter many died back to the ground. Avondale redbuds should not be grown in zone 5. Similar species like Eastern redbud (*Cercis canadensis*) would be a better option. Avondale redbuds were taller in Fall 2007 with the CR+LF fertilization but in Summer 2008, CR produced the taller plants with larger calipers. The BH treatments produced larger height, caliper and leaf area in Avondale redbuds. Geohumus influence the shoot dry weight only, increasing the dry mass when Geohumus was present in the media. If Eastern redbud react

similar to Avondale redbud to the bottom heat but not die back during winter, the growth of the trees could be accelerated.

The littleleaf linden trees were larger in root and shoot dry weight in Fall 2007 and larger in height and caliper in Fall 2008 when grown in AT. The growth for both fertilizer treatments was similar. Geohumus promoted the caliper size in Fall 2008. Comparing this species with the others grown in this experiment, littleleaf linden was easy to grow and the larger plants produced in the RRG. Trees started in Fall were close to the desire height for the market. More experiments needs to be done to promote the growth of littleleaf linden especially during the Summer season (June to October).

In Fall 2007, littleleaf lindens started at 7.62cm were 108cm after 11 months in height with no BH and had calipers of 7.1mm. Red maples trees grew from 7.62cm to 90cm and calipers of 7.8mm with CR+LF were obtained.

In Summer 2008 red maples grew in 4 months from 15.24cm to 40.9cm in height and to 5.7mm in caliper. Littleleaf lindens from 7.62cm reached a height of 71 cm and caliper of 6.2mm.

In Fall 2008, littleleaf lindens grew in 11 months 25.4cm to 113cm a 7.9mm caliper in 1GAT. Red maple grew from 7.62cm to 112 and 6.6mm caliper with BH. In Summer 2009 red maples grew in 4 months from 7.62 cm to 97 cm in height and to 8.7cm in caliper with shoots dry weight increased in 0G to 24.8gr.

Littleleaf lindens had a variable growth, in average they grew from 7.62cm to 51 cm in height and caliper 4.6mm. Japanese tree lilacs were stalled.

Chapter 4: Pot in Pot: Influence of time of planting and size of liner in PIP

Introduction

Pot in pot (PIP) system is a holder or a socket pot permanently positioned in the ground and a container plant is then placed inside the socket pot (Harris and Fanelli, 1999). In research years, PIP production has been an increasingly popular component of the overall container production trend (Klooster et al., 2010). PIP has been reported to increase tree growth (Ruter, 1998a; Ruter, 1998b; Zhu et al., 2005), increase fertilize longevity (Ruter, 1998a) provide stability and protection to root zone from extreme air temperatures (Klooster et al., 2010) and been less costly than above the ground container (Ruter, 1998b; Zhu et al., 2005). Plants in PIP are easy to put in the landscape without disturbing the root systems by digging and transplanting (Ruter, 1997).Time of planting can make a difference in the growth of container trees. Fall-transplanted trees have been reported to have much more time to acclimate to physiological transplant stress than spring-transplanted trees before the onset of spring shoot growth (Harris and Fanelli, 1999). *Acer rubrum* has been reported to start root growth before bud break (May 1) in 15 gal PIP (Harris and Fanelli, 1999). Trees

from retractable roof greenhouse (RRG) transplanted to PIP have 60% survival than bare root trees transplanted to PIP (Mathers, 2010). A tree liner production that combines RRG without planting to PIP may increase the survival, acclimatization and reduction of transplant shock of trees in the landscape. The objectives of this study are: 1) evaluate the growth of landscape trees from cell (plugs) to 3 gal 7 or 15 gal black rounded pot when grown double cropped versus a twelve- month-cycle in a RRG and out planted to PIP; 2) to evaluate the time of fall transplant versus summer transplant on plant growth.

Materials and Methods

Plants were grown in the retractable roof greenhouse (RRG) following the system in Chapter 3. Random sample of each treatment was transplanted to 7 or 15-gallon pots (Nursery Supply Co.) in a pot in pot (PIP) system (Table 4.1). The PIP system was constructed in Sherwood, Ohio (zone 5) in September 2008. Soilless mix (Kurtz Brothers Inc.) of 60% pine bark, 20% rice hulls, 10% sand, 5% composted sewage sludge (Com-Til, Lockbourne, Ohio), and 5% stone aggregate was used to fill the containers. Plants grown with 1% Geohumus in the RRG maintain their treatment by adding new media with 1% Geohumus.

All plants received a top dressing of CR 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scotts) at potting. Seven gallon pots received three tablespoon (45 grams) of fertilizer and 15 gal pots received six tablespoons (90 grams) of fertilizer. All plants were trained to a 7’ bamboo stakes (A.M. Leonard,

Inc.) of three fourths of an inch in diameter and attached to the stakes with grafting tape (A.M. Leonard, Inc.). Trees were supplied with water one time a day (4:30am). Irrigation system consisted of spaghetti tubing of one eight of an inch (Roberts Irrigation Products, Inc., San Marcos, California) with Orange Mini Flow emitters with a 160° Spray pattern (SS-AG160ORG-100, Roberts Irrigation Products, Inc., San Marcos, California) for 7 gal pots and Dark Green Medium Flow emitters with a 160° Spray pattern (SS-AG160DGN-100, Roberts Irrigation Products, Inc., San Marcos, California) for 15 gal pots from 2008 to 2009. From 2009 to 2010 emitters were all changed to the Orange Mini Flow because had better water pressure in the system. Approximately 660 ml of water was applied per day. Due to hardiness issues Avondale redbuds (zone 6) were not transplanted to the PIP system.

Year one, Fall 2007

The Fall 2007 crop (see Chapter 3) were transplanted to 15 gal pots in mid-August 2008 and placed in a PIP system at on Natorp's Garden Stores and Landscape (Mason, Ohio). Another sample of plants was up shift to 7-gallon pots at the beginning of September 2008 and grown in the PIP system located in Sherwood, Ohio. All plants were in the RRG from October 2007 to August 2008 (11 months) and from August 2008 to June 2009 (10 months) in the PIP system. Plants are label the following way: by pot size (3 gal, 7 gal, or 15 gal), all plants in 3 gal were grown all the time in the RRG and plants in 7 gal and 15 gal were

transplanted from 3 gal to those pot sizes. Numbers indicating the months that plants spent in RRG and PIP will follow the pot size in that order. For example plants in 3 gal grown for 11 months in the RRG and never move to a PIP are 3 gal 11+0. The age of the plant can be calculated by adding the months.

Plants at Natorp's Garden Stores lost their tag. Therefore, treatment comparison was not possible in 15 pots. In June 2009 all plants 7 gal 11+10 and 15 gal 11+10 height and caliper (taken at 2.4 cm above the soil) were measured. Four plants per treatment in 7 gal pots and four plants per species in 15 gal pots were randomly selected to evaluate shoot dry weight. Plants were pruned at the root collar. The shoot and leaf tissues of each plant were placed paper bags. Shoots were oven dried for one week at 54°C (Blue M Electric Forced-Air Drying Ovens, Williamsport, Virginia). Shoot dry weights were measured.

Comparison of the treatments effects after been grown in the PIP were made for the 7 gal 11+10. Growth comparison between 7 gal 11+10 and 15 gal 11+10 plants were also made.

Year one, Summer 2008

Plants from the Summer 2008 planting, were up shift to 7 and 15 gal and placed in the PIP system in Defiance, Ohio in June 2009 and October 2009. At the same time plants in 3 gal pots stayed in the RRG for comparison. Evaluation to compare plants parameters in October 2009 were for 3 gal 16+0, 7 gal 12+4, and 15 gal 12+4 plants. A sample of plants from June 2009 stayed in the PIP until

June 2010. A second evaluation was made in June 2010 for 3 gal 24+0, 7 gal 12+12, 15 gal 12+12, 7 g 16+8 and 7 gal 16+8 plants. These two comparisons were made to compare plants that were move to the PIP as small liners (less time in RRG) with larger plants more time in the RRG. Irrigation, fertilization and measurements were the same as conducted for the 7 gal pots in Fall 2007. Unfortunately, most littleleaf lindens required topping to transplant and place in the PIP. Therefore, comparisons of height were not conducted.

Year two, Fall 2008

Plants from Fall planting 2008, were up shift to the PIP system in Defiance, Ohio in June 2009 and October 2009. At each transplant, media with 1% of Geohumus was added to plants that had the Geohumus treatment during the double crop in the RRG to maintain the treatment. Evaluation to compare plants parameters in October 2009 were for 3 gal 12+0, 7 gal 8+4, and 15 gal 8+4 plants. A sample of plants from June 2009 stayed in the PIP until June 2010. A second evaluation was made in June 2010 for 3 gal 20+0, 7 gal 8+12, 15 gal 8+12, 7 g 12+12 and 7 gal 12+12 plants. Irrigation, fertilization and measurements were the same as conducted for the in Summer 2008. Loss of red maples during the double crop meant not enough red maples were left to compare in PIP.

Year two, Summer 2009

Plants from Summer planting 2009, were transplanted into the 7 and 15 gal PIP system in Defiance, Ohio in October 2009 for red maple and June 2010 for

littleleaf linden and Japanese tree lilac. Littleleaf lindens which were grown from tissue culture and were in a poor quality, also grew very poorly in the Summer crop and were not transplanted to the PIP in October 2009, they were left to grow in the RRG. Tree lilac trees received in June 2009 went into a staled growth and dormant during the beginning of the season and were also not transplanted to the PIP in October 2009 but left to grow in the RRG. Littleleaf lindens and Japanese tree lilacs were transplanted to 7 gal pots on June 2010. Loss of red maples during the double crop, meant not enough red maples were left to compare in PIP to be transplanted in June 2010. Evaluations to compare plants parameters were conducted in June 2010 for 3 gal 12+0, 7 gal 4+8,15 gal 4+8 for red maple. Evaluations of littleleaf lindens 7 gal 12+3 and Japanese tree lilac 7 gal 12+3 were made in September 2010. Plants care in the PIP and measurements were similar than previous Fall 2008.

	2007	----------2008---------			-------2009-----		------2010------	
Planting	Oct.	June	Aug.	Oct.	June	Oct.	June	Sept.
Fall 2007	P		M/D/T[z]		M/D			
Summer 2008		P		M	M/D/T	M/D/T	M/D	
Fall 2008				P	M/D/T	M/D/T	M/D	
Summer 2009					P	M/D/T	M/D/T	M/D

Table 4.1. Timeline of planting (P) of the trees in the RRG, measurements (M), destructive samples (D) and transplant (T) of the crops to pot in pot (PIP). Four crops were double cropped in the Retractable Roof Greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, Ontario, Canada), Fall 2007, Summer 2008, Fall 2008 and Summer 2009. Planting occurred either in October or June for Fall and Summer crops respectively. Measurements evaluation of height and caliper of all plants were taken. Destructive samples to evaluate leaf area, shoot and root dry weights were made for all crops before moving to a PIP system in Sherwood, Ohio. [z] 15 gal pots were placed in a PIP system at on Natorp's Garden Stores and Landscape (Mason, Ohio).

Results and Discussion

Year one, Fall 2007

June 2009 evaluation

When evaluated in June 2009, red maples in 7 gal 11+10 showed no difference in height for the temperature and fertilizer main effects that were originally applied in production in the RRG (Table 4.2). Temperature and fertilizer interaction was also significant with red maple caliper (Figure 4.1) and shoot dry weights (Figure 4.2) been adversely affected with AT (or no BH) and CR fertilizer. Although red maples did not show a significant increase in caliper or shoot dry weight with BH when evaluated in August 2008 and caliper was only improved with CR+LF treatment (Table 3.2).

Seven gallon and 15 gal transplanted trees were in different locations thus a comparison was not appropriate to compare. However horticultural difference could be made to relative pot sizes (Figure 4.3, Figure 4.4, Figure 4.5). Red maple trees grown in 15 11+10 were nearly 2x the height (Figure 4.3) caliper (Figure 4.4) and shoot dry weight (Figure 4.5) of 7 gal 11+10. Red maple increased in 73%, 77% and 320% in height, caliper and shoot dry weight, respectively, when plants were grown in the 15 gal versus 7 gal PIP. The 15 gal 11+10 trees planted in Natorp's Garden Stores and Landscape (Mason, Ohio) probably were fertilized with a CR+LF combination. The difference in growth between 7 gal and 15 gal could be attributed to a preference from red maple to

CR+LF. However, previous experiments with *Acer rubrum* 'Franksred', have reported 23 to 92% increase in height, 48 to 50% increase in caliper and 30 to 41% increase in shoot dry weight (Fare, 2006) when planted in 15 gal pots. The difference in growth between pot size could be also attributed to a preference of red maple to bigger pots.

Littleleaf linden trees grown in 7 gal 11+10 showed no differences in height, caliper and shoot dry weight, with BH or fertilizer treatments (Table 4.2). All littleleaf lindens had exceeded the optimum size we had determined when the study was initiated. Littleleaf linden had an increase of 33%, 73% and 222% in height, caliper and shoot dry weight, respectively, when plants were grown in 15 gal pots versus 7 gal pots.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Red maple	AT 7 gal 11+10	119 a	10.8 a	42.7 a
	BH 7 gal 11+10	125 a	11.5 a	47.0 a
	Significance	NS	NS	NS
	CR 7 gal 11+10	123 a	11.0 a	46.5 a
	CR+LF 7 gal 11+10	122 a	11.4 a	43.5 a
	Significance	NS	NS	NS
	AT CR 7 gal 11+10	111 a	9.90 b	38.2 b
	AT CR+LF 7 gal 11+10	127 a	11.7 a	47.9 a
	BH CR 7 gal 11+10	133 a	11.9 a	53.5 a
	BH CR+LF 7 gal 11+10	118 a	11.2 a	40.5 a
	Significance	NS	**	*
Littleleaf linden	AT 7 gal 11+10	153 a	12.3 a	38.1 a
	BH 7 gal 11+10	161 a	13.0 a	47.0 a
	Significance	NS	NS	NS
	CR 7 gal 11+10	155 a	12.2 a	39.7 a
	CR+LF 7 gal 11+10	159 a	13.2 a	46.1 a
	Significance	NS	NS	NS
	AT CR 7 gal 11+10	151 a	12.1 b	36.7 a
	AT CR+LF 7 gal 11+10	154 a	12.5 ab	39.8 a
	BH CR 7 gal 11+10	158 a	12.3 b	42.8 a
	BH CR+LF 7 gal 11+10	163 a	13.8 a	51.2 a
	Significance	NS	NS	NS

Table 4.2. Growth measures evaluated in June 2009 after 10 months in 7 gal pots in a pot in pot (PIP) system in Sherwood, Ohio.Trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red Maple (*Acer rubrum* L. 'October Glory'®), and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were treated in the RRG with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Months in the RRG+PIP noted after pot size. NS means nonsignificant, * , **, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively.

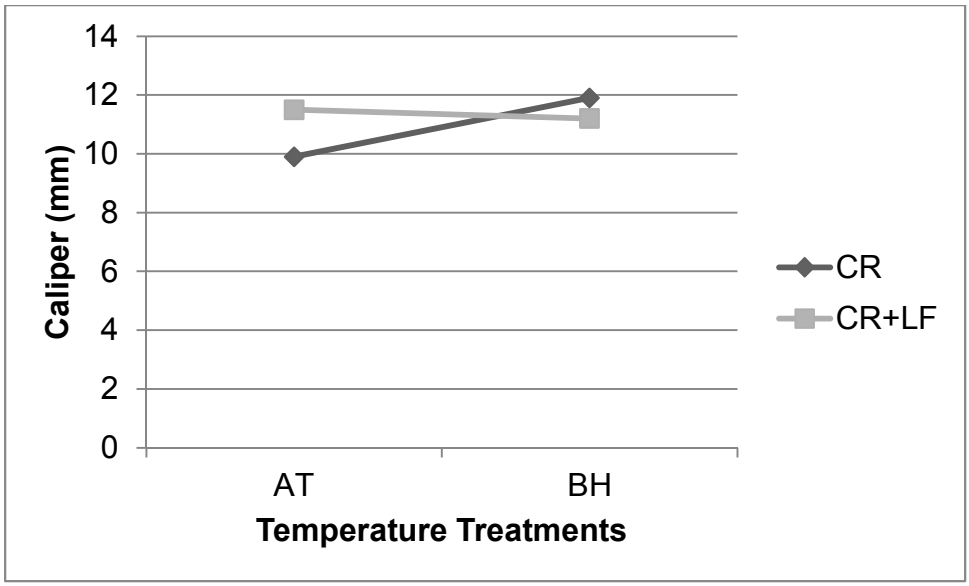

Figure 4.1. Interaction of treatments in red Maple (*Acer rubrum* L. 'October Glory'®) caliper (mm) when evaluated in June 2009 after 10 months in 7 gal pots in a pot in pot system in Sherwood, Ohio. Red maples from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada) were treated in the RRG with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks..

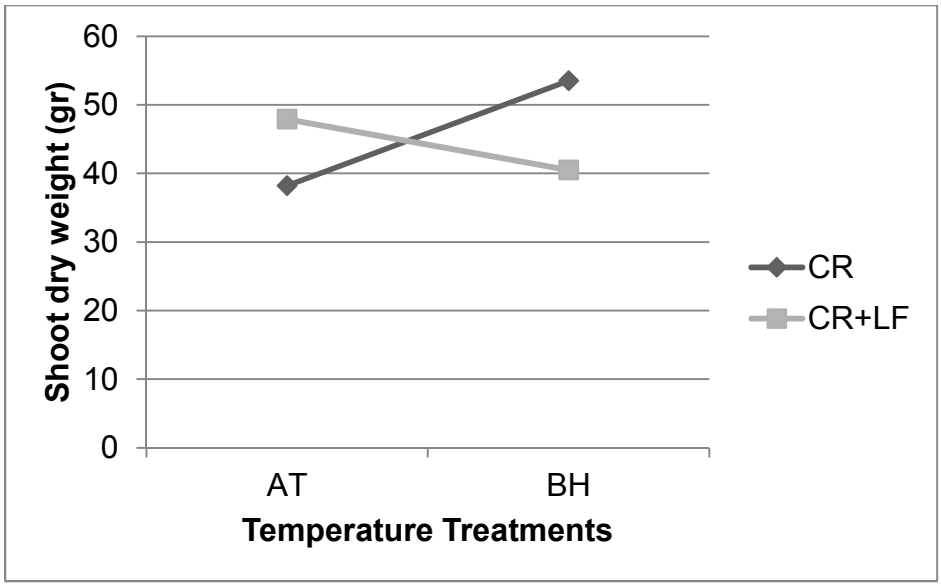

Figure 4.2. Interaction of treatments in red Maple (*Acer rubrum* L. 'October Glory'®) shoot dry weight (gr) when evaluated in June 2009 after 10 months in 7 gal pots in a pot in pot system in Sherwood, Ohio. Red maples from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada) were treated in the RRG with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008. Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks..

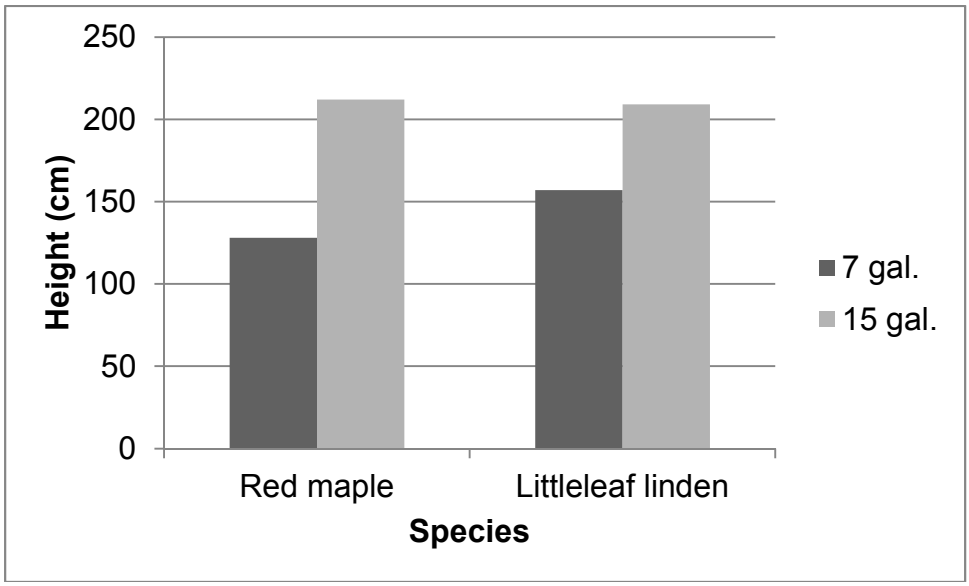

Figure 4.3. Average height (cm) of red maples (*Acer rubrum* L.'October Glory®') and littleleaf linden (*Tilia cordata* Mill. 'Greenspire®') when evaluated in June 2009. Trees were grown in The Ohio State University, Columbus, OH, retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada) for 11 months and transplanted to 7 gal pot in pot in Sherwood, Ohio and 15 gal pot in pot at Natorp's Garden Store and Landscape Mason, Ohio for 10 months.

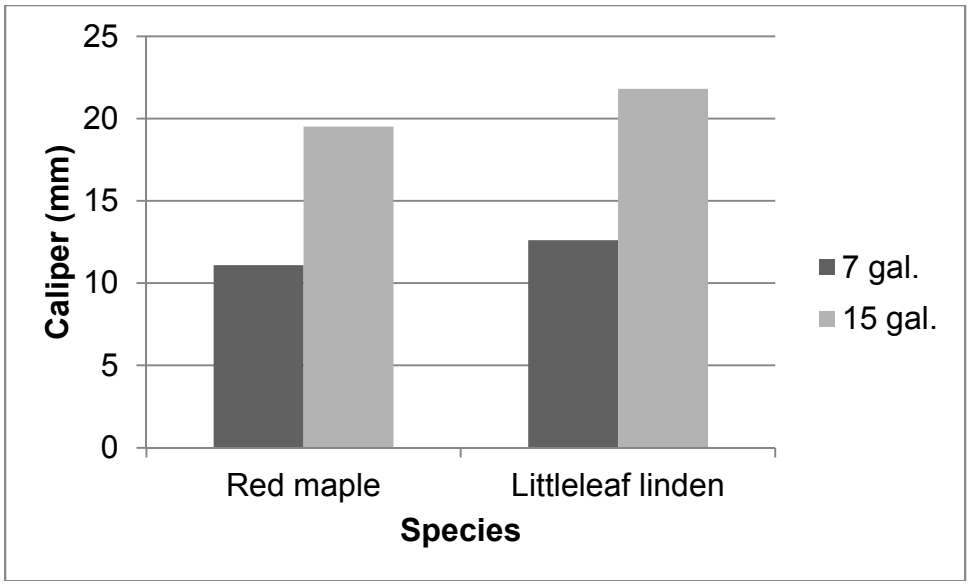

Figure 4.4. Average caliper (mm) of red maples (*Acer rubrum* L.'October Glory®') and littleleaf linden (*Tilia cordata* Mill. 'Greenspire®') when evaluated in June 2009. Trees were grown in The Ohio State University, Columbus, OH, retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada) for 11 months and transplanted to 7 gal pot in pot (PIP) in Sherwood, Ohio and 15 gal PIP at Natorp's Garden Store and Landscape Mason, Ohio for 10 months.

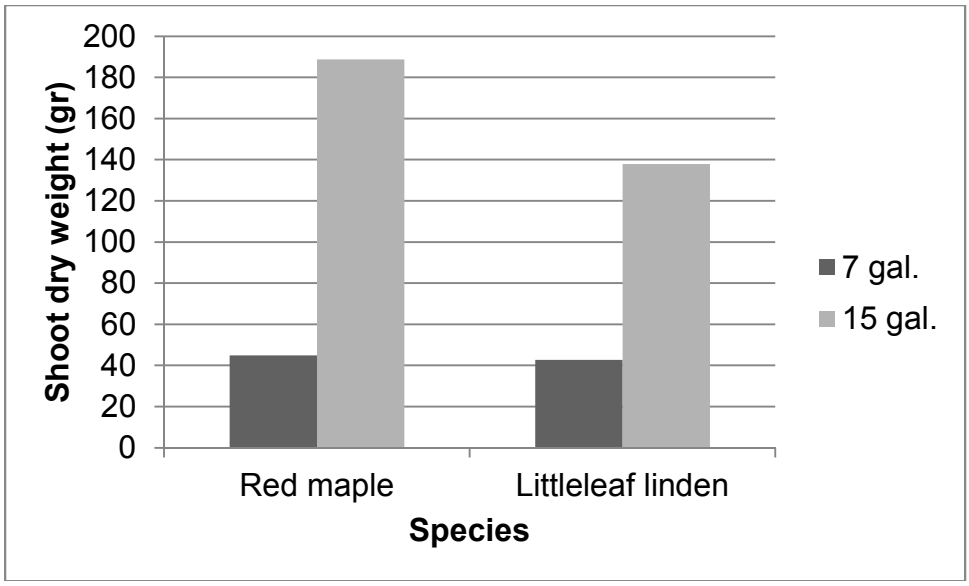

Figure 4.5. Average shoot dry weight (gr) of red maples (*Acer rubrum* L.'October Glory®') and littleleaf linden (*Tilia cordata* Mill. 'Greenspire®') when evaluated in June 2009. Trees were grown in The Ohio State University, Columbus, OH, retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada) for 11 months and transplanted to 7 gal pot in pot (PIP) in Sherwood, Ohio and 15 gal PIP at Natorp's Garden Store and Landscape Mason, Ohio for 10 months.

Year one, Summer 2008

October 2009 evaluation

Plants left in 3 gal (3 gal 16+0) containers in the RRG had been grown from June 2008 to October 2009. After 16 months in the RRG the plants now exceeded 120cm and 12.7mm in height and caliper, respectively (Table 4.3). After 16 months there was no effect of the fertilizer treatment in red maples, for any growth parameters measured.

The red maples evaluated in October 2009 that had been transplanted to the 7 gal 12+4 or 15 g 12+4 showed no difference in growth with fertilizer (Table 4.4). Red maples in the RRG in 3 gal16+0 were 20 cm and 4cm taller compared with 7 gal 12+4 and 15 gal 12+4, respectively (Table 4.5). These do not justify the additional construction of a PIP system. However, Plants had only been in the PIP for 4 months which may have not been enough time to show a significant difference in growth (Table 4.4).

Littleleaf lindens had larger calipers when fertilized with CR treatment. No other growth parameters were significant for fertilizer treatments (Table 4.3). Littleleaf lindens showed no interaction in height between the fertilizer and the pot size probably attributable to their topping in transplanting.

June 2010 evaluation

A sample of plants left in the RRG from Summer 2008 to October 2009 (16 months) were transplanted to the PIP system for 8 months until June 2010 in

both 7 gal 16+8 and 15 g 16+8 pots. Red maples and littleleaf lindens did not showed any effect from the fertilizer treatment applied at the onset of the experiment 2 years early and carried thru production in the RRG (Table 4.5). Also, red maple and littleleaf linden showed no difference in growth between 7 gal 16+8 and 15 g 16+8 was not significant (Table 4.5).

From the sample of plants moved to the PIP in June 2009 some were left for a year in the PIP in both pot sizes (12 months RRG and 12 months PIP). Red maples and littleleaf lindens showed no fertilizers difference when grown in the RRG (Table 4.6). Red maple shoot dry weight was larger in 15 g 12+12 plants (Table 4.6). Littleleaf lindens 7 gal 12+12 and 15 gal 12+12 were not influenced by pot size in this comparison (Table 4.6). The largest maples by shoot dry weight were grown in 15 gal 12+12 with CR (Table 4.6). Height of little leaf lindens may not show differences because they were topped in June 2009 at planting.

When all plants evaluated in June 2010 are compared, red maple plants in 7 g 12+12 were shorter in height and with smaller shoot dry weight than the other pot sizes of schedule (Table 4.7). These plants are the largest in the transplanting. Plants in RRG, 3 gal 24+0 after two years in the same pot had a similar growth to PIP plants. Mathers found in 2009 study that June 2009 planted birch and maple and oak, were from 3 gal transplanted into 7 gal in the RRG by August the 7 gal were 4% taller than those left in 3 gal (unpublished). RRG provide a modification of the environment and protect plants to extreme temperatures which seems to

be as good as plants transplanted to PIP. However, leaving the RRG plants in 3 gal pots for 2 years was not an acceptable practice for their root systems and if been transplanted in the landscape would be inferior. Littleleaf linden showed the opposite those that were in PIP (7 gal 16+8 or 15 g 16+8) for 8 months grew better than those left in 3 gal in the RRG or transplanted to the PIP (7 gal 12+12 and 15 g 12+12) 12 months later (Table 4.7). Plants in smaller pots were smaller (3 gal and 7 gal) but also plants that were longer in the same pot were smaller than the plants that were in 7 or 15 gal pots for 8 months (Table 4.7).

Plants topped in June 2009 had an average heigh range of 212-287 in 2 years and a caliper range of 16.5-19.4 (Table B). Even when treatments could not be compared, the littleleaf linden's growth, in 3 gal pots, from the 12th month of the experiment to the 24th month, represented an increase in growth of 8-47% in height and 46-70% in caliper. Mathers (2010) reported 86% increase in caliper of trees difficult to transplant that were grown in RRG in 3 gal pots and then transplanted to 7 gal PIP. Littleleaf linden show a potential niche-market.

Species	Treatments	Height (cm)	Caliper (mm)	Leaf area (mm2)	Root dry weight (gr)	Shoot dry weight (gr)
Red Maple	CR	183 a	13.3 a	4430.0 a	103.4 a	101.0 a
	CR+LF	189 a	13.8 a	3952.8 a	98.0 a	95.0 a
	Significance	NS	NS	NS	NS	NS
Littleleaf linden	CR	229 a	15.0 a	2329.7	86.2 a	112.1 a
	CR+LF	205 a	12.9 b	1104.7	46.3 a	83.5 a
	Significance	NS	***	NS	NS	NS

Table 4.3. Growth measures evaluated in October 2009 for the trees from Summer 2008 planting after been grown for 16 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Red maple	CR	182 a	15.1 a	155.2 a
	CR+LF	167 a	16.0 a	152.7 a
	Significance	NS	NS	NS
	7 g12+4	166 a	15.7 a	149.9 a
	15 g 12+4	182 a	15.4 a	157.6 a
	Significance	NS	NS	NS
	CR in 7 gal 12+4	173 a	16.0 ab	166.3 a
	CR in 15 g12+4	190 a	14.2 b	144.1 a
	CR+LF in 7 g12+4	157 a	15.2 ab	128.1 a
	CR+LF in 15 g12+4	174 a	16.7 a	171.1 a
	Interaction	NS	NS	NS
Littleleaf linden	CR	173 a	13.4 a	55.1 a
	CR+LF	166 a	12.6 a	49.3 a
	Significance	NS	NS	NS
	7 g12+4	173 a	13.4 a	53.3 a
	15 g 12+4	165 a	12.6 a	50.1 a
	Significance	NS	NS	NS
	CR in 7 gal 12+4	170 ab	13.7 a	53.1 a
	CR in 15 g12+4	173 a	13.2 a	57.1 a
	CR+LF in 7 g12+4	177 a	13.1 a	49.2 a
	CR+LF in 15 g12+4	156 b	12.1 a	49.4 a
	Interaction	*	NS	NS

Table 4.4. Growth measures evaluated in October 2009 for the trees from Summer 2008 planting after been grown for 12 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in June 2009 for 4 months. Months in the RRG+PIP noted after the pot size Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Red maple	CR	212 a	17.2 a	221.0 a
	CR+LF	220 a	16.6 a	234.2 a
	Significance	NS	NS	NS
	7 g 16+8	225 a	17.7 a	238.6 a
	15 g 16+8	207 a	16.2 a	216.7 a
	Significance	NS	NS	NS
	CR in 7 gal16+8	205 ab	17.6 a	216.2 a
	CR in 15 g16+8	220 ab	16.9 a	225.8 a
	CR+LF in 7 g16+8	245 a	17.7 a	260.9 a
	CR+LF in 15 g16+8	195 b	15.5 a	207.5 a
	Interaction	NS	NS	NS
Littleleaf linden	CR	281 a	19.5 a	208.8 a
	CR+LF	261 a	17.9 a	184.9 a
	Significance	NS	NS	NS
	7 g16+8	258.1 a	18.4 a	178.1 a
	15 g 16+8	287.1 a	19.2 a	215.6 a
	Significance	NS	NS	NS
	CR in 7 gal16+8	284 a	19.2 a	201.7 ab
	CR in 15 g16+8	277 a	19.7 a	215.7 a
	CR+LF in 7 g16+8	232 a	17.5 a	154.5 b
	CR+LF in 15 g16+8	300 a	18.5 a	215.4 a
	Interaction	NS	NS	NS

Table 4.5. Growth measures evaluated in June 2010 for the trees from Summer 2008 planting after been grown for 16 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in October 2009 for 8 months. Months in the RRG+PIP noted after the pot size Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Red maple	CR	203 a	18.4 a	210.1 a
	CR+LF	200 a	16.9 a	176.8 a
	Significance	NS	NS	NS
	7 g12+12	198 a	16.4 a	159.5 b
	15 g 12+12	206 a	19.3 a	231.7 a
	Significance	NS	NS	**
	CR in 7 gal 12+12	195 a	17.4 a	164.9 b
	CR in 15 g12+12	217 a	20.2 a	285.3 a
	CR+LF in 7 g12+12	201 a	15.5 a	154.0 b
	CR+LF in 15 g12+12	197 a	18.7 a	199.5 b
	Interaction	NS	NS	NS
Littleleaf linden	CR	210 a	16.9 a	118.7 a
	CR+LF	231 a	17.2 a	127.8 a
	Significance	NS	NS	NS
	7 g12+12	228 a	17.6 a	127.2 a
	15 g 12+12	212 a	16.5 a	118.7 a
	Significance	NS	NS	NS
	CR in 7 gal 12+12	230 a	18.1 a	131.4 a
	CR in 15 g12+12	195 a	15.9 a	110.4 a
	CR+LF in 7 g12+12	227 a	17.1 a	123.0 a
	CR+LF in 15 g12+12	235 a	17.4 a	135.2 a
	Interaction	NS	NS	NS

Table 4.6. Growth measures evaluated in June 2010 for the trees from Summer 2008 planting after been grown for 12 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in June 2009 for 12 months. Months in the RRG+ PIP noted after the pot size. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Species	Treatment	Height	Caliper	Shoot dry weight
Red maple	3 gal 24+0	221 a	17.1 a	204.7 a
	7 g 16+8	225 a	17.7 a	238.6 a
	7 gal 12+12	183 b	16.9 a	152.7 b
	15 g 16+8	207 a	16.2 a	216.7 a
	15 g 12+12	206 a	19.3 a	231.7 a
	Significance	NS	NS	0.0157
Littleleaf linden	3 gal 24+0	232 b	18.3 a	126.9 b
	7 g 16+8	258 ab	18.4 a	178.1 a
	7 gal 12+12	228 b	17.6 a	127.2 b
	15 g 16+8	287 a	19.2 a	215.6 a
	15 g 12+12	212 b	16.5 a	118.6 b
	Significance	NS	NS	NS

Table 4.7. Growth measures evaluated in June 2010 for the trees from Summer 2008 planting. Trees have been grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Plants transplanted to pot in pot (PIP) system in Sherwood Ohio. Months in the RRG+ PIP noted after the pot size. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Year two, Fall 2008

October 2009 evaluation

Red maple tree death during overwintering created incomplete an insufficient number of plants per treatment to analyze. Red maple data per treatment will not be shown. Average of all plants available over treatments show that the plants transplanted in 7 gal 8+4 and 15 g 8+4 were similar but smaller than the plants left in the RRG for 12 moths (Table). Littleleaf linden trees that were left in the RRG in 3 gal pots from October 2008 to October 2009 (3 gal 12+0) showed no growth parameter differences with Geohumus or temperature treatment (Table 4.8). Also, trees that were planted to the PIP in June 2009, 7 gal 8+4 and 15 g 8+4, showed no promotion of the growth carried by temperature treatment applied during winter 2008 in the RRG, (Table 4.8). A significant interaction between Geohumus and pot size occurred (Table 4.9), 1% Geohumus additions to 7 g 8+4 increased the calipers of littleleaf linden.

June 2010 evaluation

From plants transplanted in June 2009 to the PIP, a complete set of plants were left for a year, 7 gal 8+12 and 15 gal 8+12. Littleleaf lindens calipers with 1% Geohumus were larger than 0G (Table 4.10). Height and shoot dry weight was not affected by Geohumus treatment in PIP. Temperature and pot size were had no other significant affect with littleleaf lindens in PIP (Table 4.10).

Plants that were transplanted to the PIP in October 2009, 7 gal 12+3 and 15 gal 12+3, showed no difference in any growth parameter or any treatment between

Geohumus or temperature or pot size for any of the measures (Table 4.11). Also, no interaction was found between treatments.

Schedules of cropping 3 gal 20+0, 7 gal 8+12, 15 gal 8+12, 7 gal 12+8 and 15 gal 12+8 (RRG+PIP) respectively, littleleaf lindens in 3 gal 20+0 were taller than plants moved to the PIP (Table 4.12). Littleleaf linden had a vigorous growth inside of the RRG, probably the protection inside of the greenhouse to changes in temperature promoted the growth of these plants versus outside in the PIP system. As two set of plants were moved to the PIP in different times, a comparison of growth versus the time spend in the PIP was made. The main effect of time was significant. Schedules of cropping 3 gal 20+0, 7 gal 12+8 and 15 gal 12+8 were larger than plants with 12 months (8+12) in the PIP for all the measures (Table 4.12). There was no interaction between pot size and time in the PIP. Plants in the RRG for 20 months (3 gal 20+0) were similar to plants that were in the PIP for 8 months only, regardless the pot size, 7 or 15 gal (Table 4.12). Plants that stayed in the RRG for a year and were moved in October 2009 to the PIP (12+8) were larger than plants that spend 8 months in the RRG and 12 months in the PIP (8+12). This is similar to our results for the crop planted in Summer 2008. The plants that spent more time in the RRG, 16 months (16+8) were larger than the plants moved earlier (12+12) at 12 months in the RRG. This similarity is not true with the Fall 2007 crops. The Fall 2007 was also transplanted to the PIP in Summer and not in Fall as the crops from Summer 2008 and Fall 2008.

From the results of Fall planting 2007 and 2008, show that littleleaf lindens preferred the AT over BH. However, Fall plantings growth over treatments show that littleleaf lindens were over 108 cm in height and 7.1 mm caliper (). Littleleaf lindens did not get to 120 cm in height and 12.7 mm in caliper as it was desired but the growth is excellent for plant considered difficult to grow.

Species	Treatments	Height (cm)	Caliper (mm)	Leaf area (mm^2)	Root dry weight (gr)	Shoot dry weight (gr)
Littleleaf linden	0G	251 a	14.0 a	4230.8 a	33.3 a	98.0 a
	1G	259 a	14.6 a	4383.4 a	37.3 a	100.8 a
	Significance	NS	NS	NS	NS	NS
	AT	242 a	14.0 a	5148.2 a	39.1 a	99.3 a
	BH	268 a	14.7 a	3669.9 a	32.7 a	99.8 a
	Significance	NS	NS	NS	NS	NS
	0G AT	236 a	13.6 a	4293.0 a	33.4 a	81.5 a
	0G BH	269 a	14.4 a	4184.2 a	33.2 a	110.4 a
	1G AT	249 a	14.4 a	5789.5 a	43.4 a	112.6 a
	1G BH	267 a	14.9 a	3258.4 b	32.3 a	91.3 a
	Interaction	NS	NS	NS	NS	NS

Table 4.8. Growth parameters evaluated in October 2009 to the trees from Fall 2008 planting grown for 12 months in 3 gal. pots at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Littleleaf linden	0G	152 a	11.6 a	39.0 a
	1G	153 a	11.8 a	35.4 a
	Significance	NS	NS	NS
	AT	157 a	11.8 a	36.4 a
	BH	147 a	11.6 a	38.5 a
	Significance	NS	NS	NS
	7 gal. 8+4	154 a	12.1 a	40.5 a
	15 gal. 8+4	150 a	11.4 b	35.0 a
	Significance	NS	***	NS
	0G in 7 gal. 8+4	150 a	11.8 b	40.5 a
	0G in 15 gal. 8+4	153 a	11.4 b	37.8 a
	1G in 7 gal. 8+4	160 a	12.4 a	40.4 a
	1G in 15 gal. 8+4	147 a	11.4 b	31.6 a
	Interaction	NS	*	NS
	AT in 7 gal. 8+4	162 a	12.5 a	39.1 a
	AT in 15 gal.8+4	154 a	12.8 a	34.2 a
	BH in 7 gal. 8+4	147 a	15.5 a	41.8 a
	BH in 15 gal.8+4	147 a	14.2 a	35.9 a
	Interaction	NS	NS	NS

Table 4.9. Growth parameters evaluated in October 2009 to littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) trees from Fall 2008 planting grown for 8 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in June 2009 for 4 months. Months in the RRG+PIP noted after the pot size. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Littleleaf linden	0G	193 a	15.5 b	132.9 a
	1G	221 a	17.1 a	125.7 a
	Significance	NS	*	NS
	AT	206 a	16.1 a	119.8 a
	BH	217 a	16.9 a	135.6 a
	Significance	NS	NS	NS
	7 gal.	227 a	17.4 a	128.8 a
	15 gal.	192 a	15.5 a	126.8 a
	Significance	NS	NS	NS
	0G in 7 gal.8+12	213 a	16.7 a	120.8 a
	0G in 15 gal.8+12	186 a	15.1 b	137.5 a
	1G in 7 gal.8+12	230 a	17.5 a	130.3 a
	1G in 15 gal. 8+12	200 a	16.1 a	114.6 a
	Interaction	NS	NS	NS
	AT in 7 gal.8+12	217 a	17.1 a	118.4 a
	AT in 15 gal.8+12	189 a	14.6 a	122.4 a
	BH in 7 gal.8+12	240 a	17.7 a	141.5 a
	BH in 15 gal.8+12	195 a	16.2 a	129.7 a
	Interaction	NS	NS	NS

Table 4.10. Growth parameters evaluated in June 2010 to littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) trees from Fall 2008 planting grown for 8 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in June 2009 for 12 months.Months in the RRG+PIP noted after the pot size. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Littleleaf linden	0G	277 a	19.7 a	193.7 a
	1G	284 a	19.9 a	230.1 a
	Significance	NS	NS	NS
	AT	268 a	19.5 a	189.8 a
	BH	290 a	20.1 a	219.5 a
	Significance	NS	NS	NS
	7 gal.12+8	268 a	19.5 a	174.9 a
	15 gal. 12+8	283 a	19.9 a	217.3 a
	Significance	NS	NS	NS
	0G in 7 gal.12+8	268 a	19.4 a	174.9 a
	0G in 15 gal.12+8	283 a	19.9 a	207.7 a
	1G in 7 gal.12+8	.	.	.
	1G in 15 gal.12+8	284 a	19.9 a	230.1 a
	Interaction	NS	NS	NS
	AT in 7 gal.12+8	262 a	19.7 a	175.9 a
	AT in 15 gal.12+8	271 a	19.4 a	195.7 a
	BH in 7 gal.12+8	275 a	19.2 a	174.0 a
	BH in 15 gal.12+8	296 a	20.5 a	238.9 a
	Interaction	NS	NS	NS

Table 4.11. Growth parameters evaluated in June 2010 to littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) trees from Fall 2008 planting grown for 12 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in October 2009 for 8 months. Months in the RRG+PIP noted after the pot size. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant. (.) no data.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Littleleaf linden	0G	259 a	18.9 a	174.1 a
	1G	243 a	17.9 a	150.7 a
	Significance	NS	NS	NS
	AT	250 a	18.4 a	167.6 a
	BH	252 a	18.5 a	157.3 a
	Significance	NS	NS	NS
	3 gal. 20+0	312 a	20.2 a	176.6 a
	7 gal.[z]	242 b	18.1 b	147.0 a
	15 gal.	238 b	18.1 b	172.2 a
	Significance	NS	NS	NS
	0G in 3 gal.	305 a	20.3 a	181.5 a
	0G in 7 gal.	259 b	18.9 a	168.4 a
	0G in 15 gal.	238 b	18.3 a	175.5 a
	1G in 3 gal.	333 a	20.2 a	170.7 a
	1G in 7 gal.	230 b	17.5 a	132.8 a
	1G in 15 gal.	239 b	17.8 a	167.9 a
	Interaction	NS	NS	NS

continued

Table 4.12. Growth parameters evaluated in June 2010 to littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) and were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009. Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in different times. Months in the RRG+PIP noted after the pot size. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.[z] Average over plantings when RRG+PIP not indicated.

Table 4.12 continued

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Littleleaf linden	AT in 3 gal.	311 a	19.8 a	167.9 a
	AT in 7 gal.	234 b	17.9 a	144.9 a
	AT in 15 gal.	237 b	18.2 a	166.1 a
	BH in 3 gal.	316 a	21.1 a	191.9 a
	BH in 7 gal.	250 b	18.2 a	149.4 a
	BH in 15 gal.	239 b	18.0 a	177.5 a
	Interaction	NS	NS	NS
	3 gal 20+0	313 a	20.1 a	176.6 a
	7 g 12+8	276 a	19.7 a	183.4 a
	7 gal 8+12	227 b	17.4 b	128.8 b
	15 gal. 12+8	284 a	19.9 a	233.9 a
	15 gal. 8+12	198 b	16.5 b	124.9 b
	Significance	NS	NS	NS

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Year two, Summer 2009

June 2010 evaluation

There were not enough red maples in 3 gal 12+0 to do a proper comparison (Table 4.13). Two red maples without Geohumus (0G) and three red maples with 1% of Geohumus (1G) average growth parameters are shown (Table 4.13). Japanese tree lilacs, after been stalled, started to grow later and were not affected by the Geohumus treatment to any of the parameters (Table 4.13). Littleleaf lindens were highly variable in growth, so even that the averages look different it showed no significant difference with the Geohumus treatment (Table 4.13). This may be attributed to the lack of normal growth at the beginning of the planting due to poor quality seedlings were received.

Red maples in the PIP, 7 gal 4+8 and 15 gal 4+8, were evaluated June 2010 had a larger caliper when where in 0G than 1G (Table 4.14). Red maples grown in 1G and 15 gal 4+8 were smaller than 1G in 7 gal 4+8 or 0G in 7 gal 4+8. The average height and caliper of red maples in 3 gal was 140 cm and 7.4mm, respectively (Table 4.14). Plants that stayed in the RRG in 3 gal pots were taller than plants in the PIP but caliper was smaller. Plants in the RRG have been in the 3 gal pots for a year. Plants upshifted to the PIP were for four months in the RRG (June to October) and 8 months in the PIP (October to June). Red maples reached the desired height for whips of 120 cm in the RRG but plants transplanted to the PIP were smaller than 120 cm when averaged over treatments (Table).

September 2010 evaluation

Summer crops of red maples reached the desirable height of 120 cm when averaged over treatment (Table) even after 12 months in the RRG. This suggests that plantings from Fall are better acclimatized than plants from summer.

Acer rubrum have been reported to have a much more time to acclimate to physiological transplant stress than spring-transplanted trees before the onset of spring shoot growth when transplanted to PIP (Harris and Fanelli, 1999). However, this seems to be true also to transplants in RRG.

Height, caliper and shoot dry weights were similar between the Geohumus treatments for the Japanese tree lilac and littleleaf lindens (Table 4.15). There was a lot of variation in the growth of the trees and differences were difficult to found. Japanese tree lilacs were smaller than the desire size but littleleaf lindens had reveled acceptable height and caliper. There was only enough littleleaf lindens and Japanese tree lilac to transplant into 7 gal PIP and no 15 gal PIP were grown.

Species	Treatments	Height (cm)	Caliper (mm)	Leaf area (mm^2)	Root dry weight (gr)	Shoot dry weight (gr)
Red Maple	0G	115	5.0	.	77.6	.
	1G	148	8.5	2095.6	33.7	43.9
Japanese tree lilac	0G	57 a	2.6 a	1555.9 a	10.5 a	31.1 a
	1G	53 a	2.6 a	1227.8 a	3.2 a	9.3 a
	Significance	NS	NS	NS	NS	NS
Littleleaf linden	0G	128 a	10.4 a	1081.7 a	13.0 a	25.8 a
	1G	108 a	9.1 a	2566.3 a	10.1 a	22.7 a
	Significance	NS	NS	NS	NS	NS

Table 4.13. Growth parameters evaluated in June 2010 to the trees from Summer 2009 planting grown for 12 months in 3 gal. pots at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Red maple (*Acer rubrum* L. 'October Glory'®), littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) and Japanese tree lilacs (*Syringa reticulate* 'Sigzam') were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G). Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant, (.) no data to compare.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Red maple	0G	98 a	11.0 a	99.7 a
	1G	88 a	9.8 b	41.2 a
	Significance	NS	*	NS
	3 gal 12+0	140	7.4	43.9
	7 gal.4+8	102 a	10.8 a	76.7 a
	15 gal.4+8	78 a	10.1 a	65.7 a
	Significance	NS	NS	NS
	0G in 7 gal. 4+8	93 a	11.3 a	140.7 a
	0G in 15 gal. 4+8	82 a	10.8 a	66.9 a
	1G in 7 gal. 4+8	109 a	10.4 a	34.0 b
	1G in 15 gal .4+8	67 a	8.1 b	62.7 a
	Interaction	NS	NS	NS

Table 4.14. Growth parameters evaluated to red maple (*Acer rubrum* L. 'October Glory'®) in June 2010 to the trees from Summer 2009 planting grown for 4 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G). Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in October 2009 for 8 months. Months in the RRG+PIP noted after the pot size. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Species	Treatment	Height (cm)	Caliper (mm)	Shoot (gr)
Japanese tree lilac	0G 7 gal. 12+4	98 a	8.7 a	40.8 a
	1G 7 gal. 12+4	63 a	6.3 a	17.4 a
	Significance	NS	NS	NS
Littleleaf linden	0G 7 gal. 12+4	169 a	12.6 a	58.6 a
	1G 7 gal. 12+4	137 a	12.1 a	44.7 a
	Significance	NS	NS	NS

Table 4.15. Growth parameters evaluated in June 2010 to the trees from Summer 2009 planting grown for 12 months at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) and Japanese tree lilacs (*Syringa reticulate* 'Sigzam') were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G). Plants transplanted to pot in pot (PIP) system in Sherwood Ohio in June 2010 for 3 months. Months in the RRG+PIP noted after the pot size. Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Conclusion

Plants grown in the RRG were transplanted to PIP in 7gal and 15 gal. Our data suggest that red maple have a preference with the CR+LF. CR+LF was used through the PIP production in 15 gal in Natorp's Garden Store and Landscape (Mason, OH). Plants that stayed in the RRG were larger than plants transplanted to PIP (Table 4-16), except in Summer 2008 when all plants stayed for 12 months before transplanting to PIP. The RRG plants and PIP plants were similar (Table 4-16). After 24 months, plants transplanted to the PIP average growth over treatment were similar with plants in the RRG (Table 4-16). The use of BH at 70°F during Fall plantings was beneficial but did not carry through time. Future studies with BH in red maple should be conducted. Our results agree with Harris (1999) that Fall transplanted plants trees have more time to acclimate to physical transplant stress than spring transplanted trees (Harris and Fanelli, 1999). Acer rubrum is been reported to have a pre-bud break root growth (Harris and Fanelli, 1999). Nursery operators can probably pest exploit the pre-budbreak root growth of red maple by planning liners in Fall instead spring (Harris and Fanelli, 1999). He suggested that Fall transplanting will assure growers an "ample pre-budbreak" root growth to support rapid spring shoot growth. Our results suggest that Fall plantings in RRG also acclimatize better than Summer plantings. However Zhu (2005) reported an increase in caliper from July to November of 178% in 15 gal pots of *Acer rubrum* (Zhu et al., 2005). More studies should be

done evaluating the growth of red maple in the combination of double crop in RRG and out plant to PIP.

Littleleaf lindens preferred to be grown without BH. Plants that stayed for 12 months in the RRG, grew larger than plants that where 8 months in the RRG and then transplanted to PIP (Table 4-17). Geohumus have an effect in the littleleaf lindens growth. More investigation with different amounts of Geohumus without any BH should be conducted.

Avondale redbud was benefit by the BH and the 1G. BH effect was carried thought after 20 months in the RRG. AS a comparable plant for the zone 5, *Cercis canadensis* should be studied with BH and 1G (Table 4-18).

Table 4.16 Timeline with the significant growth parameters results for red maples (*Acer rubrum* L. 'October Glory'®) for each planting during the whole experiment at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada) in 3 gallon pots. Fall 2007 and Summer 2008 plants were fertilize with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Fall 2008 and Summer 2009 trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G). Fall 2007 and Fall 2008 were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F (Fall 2007) with an increase to 70ºF (Fall 2008) or left at ambient temperature (AT) from December to March. Plants were evaluated through the experiment for height in cm (H), caliper in mm (C) and shoot dry weights in gr (S). RRG plants were transplanted to pot in pot (PIP) system in Sherwood, Ohio or Mason, Ohio. Months in the RRG+PIP noted after the pot size. Means averaged over treatments. Parameters significant at least significant differences (LSD) = 0.05. NS non-significant.

	2007	2008	2008	2008	2008	2009	2009	2009	2010
Planting	Oct	Apr	Jun	Aug	Oct	Apr	Jun	Oct	Jun
Fall 07	Planted	6 mo.		10 months old			21 months old		
3 gal 10+0	H 7.62	NS root vol.		CR+LF caliper H 90, C 7.8, S 29.6			No plants in 3gal Pots		
7 gal 11+10				Transplant to PIP (Sherwood, OH)			AT+CR caliper and shoot **worst growth** Interaction H 122, C 11.0, S 45.0		
15 gal 11+10				Transplant to PIP (Mason, OH)			Height, Caliper & shoot larger than 7 gal H 212, C 19.5, S 18.8		
Su 08			Planted		4 months old		12 months old	16 months old	24 months old
3 gal 24+0			H 15.24		CR Height and caliper H 401, C 5.7		CR Height H 140, C 8.1	NS(12+0) H 186, C 13.5, S 98.0	H 221, C 17.1, S 204
7 gal 12+4							Transplant to PIP (Sherwood, OH)	NS H 166, C 15.7, S 149.9	
15 gal 12+4							Transplant to PIP (Sherwood, OH)	NS H 182, C 15.4, S 157.6	
7 gal 12+12							Transplant to PIP (Sherwood, OH)		Height, shoot smaller than rest of crops b/b H 183, C 16.9, S 152.7
15 gal 12+12							Transplant to PIP (Sherwood, OH)		Shoot larger CR a/a H 206, C 19.3, S 231.7
7 gal 15+8								Transplant to PIP (Sherwood, OH)	NS/a H 225, C 17.7, S 238.6
15 gal 15+8								Transplant to PIP (Sherwood, OH)	NS/a H 207, C 16.2, S 216

Table4.16 Continued

Table 4.16 Continued

	2007	2008	2008	2008	2008	2009	2009	2009	2010
Planting	Oct	Apr	Jun	Aug	Oct	Apr	Jun	Oct	Jun
Fall 08					Planted	6 months old	8 months old	12 months old	20 months old
3 gal 20+10					H 7.62	No Plants evaluated	BH0G Height and BH Caliper H 112, C 6.6, S 3.6	NS 2 plants only H 212, C 13.9, S 121.8	H 205, C 13.9
7 gal 8+4							Transplant to PIP (Sherwood, OH)	H 148, C 13.1, S 101.9	
15 gal 8+4							Transplant to PIP (Sherwood, OH)	H 142, C 13.4, S 109.5	
Su 09							Planted	4 months old	12 months old
3 gal 12+0							H 7.62	0G Shoots H 97.5, C 8.7, S 24.8	H 140, C 7.4, S 43.95
7 gal 4+8								Transplant to PIP (Sherwood, OH)	0G Caliper Main Effect H 162, C 10.8, S 76.7
15 gal 4+8								Transplant to PIP (Sherwood, OH)	NS Variable # of Plants H 78, C 10.1, S 65.7

Table 4.17. Timeline with the significant growth parameters results for littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) for each planting during the whole experiment at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada) in 3 gallon pots. Fall 2007 and Summer 2008 plants were fertilize with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Fall 2008 and Summer 2009 trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G). Fall 2007 and Fall 2008 were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F (Fall 2007) with an increase to 70ºF (Fall 2008) or left at ambient temperature (AT) from December to March. Plants were evaluated through the experiment for height in cm (H), caliper in mm (C) and shoot dry weights in gr (S). RRG plants were transplanted to pot in pot (PIP) system in Sherwood, Ohio or Mason, Ohio. Months in the RRG+PIP noted after the pot size. Means averaged over treatments. Parameters significant at least significant differences (LSD) = 0.05. NS non-significant.

	2007	2008	2008	2008	2008	2009	2009	2009	2010
Planting	Oct	Apr	Jun	Aug	Oct	Apr	Jun	Oct	Jun
Fall 07	Planted	6 mo.		10 months old	12 months old		21 months old		
3 gal 10+0	H 7.62	NS root vol.		AT root and shoot dry weight H 108, C 7.1, S 24.5					
7 gal 11+8					Transplant to PIP (Sherwood, OH)		NS H 157, C 12.5, S 42		
15 gal 11+8					Transplant to PIP (Mason, OH)		Height, caliper and shoot larger than 7 g H 209, C 21.8, S 137		
Su 08			Planted		4 months old		12 months old	16 months old	24 months old
3 gal 24+0			H 7.62		NS H 71, C 6.2		NS H 195, C 11.3	CR caliper H 221, C 14.3, S 99.8	H 232 C 18.3 S 126.9
7 gal 12+4							Transplant to PIP (Sherwood, OH)/Topped	H 173, C 13.4, S 53.3	
15 gal 12+4							Transplant to PIP (Sherwood, OH)/Topped	CR+LF height worst/b Interaction H 165, C 12.6, S 50.1	
7 gal 12+12							Transplant to PIP (Sherwood, OH)/Topped		NS H 228, C 17.6, S 127.2
15 gal 12+12							Transplant to PIP (Sherwood, OH)/Topped		NS H 212, C 16.5, S 118.6
7 gal 16+8								Transplant to PIP (Sherwood, OH)	NS H 258, C 18.4, S 178.1
15 gal 16+8								Transplant to PIP (Sherwood, OH)	NS H 287, C 19.2, S 215

Table 4.17 Continued

Table 4.17 Continued

	2007	2008	2008	2008	2008	2009	2009	2009	2010	2010
Planting	Oct	Apr	June	Aug	Oct	Apr	Jun	Oct	Jun	Sep
Fall 08					Planted		8 months old	12 months old	20 months old	
3 gal 20+0					H 25.4	BH shoot	AT height and caliper 1G caliper H 113, C 7.9, S 4.9	NS H 255, C 14.3, S 99.6	Over all height and caliper larger than 7 and 15/a H 313, C 20.1, S 203.9	
7 gal 8+4							Transplant to PIP (Sherwood, OH)	1G caliper interaction pot size /a H 154, C 12.1, S 40.5		
15 gal 8+4							Transplant to PIP (Sherwood, OH)	/b H 150, C 11.4, S 35.0		
7 gal 8+12							Transplant to PIP (Sherwood, OH)		1G main effect H 227, C 17.4, S 128.8	
15 gal 8+12							Transplant to PIP (Sherwood, OH)		H 198, C 16.5, S 124.95	
7 gal 12+4								Transplant to PIP (Sherwood, OH)	NS N01G H 276, C 19.7, S 183.4	
15 gal 12+4								Transplant to PIP (Sherwood, OH)	NS H 284, C 19.9, S 233.9	
Su 09							Planted	4 months old	12 months old	
3 gal 12+0							H 7.62	NS, variable H 51 C 4.6	NS variable data	
7 gal 12+3								No plants	Transplant to PIP (Sherwood, OH)	NS H 153, C 12.4, S 51.75

Table 4.18. Timeline with the significant growth parameters results for Avondale redbuds (*Cercis chinensis* L. 'Avondale') (Fall 2007, 2008 and Summer 2008) and Japanese tree lilacs (*Syringa reticulate* 'Sigzam') (Summer 2009) for each planting during the whole experiment at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada) in 3 gallon pots. Fall 2007 and Summer 2008 plants were fertilize with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. Fall 2008 and Summer 2009 trees were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G). Fall 2007 and Fall 2008 were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F (Fall 2007) with an increase to 70ºF (Fall 2008) or left at ambient temperature (AT) from December to March. Plants were evaluated through the experiment for height in cm (H), caliper in mm (C) and shoot dry weights in gr (S). RRG plants were transplanted to pot in pot (PIP) system in Sherwood, Ohio or Mason, Ohio. Months in the RRG+PIP noted after the pot size. Means averaged over treatments. Parameters significant at least significant differences (LSD) = 0.05. NS non-significant.

	2007	2008	2008	2008	2008	2009	2009	2009	2010	2010
Plant-ing	Oct	Apr	Jun	Aug	Oct	Apr	Jun	Oct	Jun	Sep
Fall 07			Planted	2 months old						
3 gal 2+0			H 7.62	CR+LF height H 57, C 5.0, S 24.2						
7 gal 2+8 Died					Transplant to PIP (Sherwood, OH)		Died back not hardy			
15 gal 2+8 Died					Transplant to PIP (Sherwood, OH)		Died back not hardy			
Su 08			Planted		4 months old		12 months old			
3 gal RRG			H 7.62		CR height and caliper H 64, C 5.8		NS H 109, C 8.5	NS		
Fall 08					Planted	6 mo.	8 months old			
3 gal 20+0					H 15.64	BH1G shoot interaction	BH height, caliper, leaf 1G shoot H 51, C 4.1, S 2.3	BH Temp H 140, C 10.4, S 72.6	BH Temp H 183, C 13.5, S 120.4	
Su 09							Planted	4 months old	12 months old	15 months old
3 gal 12+0							**Japanese lilac** H 7.62	No Growth, slated	No # plants to evaluate H 55, C 2.6, S 21.7	
7 gal 12+3								No Growth	Transplant to PIP (Sherwood, OH)	H 81, C 7.5, S 29.1

Table 4.19

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