Yearly Research Summary Report
2009 Ornamental Research

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THE OHIO STATE UNIVERSITY EXTENSION

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Growth Acceleration and Increased Out Plant Survival of Ontario and Ohio Grown Tree Liners

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Significance to the industry. A production system developed at Ohio State University (OSU), Columbus, OH, using retractable roof greenhouses (RRGs) (Cravo Equipment, Ltd., Brantford, ON, Canada) and containerized tree liner production has indicated acceleration of production times when outplanted to Pot-in-Pot (PIP) or nursery fields versus conventional bareroot (BR) or polyhouse production. The system has also increased cropping consistency via reduced mortalities and environmental affects and shown promise in new market expansion, including higher priced, difficult-to-grow species. In 2004, #3 (trade 3-gallon) (11.4 L) containerized tree liners from RRGs had 0% mortality versus field BR production *Quercus rubra* at 42% after out-planting into nursery fields to grow on as specimen trees. Averaged over species, RRG liners reached saleable size of 50 mm caliper two years sooner than the BR liners, or a 40% reduction in production time. In 2006, #3 containerized tree liners from RRG's had 27% mortality versus field BR production at 87% after out-planting to #7 (trade 7-gallon) (26.5 L) containers and harsh (Mar. 2006, Avon, OH) conditions in PIP fields. Averaged over species and one growing season, caliper and height of RRG liners were 82 and 84% larger than BR liners, respectively. In only four months, between May1 and August 30, 2007, heights and calipers of 178cm and 9.9 mm for *Cercis canadensis (Eastern red bud)*; 146 cm and 9.7 mm for *Tilia cordata* 'Green spire' (Green spire linden); and 118.4 cm and 7.4 mm *Acer* x*freemanii* 'Jeffersred' (Autumn Blaze™ red maple) liners were produced at OSU, Columbus, OH, supporting our hypothesis that RRG liners can be double-cropped to accelerate production further. Recently RRG liners have shown utility in high stress environments along Ontario, Canada highways leading The Ontario Ministry of Transportation to research an optimized planting process including the use of retractable roof greenhouses (RRG's) liners.

Transplant mortality is high enough that it prevents production of some taxa such as blackgum, oak, hickory and walnut that are course-rooted and do not transplant well (Struve et al., 1987). These species can be produced profitably in containers. Labor utilization is also a challenge. Greater than 50% of sales occur in the spring in the nursery industry. Any practice that can be performed in the fall would optimize labor utilization, reduces the seasonality of labor and facilitates more full time, year-round employment. Fall planting is also preferred to spring in terms of ease of tree establishment and growth. Receiving liners in the spring from the PNW for transplanting creates additional strains on the U.S. Midwestern nursery labor force, at this already hectic time. Thus, outside container whip production systems were developed to minimize transplant shock and allow difficult-to-transplant species to be produced profitably (Struve et al., 1987; Struve, 1996). Further advantages to this system were developed when tree liners were produced in RRG's relative to the outside environment. Stoven et al., (2006) found RRG produced liners had 15% greater height, 6% increased caliper growth, 25% higher nitrogen use efficiency (NUE) and 11% higher water use efficiency (WUE) than those produced in a combination heated greenhouse-outdoor (CHGO) production environment as per Struve et al. (1987) and (Struve, 1996).

Pot-in-pot (PIP) consists of a holder pot that has been permanently placed in the ground into which a planted container is positioned. With PIP versus conventional field production approximately three times the number of plants per unit area of land can be produced. Plants are harvested in a shorter period of time and greater mechanization potential exists. Labor and equipment needs in terms of digging are also reduced and plants can be harvested year-round (Mathers et al., 2002).

RRGs researched at Ohio State University (OSU) in addition to their utility in increasing WUE, NUE and growth as indicated above have also been found to cut production times of certain crops in half (Mathers, 2001) reduce wind throw problems and extend growing seasons (Stoven et al., 2005; Mathers et al., 2006a). For some growers the costs of PIP and RRG's have made their use prohibitive. 2008 installation costs of PIP systems in Ohio were running $30-32,000.00/A and RRG installations $250,000/A (peaked-roof) (T. Demaline, Willoway Nursery, personal communication). Accelerating and increasing productivity of PIP and RRG installations would make their use more affordable and equitable. The objective of this study was to examine five tradition bareroot or polyhouse "difficult-to-grow" species that have Midwestern U.S. niche-market potential to see if four different production environments affected growth during and postharvest in fields and PIP. A second objective was to examine postharvest survival and growth of four traditionally "easy-to-grow" or common species from three nursery production environments.

Materials and methods.

Experiment 1. Postharvest field evaluations of common tree liners. At Ohio State University (OSU) Waterman Farm, Columbus, OH (40°00'N, 83°02'W), in heavy clay soils, four species of tree liners were transplanted from three nursery production environments. The three production environments were a peak-RRG white woven polyethylene film with a glazing of 35% shade (RC98) (Cravo Equipment, Ltd., Brantford, ON, Canada) in 11.4 L (#3) classic Spinout® treated containers (Nursery Supplies, Inc., Fairless Hills, PA), a combination heated greenhouse-outdoor (CHGO) production environment also in #3 containers at OSU, Columbus, OH and BR liners from PNW nursery fields, Canby, OR (45°15'N, 122°42'W). Trees were irrigated and fertilized at Waterman Farm as per Mathers et al. (2005a). The OSU liners had been produced according to the methods described by Stoven et al. (2005). The OSU liners were planted in the field in October 5, 2003 and PNW BR liners were planted when traditionally available for planting in Ohio, April 26, 2004. Before planting the PNWBR liner roots were hydrated in a 5°C cooler for two days. All plants were trained to 2 m tall bamboo stakes (A.M. Leonard, Inc., Piqua, OH) installed at planting. In August 2005, the bamboo stakes were replaced with TMO-PRO stakes (T-MATE-O, Charlestown, IN). The four species evaluated were, *Acer* x*freemanii* 'Jeffersred' (Autumn Blaze™ red maple), *Malus* 'Prairifire' (Prairifire crabapple), *Cercis canadensis* (Eastern redbud) and *Quercus rubra* (red oak). Growth measures of height and caliper (taken at 15.2 cm above the soil) were recorded at planting and June and September 2004, 2005 and 2006. Average initial heights and calipers for redbud, maple, crabs and oaks out-planted from the RRG were as cited in Mathers et al., (2005a).

The PNW BR liners compared to the RRG or CHGO liners of maple and oak had greater height and greater caliper at planting. The PNW BR liners compared to the RRG or CHGO liners at planting of redbud and crabapple had less height/greater caliper and less height/less caliper, respectively. In early November 2003, all the RRG and CHGO trees were pruned according to normal nursery practices. No pruning was done to PNW BR liners at time of planting. Perennial ryegrass was seeded in the fall of 2003 between the rows and mowed as required. Between row spacing is 3.6 m and in-row 2 m. Height and caliper from the six dates of evaluation were subjected to ANOVA using the GLM procedure within SAS® (SAS Institute, Inc., Cary, NC, 2000). Fisher's least significant difference test was used to compare means at P ≤ 0.05 (SAS© Institute Inc.). The Type I Sum of Squares analyses were performed and graphs were produced in Excel from the analyses. All factors were considered fixed effects; therefore all terms were tested for significance against the error mean square.

*Experiment 2. Optimum environment for niche-market species production. F*ive species of trees were selected after discussions with Ohio growers to determine which difficult-to-grow species had the greatest niche market potential in Midwest shade tree production. Niche market for this study included species that were coarse-rooted, difficult-to-transplant and/or native taxa. The three environments, peak-RRG with white woven polyethylene film with a glazing of 35% shade (RC98) (Cravo Equipment, Ltd., Brantford, ON, Canada), a flat-RRG white woven polyethylene film 50% shade (RAR-40) (Cravo Equipment, Ltd., Brantford, ON, Canada) and a Rutgers' style 6-mil polyethylene covered polyhouse at OSU, Columbus, OH were evaluated. We hypothesized that if the polyhouse or flat-RRG provided similar growth and quality liners to the peaked-RRG then Midwest tree liner production could be more attractive to a larger audience due to lower start-up and construction costs. The five species selected for the study were yellowwood, (*Cladrastis kentukea*), a difficult to acclimate species; red oak (*Quercus rubra*), coarse rooted and in previous studies requiring at least two years to reach marketable size; stewartia (*Stewartia pseudocamellia*), a species prone to root rot diseases; Japanese tree lilac (*Syringa reticulata* 'Ivory Silk') and littleleaf linden (*Tilia cordata* 'Greenspire,') two species in short supply as bareroot liners.

The trial was repeated over two years, 2005 and 2006, so that environment could be replicated. Seedlings of yellowwood, red oak, stewartia and Japanese tree lilac were transplanted from copper-treated 250XL containers to 11.4 L classic Spinout® treated containers (Nursery Supplies, Inc., Fairless Hills, PA) in October, 2004 and 2005. Little leaf linden, was left in copper-treated 250XL containers until March 15, 2005 and 2006, due to their small size and then transplanted to 11.4 L pots. In October of each year, all of the plants were placed in a peaked-RRG. The roof on the RRG was set to open at 3 °C. Temperatures were kept above -4 °C in the RRG by a forced air propane heater. Plants were hand watered twice monthly during the winter. On March 15, 2005 and 2006, all of the plants were fertilized with 48.0g 19-5-8 Osmocote® (Scott's Co., Marysville, OH) slow release fertilizer. They were then moved to their respective environments: one-third of the plants were kept in the peaked-RRG, one-third was moved to the flat-RRG, and one-third was moved to a polyhouse covered with 6-mil, white polyethylene at OSU, Columbus, OH. On March 15, 2005 and 2006, settings in the peak-roof and flat-roof RRG were changed. The sidewalls were set to open at 13°C. The roofs remained closed unless temperatures exceeded 24°C. On April 1, 2005, sidewalls were reset to open at 18°C, and on April 15, 2005, sidewalls were set to open at 24°C for the remainder of the season. However, if temperatures exceeded 29°C during the day, then the roof was set to close for shading, and the sidewalls remained open for air circulation. The polyethylene was left on the polyhouse until May 15 (the first frost free day for Columbus, OH) when it was removed. Growth was evaluated in June, August and October of both years by collecting leaf area, caliper, height, and dry weights of shoots and roots. Irrigation was conducted with inline emitters, delivering 1.14 L/day in three equally timed periods per day, at 10:00, 2:00 PM, and 4:00 PM.

Experiment 3. Optimum environment for niche-market species postharvest survival. 11.4 L pots of the five species grown in experiment described immediately above were out-planted into fields at OSU Waterman Farm, Columbus, OH (40°00'N, 83°02'W), in November 2005 and Willoway Nurseries, Avon, OH (41°25'N, 82°01'W) in November 2006. The plants at Willoway Nurseries were transplanted to 26.5 L (#7) containers in March 2007 and placed in PIP socket pots along with PNWBR liners for comparison. Plants were also planted from 11.4 L containers from Willoway Nurseries into nursery fields at Split Rail Nursery, Circleville, OH (39°35'N, 82°55'W) in March 2007. The PIP 26.5 L containers at Willoway were replicated five times in a completely randomized design with tree liners produced from the OSU peaked-RRG, flat-RRG, and polyhouse and PNW fields (lifted BR). The plants at Waterman were also replicated five times but no PNWBR liners were planted. Temperatures were recorded for daily highs and lows at OSU, Willoway Nursery and Circleville, OH. Heights and calipers were recorded in September 2007.

Results and Discussion.

Experiment 1. Postharvest field evaluations of common tree liners. As reported in Mathers et al. (2006b) 11.4 L containerized tree liners from RRG's planted in October 2003 in nursery fields to grow on as specimen trees had 0% mortality versus 42% with PNW field BR liners. The greatest tree mortality occurred in PNW red oak with five of 12 BR liners having died by September 2004. Averaged over species, RRG liners reached saleable size (50 mm) two years sooner than the PNWBR liners (Fig. 1). Using a linear regression ($y=3.5752x + 10.048$, $r^2=0.9432$) to estimate growth PNWBR liner caliper growth was not projected to reach 50 mm until June 2009 (Fig. 1). This represents a 40% cut in production time using RRG tree liners ($y = 5.9099x + 6.1247$, $r^2 = 0.9672$) versus BR. Caliper measurements over date and species were significant for environment at ($P=0.0011$) with RRG liners producing significant increases in caliper growth of 4.2 mm in the field versus the PNW BR (data not shown). The effects of original growing environment for caliper were non-significant for the first year after out-planting; however, environment became more significant in the second and third year after out-planting (Fig. 1). Heights over species and environment were increasing at 15.8 cm /evaluation date ($r^2=0.9244$) (Fig.2). Most differences in height were recorded between September to June (Fig. 2) indicating the most active period of tree growth. The only June to September evaluation period that differed for height occurred in 2006 (Fig.2) indicating a relative acceleration in height as time progressed in the field, especially for the RRG liners (data not shown).

Experiment 2. Optimum environment for niche-market species production. Environment pooled over species, date and year was significant for caliper ($P=0.04$) and height ($P=0.02$). Environment main effect calipers and heights were significantly larger in either RRG flat- or peak- versus the polyhouse (data not shown). No significant differences for caliper or height were present between the Peaked-RRG and Flat-RRG. Although pooled over years the height and caliper differences of 7.7 cm and 0.5 mm, respectively between RRG and poly were significant, they were not sufficient to justify the expense of a RRG construction over a polyhouse for containerized tree liner production. However, the RRG reduced environmental fluctuations between years, thus increasing cropping consistency by 30% over species. This increase in consistency was statistically and economically significant and justifies the RRG construction versus a polyhouse for tree liner production. The variability between years was highly significant in the polyhouse for height (Fig. 3a), caliper (Fig.3b) and root weight (data not shown). The root weights were 5 grams lower, averaged over species, in the polyhouse in 2005 versus 2006. Height growth was increased by 18% in the flat-RRG (2005) versus the polyhouse (2006) (Fig. 3a) and calipers were increased by 15% in the peak-RRG (2006) versus the polyhouse (2006) (Fig. 3b). Hemming et al. (2006) found sweet pepper production in The Netherlands can potentially be increased by 5-6% during summer months due to use of diffuse greenhouse covering materials. Nelkin and Schuch (2004) found lemon grass (*Cymbopogon citrates* L.) biomass could be increased 7 times in a 35% shade RRG versus filed production. A more consistent crop could be grown year to year in either RRG versus the polyhouse, with variability being species dependent (Fig. 4). Only *Syringa* showed no variability, year-to-year with environment (Fig. 4). Oak demonstrated the most variability year-to-year due to environment (Fig. 4).

Percent saleable (120 cm) height was achieved earlier in the RRGs versus the polyhouse (data not shown). Yellowwoods by August in the flat-RRG had 50% saleable, the peak-RRG 63%, and polyhouse only 20%. In October, only one yellowwood made it to saleable size in the polyhouse. In October, 50% the oaks in the flat- or peak- RRG peak were of saleable size; however, only 33% were saleable in the polyhouse. The Stewartia grew to saleable size in all environments by October; however, in August, in the flat-RRG roof 58% were saleable, 83% in the peak-RRG, and 42% in the polyhouse (data not shown). The species with the largest heights (Fig. 4) and calipers in 2005 and 2006 was Japanese tree lilac followed by Linden. Again, Lilac was also the most consistent species from year to year (Fig. 4). Yellowwood and red oak were the least consistent species and grew best in 2005. Linden and Stewartia grew best in 2006 (Fig. 4).

This study indicates even difficult-to-grow species can be produced in Ohio RRG's with good results. The RRG provides the benefits of manipulating the growing environment and scattering light through its white woven polyethylene-film roof material, which helps reduce heat loads, improve growth and plant canopy development (Mathers, 2001). Diffuse light is able to penetrate deeper into a plant canopy in comparison to direct light (Young and Smith, 1983).

Typical light saturation levels for sun leaves of woody plants is between 25-50 klx (Larcher, 1995), or 475-950 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (Langhans and Tibbitts, 1997). Assuming levels above 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$ would not result in increased net photosynthesis, and would be inhibitory to plant growth Stoven et al. (2006) found CHGO *PAR* levels exceeded 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$ 72% of the growing season. However, in the RRG *PAR* levels never exceeded 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Although *PAR* levels were lower in the RRG than with the CHGO, levels were not low enough to reduce net photosynthesis and resulted in greater dry weights (Stoven et al., 2006). As a result of light scattering effect of the RRG roof reducing sun saturation conditions the improvement in the plant canopy development is evident (Table 1). Stoven et al. (2006) found with the exception of maple all leaf area measures were greater with the RRG than in the CHGO (Table 1). The difference with the maple was attributed solely to this species preference for water soluble fertilizer versus controlled release in the CHGO, especially. The effect of increased leaf areas was greatest in the middle layers of the canopy in this study (data not shown). Hemming et al. (2006) observed in greenhouses during summer months in The Netherlands increases in photosynthesis occurred in all crop layers of sweet pepper, except the top layer using diffuse light covering materials versus clear glass coverings. The highest increase was noticed in the middle layers of the plant canopy (Hemming et al., 2006).

Light quality is also changed with greater leaf areas. Plant leaves filter light. Specifically, leaves allow more far red light (720 -740 nm) to pass through than red light (660-680 nm), thus altering the red: far red ratio below them. By altering light quality, plants perceive canopy shading via alterations in phytochrome photoequilibria that can result in increased stem elongation, reduced leaf areas and reduced branching (Erwin, et al., 2006). This partially

explains increases in height growth in the RRG's versus the polyhouse; however, the RRG diffuse light mediates the effects of increased leaf shading and phytochrome photoequilibria alterations particularly in branching and leaf area response. The diffuse light and roll-up sidewalls to increase air-flow and plant movement, resulted in improved caliper and branching. It is considered that a positive correlation exists between increased branching and increased caliper development (T. Demaline, Willoway Nursery, personal communications). However, Sternberg and Struve (2007) studying Cyclanilide to promote lateral branching in container-grown whips found no such relationship. The RRG roof material also allows for UV-B light to enter which has been found to be important in secondary plant metabolite development (Johnson et al., 1999). RRG's are more expensive than a polyhouse and the cost deters many growers. However, the light utilization, crop consistency and crop acceleration (49 – 68%, depending on species) obtained in the RRG versus the polyhouse makes their construction advantageous.
*Experiment 3. Optimum environment for niche-market species postharvest survival. O*n April 7, 2007 in the early morning hours of 4:00 AM at Willoway Nurseries low temperatures of -10º C were experienced following several days of record high temperatures for the area. Temperatures of -7º and -8º C were also experienced in Columbus and Circleville, OH. These low temperatures caused significant damage to vascular tissue of tree liners that had been planted from PNW BR and peaked-RRG, flat-RRG 11.4L pots to 26.5 L pots placed in PIP sockets in March at Willoway Nursery and foliage that had flushed in the warm days proceeding April 7. In late April 2007, PNWBR liners had 87% postharvest mortality versus flat- or peak-RRG's with 27% postharvest mortality at Willoway Nursery. We speculate that this 60% survival increase with RRG liners may be due in part to greater secondary metabolite synthesis and reduced heat and light stress afforded by the light diffusing roof materials of the RRGs. The species contributing to the 27% RRG mortality were Stewartia (with 0% survival regardless of production environment) followed by yellowwood (data not shown). Measures taken in September 2007 in 46.5 L PIP socket pots at Willoway indicated of the trees surviving the April 7 frost, the peak-RRG or flat-RRG had greater caliper (Fig. 5) versus PNWBR liners or the polyhouse liners. Averaged over species and one growing season, caliper (18.9 mm) and height (166.43 cm) of RRG liners were significantly larger than bareroot liners (3.6 mm and 26 cm) or 82 and 84% larger (Fig. 5).

The consistency of cropping described above for experiment 2 for the peak-RRG seemed to have followed through post harvest for caliper (Fig. 5) and height (data not shown). Some polyhouse liners survived the frost; however, the peak-RRG liners survival was most consistent. Yellowwood mortality was 33%, 55% and 55% from the peak-RRG, flat-RRG and polyhouse, respectively. Syringa mortality was 0%, 8% and 25% from peak-RRG, flat-RRG and polyhouse, respectively. 11.4 L pots of the same five species planted into fields at OSU Waterman Farm, Columbus, OH (40°00'N, 83°02'W), in November 2005 versus Willoway 2006 also suffered in the April 2007 frost. Field caliper changes between planting (Sept. 2006) and June 2008 indicated yellowwood due to high mortality rates within the species had actually shown a reduction in caliper (Fig. 6). In Waterman farm planting as at Willoway Nursery the Stewartia had 100% mortality after the April 7 frost regardless of environment; therefore, no caliper measures were presented (Fig. 6). Lilac liners at Waterman farm showed the greatest difference in postharvest survival or growth due to production environment (Fig. 6). The peak-RRG Lilac had postharvest calipers of 60% larger than polyhouse liners after 1.5 years in the field (Fig. 6). Tree liners produced at Willoway Nursery in 11.4L containers in RRGs and transplanted Split Rail Nursery fields in March 2007 also had 75 and 80% larger postharvest heights and calipers, respectively, versus PNWBR liners evaluated in October 2007. The growth differences at Split Rail Nursery were also attributed largely to the April 7 frost (Fig. 7).

The modified environment of the RRG provides advantages in the production of difficult-to-grow tree liner species and increased postharvest survival. RRG's had 60% less mortality versus field bareroot production indicating utility in high stress conditions (severe spring-frost conditions) and possibly high stress environments such as along highways. Liners produced in RRG's have also been found to surpass bareroot produced liners in quality, growth, mortality rates and time to marketable size after transplanting into Ohio nursery fields and PIP under normal spring conditions. The less expensive structure of a polyhouse was not found to produce liners with the same cropping consistency or increased survival under severe spring-frost conditions as afforded with the RRG structure.

Midwest, Eastern seaboard, Southern U.S. and Ontario nursery growers import conservatively $300 million worth of tree liners annually from traditional liner production regions such as the PNW. Growers in these non-traditional liner production regions have been reluctant to enter into tree liner production mainly due to shortened growing seasons. Retractable-roof greenhouses make tree liner production viable in these locations via extending the growing season, temperature modification, accelerating caliper tree production, increase cropping consistency and expand existing markets. Increasing fuel costs and other transportation issues continue to add challenges in receiving plant material from long distances. It makes sense to consider production methods that are more sustainable and increase the local economy.

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Table 1. Plant leaf areas and differences of four taxa grown in a RRG = retractable-roof greenhouse (Cravo Equipment, Ltd., Brantford, ON, Canada) and CHGO = combination heated greenhouse-outdoor environment when pooled over fertilizer methods.

Species	Fertilizer	Leaf area CHGO (cm^2)	Leaf area RRG (cm^2)	Leaf area (cm^2) difference between RRG and CHGO
Red Bud	CRF^{w} and WS	7463^{x}	8186	724^{+}
Red Oak	CRF and WS	1747	1920	173^{+}
Autumn Blaze® maple	CRF and WS	11695	11514	182^{-}
Prairifire Crabapple	CRF and WS	2149	3281	1132^{+}

Source: Stoven et al. (2006)

[w] Plants were fertilized with a controlled-release fertilizer (CRF) of Osmocote® 20N-2.2P-6.6K, 9-mo. release, top dressed at 9 g N·pot^{-1}, or a water soluble (WS), Peter's, 21N-3.1P-5.9K at 100 mg·day^{-1} for a total of 9.2 g N for the season.

[x] Each value is the mean of three single-plant subsamples from ten replications pooled over fertilizer.

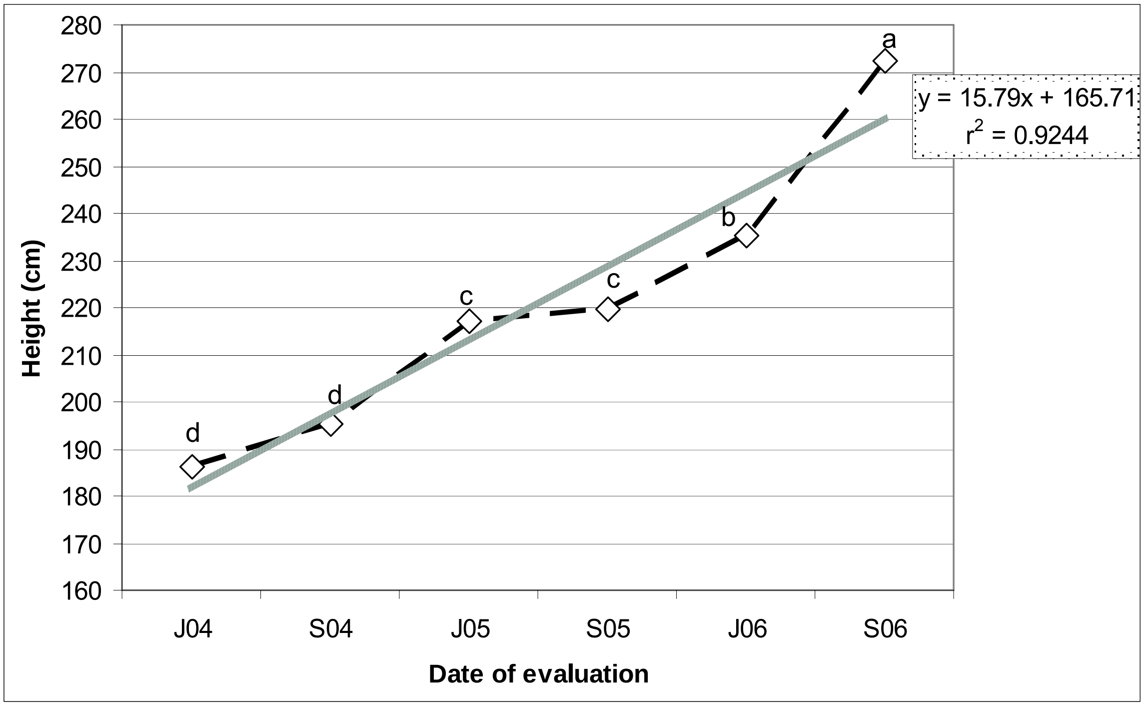

Fig. 1. Postharvest field caliper measures (recorded 15.2 cm above the soil) of tree liners at Ohio State University Waterman Farm, Columbus, OH transplanted October 2003 and recorded June (J) and September (S) 2004-2006 pooled over species *Acer xfreemanii* 'Jeffersred' (Autumn Blaze™ red maple), *Malus* 'Prairifire' (Prairifire crabapple), *Cercis canadensis* (Eastern redbud) and *Quercus rubra* (red oak) from three production environments, CHGO= combination heated greenhouse-outdoor, PNWBR = Pacific Northwest bareroot and RRG= retractable roof greenhouse (Cravo Equipment, Ltd., Brantford, ON, Canada). Linear regressions estimate time to reach 50 mm caliper or saleable size are predicted forward J07-J09 (shown in bold).

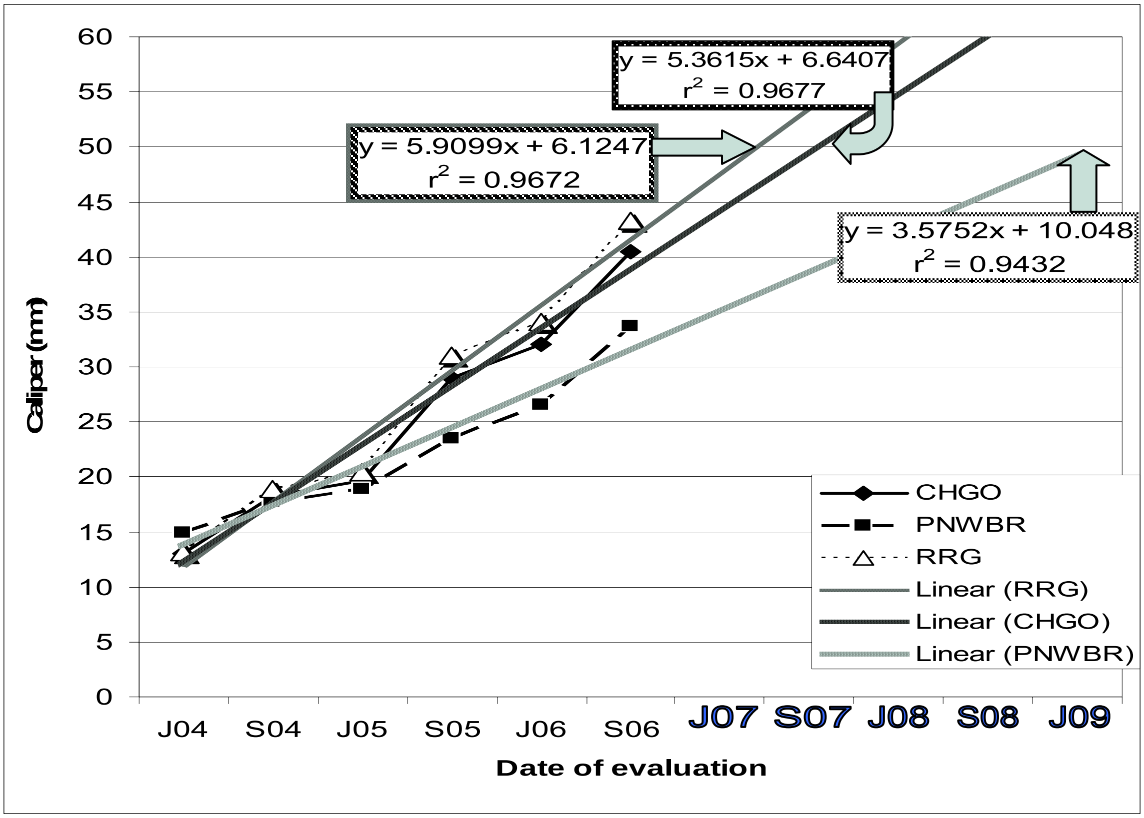

Fig. 2. Postharvest field height measures of tree liners at Ohio State University Waterman Farm, Columbus, OH transplanted October 2003 and recorded June (J) and September (S) 2004-2006 pooled over species *Acer xfreemanii* ‘Jeffersred’ (Autumn Blaze™ red maple), *Malus* ‘Prairifire’ (Prairifire crabapple), *Cercis canadensis* (Eastern redbud) and *Quercus rubra* (red oak) and three production environments, combination heated greenhouse-outdoor (CHGO), Pacific Northwest bareroot (PNWBR) and retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada). Different letters signify least significant difference (LSD) P = 0.05. Linear regression indicates heights were increasing 15.8 cm per measuring period.

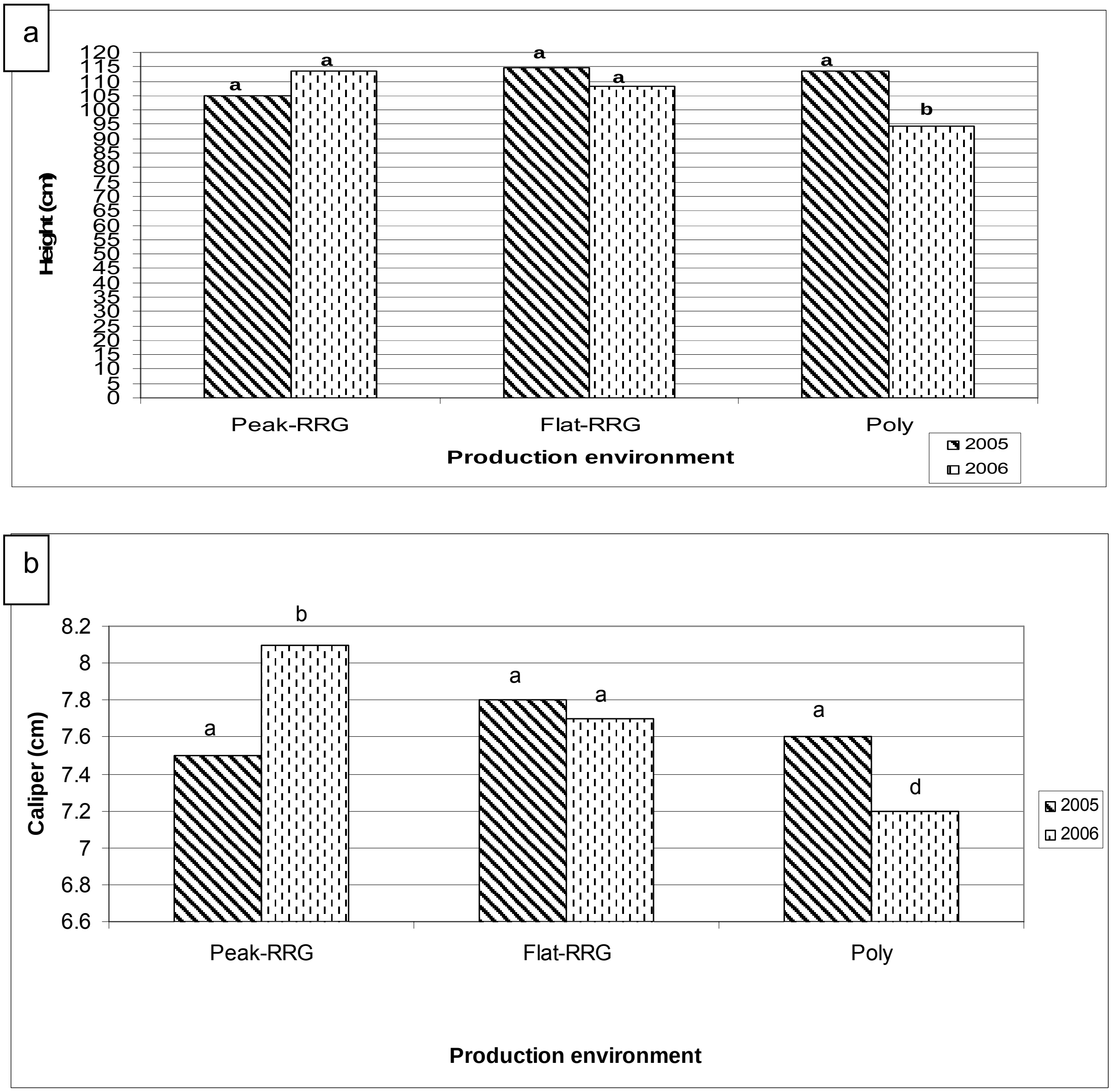

Fig. 3. Production environment (a) height measures and (b) caliper of tree liners in 2005 and 2006 at Ohio State University Columbus, OH pooled over five species yellowwood, (*Cladrastiskentukea*), red oak (*Quercus rubra*), stewartia (*Stewartia pseudocamellia*), Japanese tree lilac (*Syringa reticulata* 'Ivory Silk') and littleleaf linden (*Tilia cordata* 'Greenspire') and three evaluation dates (June, August and October/ yr) for three production environments, Peak = retractable roof greenhouse (RRG) Flat= flat RRG (Cravo Equipment, Ltd., Brantford, ON, Canada) and a 6 mil while polyethylene polyhouse. Different letters signify least significant difference (LSD) P = 0.05.

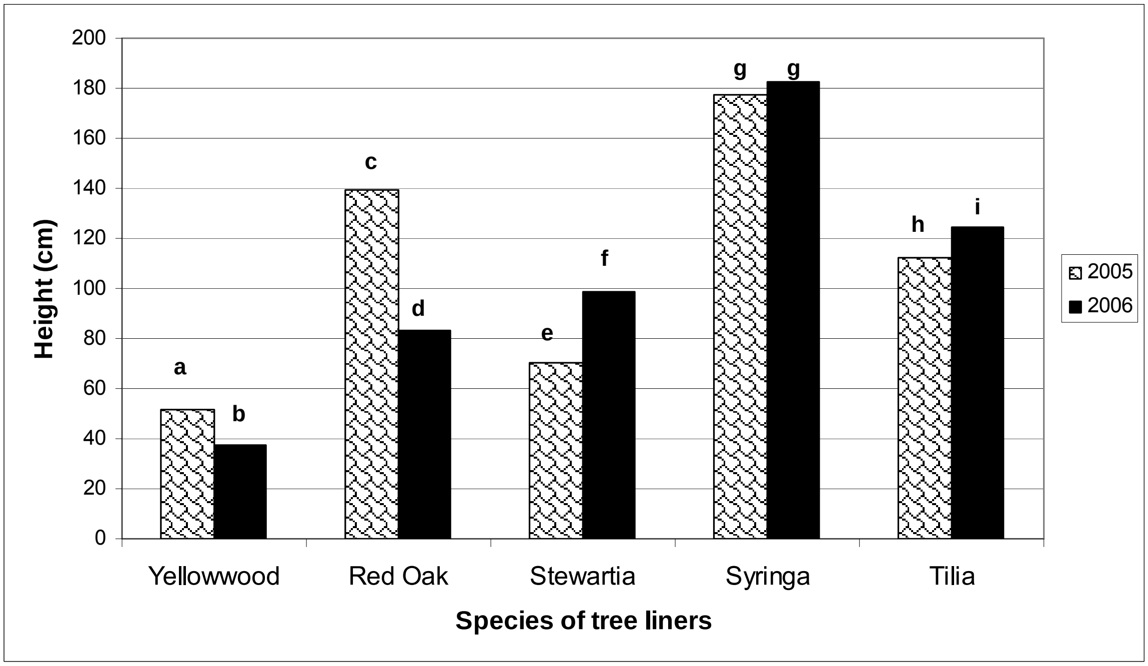

Fig. 4. Production environment height measures for tree liners at Ohio State University, Columbus, OH pooled over three environments [peaked-and flat-retractable roof greenhouses (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada), and a 6 mil while polyethylene polyhouse] and three evaluation dates (June, August and October/ yr) for five species; yellowwood, (*Cladrastiskentukea*), red oak (*Quercus rubra*), stewartia (*Stewartia pseudocamellia*), Japanese tree lilac (*Syringa reticulata* 'Ivory Silk') and littleleaf linden (*Tilia cordata* 'Greenspire'). Different letters signify least significant difference (LSD) P = 0.05.

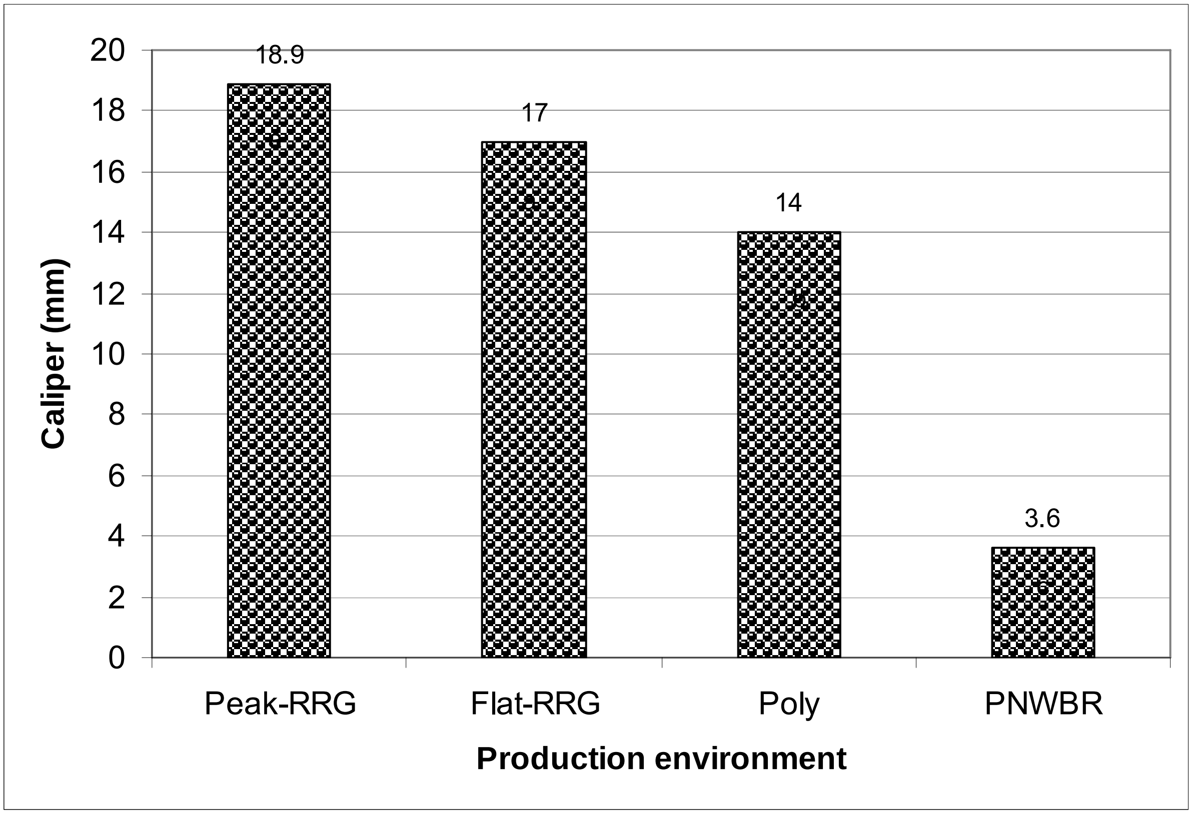

Fig. 5. September, 2007, postharvest caliper measures of tree liners in 46.5 L pots at Willoway Nurseries, Avon, OH pooled over five species; yellowwood, (*Cladrastiskentukea*), red oak (*Quercus rubra*), stewartia (*Stewartia pseudocamellia*), Japanese tree lilac (*Syringa reticulata* 'Ivory Silk') and littleleaf linden (*Tilia cordata* 'Greenspire') produced in four production environments peak-and flat-retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada), and a 6 mil while polyethylene polyhouse (Ohio State University, Columbus, OH), or Pacific Northwest fields (Canby, OR) shipped bareroot (PNWBR), planted from 11.4 L or BR to 46.5 L pot-in-pot (PIP) sockets in March 2007. Different letters signify least significant difference (LSD) P = 0.05.

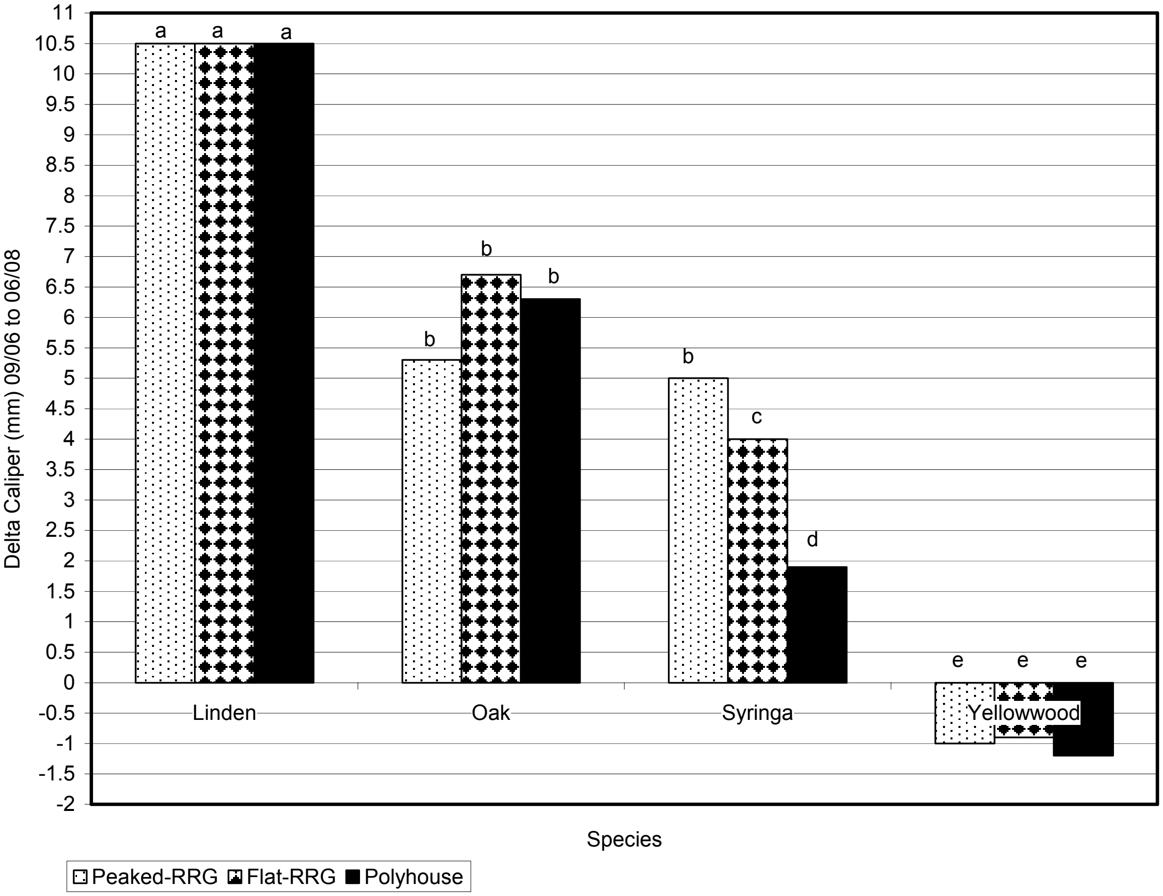

Fig. 6. September 2006 to June 2008 field postharvest caliper delta (Δ) (change between 09/2006-06/2008), environment X species interaction of tree liners (p=0.0040) from 11.4 L pots transplanted to Ohio State University, Waterman farm fields of four species; yellowwood, (*Cladrastiskentukea*), red oak (*Quercus rubra*), Japanese tree lilac (*Syringa reticulata* 'Ivory Silk') and littleleaf linden (*Tilia cordata* 'Greenspire') produced in three production environments peak-and flat- retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada), and a 6 mil while polyethylene polyhouse (Ohio State University, Columbus, OH). Different letters signify least significant difference (LSD) P = 0.05. Environment effects were greater with time in out planting.

Fig. 7. 11.4 L pots of one maple species at Split Rail Nursery, Circleville, OH (39°35’N, 82°55’W) transplanted in March 2007 from tree liners produced at Willoway Nurseries, Inc, Avon, OH (center row and rows to left) and Pacific Northwest bareroot liners (rows to right). Picture taken September 2007, still showing tree injury from April 7, 2007 spring frost event -8º C Circleville, OH following several days of above average high temperatures.

Field Evaluation of Various Herbicide and Mulch Combinations for Ornamental Weed Control

Principle investigators: Upender Somireddy, Hannah Mathers, and Luke Case

Significance to the industry: Weed control is an essential part in the landscape and nursery industries and takes up most of the production costs. Weeds not only compete for resources like nutrients, light and space etc., but also reduce the aesthetics of plants and landscape. Expenses of hand weeding, environmental concerns with herbicides and pesticide bans have led researchers to find alternate weed control techniques. Usage of pre emergence herbicides is the most common method to control weeds in the nursery and landscape industries. Multiple applications of herbicides per year are often required. Some of the problems associated with the use of herbicides are phytotoxicity, leaching, spray drift, runoff, and herbicide resistance. Organic mulches have been widely used by nursery and landscape industry for many reasons, but weed control and mositure conservation. The combination of herbicides and mulches can be a potential approach to control weeds for a longer period of time while reducing the weed control costs, and negative effects of herbicides on the environment. Herbicide treated mulch is an integrated weed management approach in which two weed control methods are combined in order to control weeds effectively. Previous studies demonstrated that herbicide treated mulches work effectively in controlling weeds. Fretz (1973), and Fretz and Dunham (1971) reported higher weed control efficiency with herbicide impregnated mulches. Mathers (2003) obtained higher weed control efficacy with herbicide treated bark nuggets in containers. Case and Mathers (2006) found that pine nuggets combined with various herbicides provided weed control for one year in the field.

The objectives of this study were to evaluate the efficacy of previously untested granular herbicides and mulch combinations compared to tested liquid formulations of herbicides combined with mulches, to evaluate the different mulching depths on efficacy, and to determine the influence of herbicide application methods on efficacy. In addition, two new granular + mulch combinations (one of those is commercially available) were evaluated.

Materials and Methods. Two types of mulches, Hardwood (HW) mulch and pine nuggets (PN) (>2”), were trialed alone at different depths (1, 2.5, and 5”) and in combination with granular Snapshot (SS) 2.5TG [isoxaben + trifluralin at 1.0 lb ai/ac + 4 lb ai/ac respectively (Dow AgroSciences, Indianapolis, IN)] or a similar liquid combination of Treflan HFP (Dow AgroSciences) + Gallery (Dow AgroSciences) at 1.0 lb ai/ac + 4 lb ai/ac, respectively. The three mulching depths represent the recommended depth (2.5”), the depth previously evaluated (1”) and a depth closer approximating what is used in industry (5”). Granular SS was directly applied on top of the mulch in the field. The liquid combination was applied below, above and used to pre-treat the mulch at each depth.

Two separate experiments with a randomized complete block design were conducted. One started in fall 2006 (Sept, 2006) and was repeated in fall 2007 and another started in spring 2007 (May, 2007) and was repeated in spring 2008, at The Ohio State University’s (OSU) Waterman farm, Columbus, Ohio (Fig. 2). Visual readings were taken at 30, 180 and 210 days after treatment (DAT) for the fall start experiments and 30, 60, 90, 120 DAT for the spring start experiments. Visual readings were based on a scale of 0 (no control) to 10 (complete control), with 7 and above being commercially acceptable.

Results and Discussion: Two types of analysis were performed, one using all the treatments and another one using only mulch and herbicide combined treatments. Data from fall 2006 experiment is not included in the analysis as there were many perennial weeds in the experimental plot. Visual ratings at 30 DAT from fall 2007 experiment is not included in the analysis as there is no weed pressure at that time.

There is a significant difference in the efficacy between herbicide application methods only at 1” depth (except liquid-under @ 2.5” HW mulch in spring expt.) with both mulches and during both seasons. Liquid herbicide applied under the mulch performed better than the rest of the methods (Fig.1 and Fig.2). This may be attributed to the persistence of herbicide in the soil as it is protected from volatilization.

Three treatments, treflan+gallery (T+G), untreated hardwood at 1” depth, and control treatment, showed below commercially acceptable level of weed control in the fall experiment. All other treatments have shown above commercially acceptable level of weed efficacy. In spring experiment, six treatments-untreated HW @ 1”, T+G (Treflan+Gallery), Snapshot, untreated PN @ 1”, Snapshot over HW @ 1”, and control, performed below commercially acceptable level of weed control (Fig.3). The difference in the number of treatments that performed below commercially acceptable level in fall and spring might be due to the difference in the intensity of weed pressure. There was less weed pressure (data not presented) in the fall experiment compared to spring experiment. Two commercially available granular herbicide treated mulches have shown commercially acceptable level of efficacy and equally with the other herbicide treated mulches @ 2.5” and 5” (Fig.3).

There is a significant difference between the three depths of mulches (main affects with all herbicide and combined treatments, data not presented). When mulches @ 1” depth combined with herbicides, the weed control efficacy is at 7 or above (Fig.1., Fig.2., and Fig.3). Though the difference between the 2.5” and 5” is statistically significant, application of 5” mulch is not cost effective. Mulches @ 2.5” combined with herbicides gives effective and long term weed control. The slow releasing ability of the herbicide from mulches explains their ability to control weeds for a longer period of time versus herbicides applied alone (Mathers, 2003).

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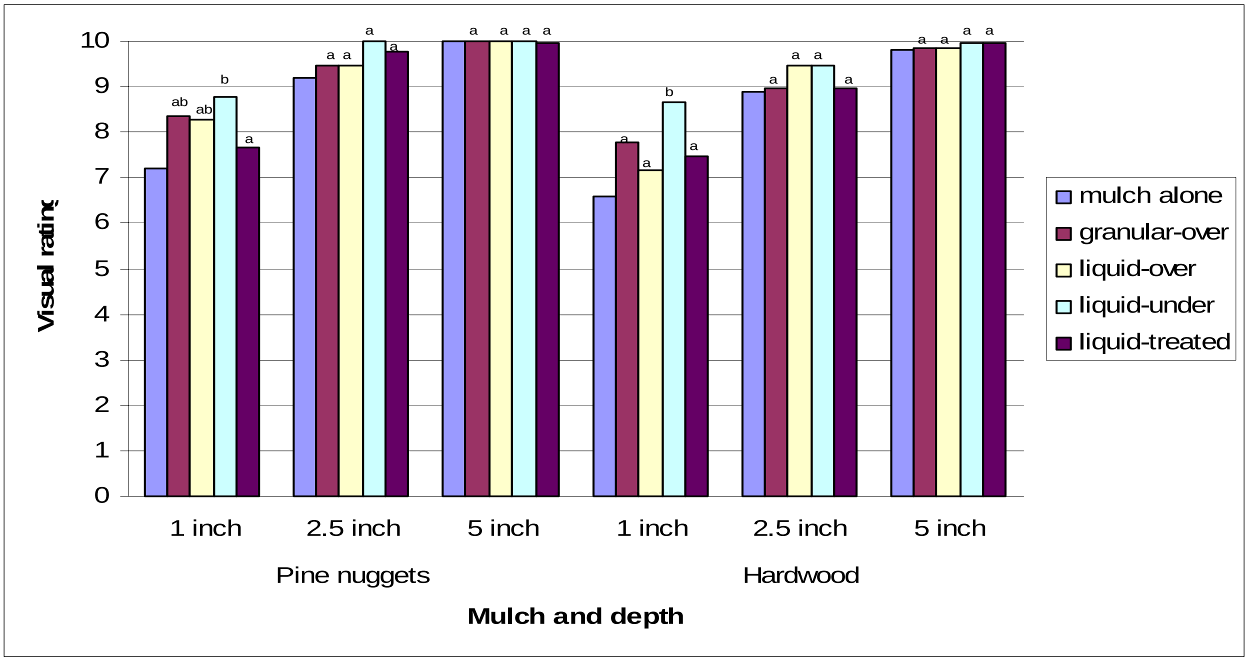

Fig.1. Fall 2007 experiment, mulch, depth and herbicide application methods interaction evaluated by visual ratings (0=0%, 10=100% and $\geq$7 = 70% or more or commercial acceptable control) and over 180 and 210 DAT. Mulch alone treatments are included in the graph for the comparison.

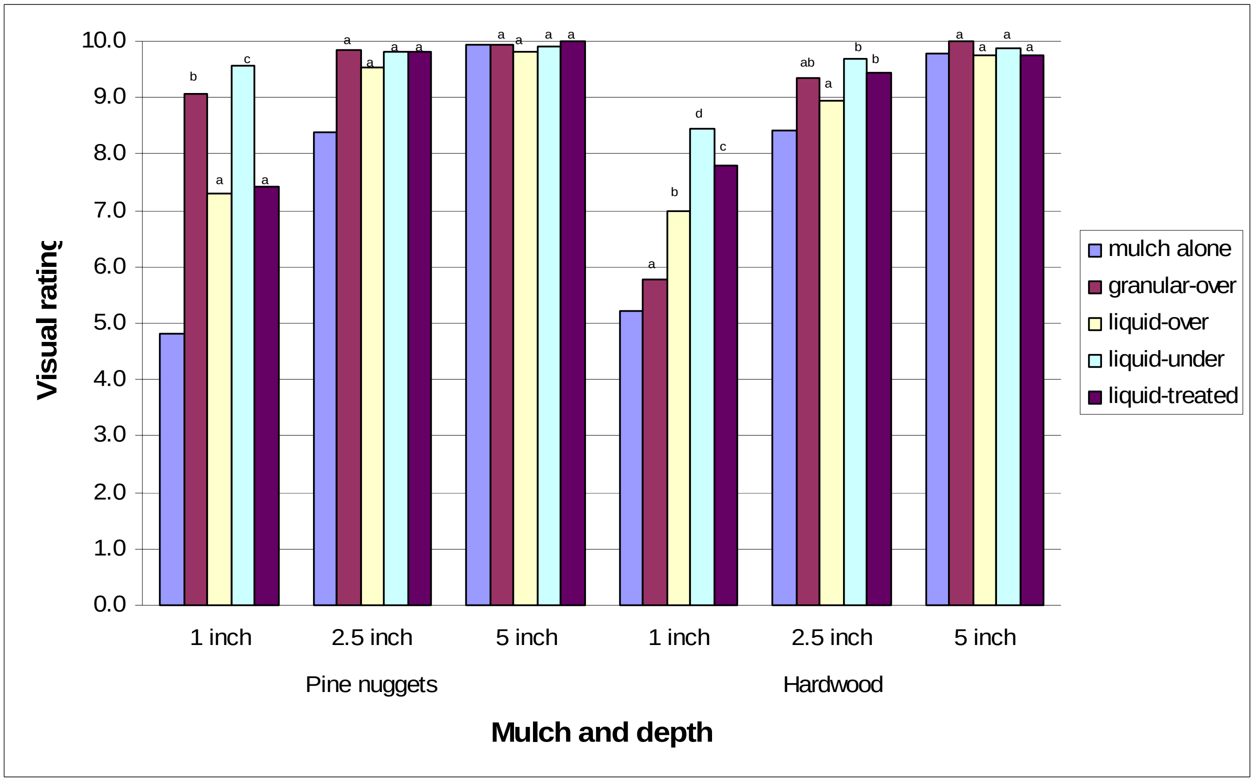

Fig.2. Spring 2007 & 2008 experiments, mulch, depth and herbicide application methods interaction evaluated by visual ratings pooled over 30, 60, 90 and 120 DAT. Mulch alone treatments are included in the graph for comparison only.

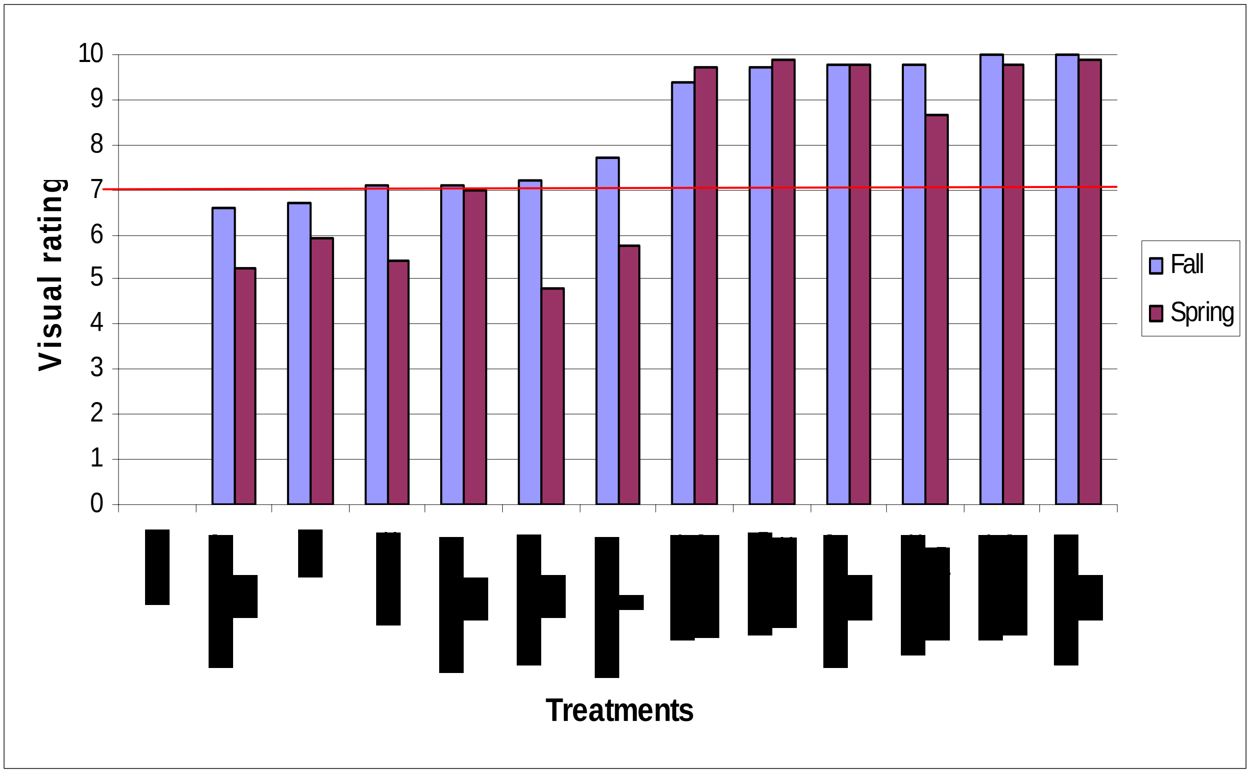

Fig.3. Weed control efficacy of all the treatments for the fall and spring start experiments. The data is pooled across the years and dates for spring experiment and across the dates for the fall (2007) experiment. Only important treatments are included in the graph. The redline indicates the commercially acceptable level.

Effect of Postemergent Herbicide on Sucker Removal/Injury of Field Tree Liners

Priniciple investigators: Kyle M. Daniel and Hannah M. Mathers

Significance to Industry:

The economic cost to the U.S. nursery industry of bark cracking is conservatively estimated at $6.6M annually (or 2.5% of finished inventory) according to recent calculations (Mathers, 2008). The nursery cost estimates continue a pattern of strong and steady increased severity and frequency of bark cracking throughout the US nursery/landscape industry since 2004. However, in 2005 researchers at Ohio State University (OSU) speculated that bark cracking was *not solely* related to cold injury, or Southwest injury, as was widely and previously accepted (Mathers, 2006) but that the absorption of glyphosate into thin or pigmented-bark was also a factor due to the reduction of cold hardiness. Exposure of an ornamental plant to glyphosate through green bark is considered a sub-lethal dose (Kuhns, 1992). In order for a crack to occur, there must first be a point of injury.

Many species of trees are susceptible to producing suckers (or waterspouts). Suckers are not appealing to the consumer, so they must be removed. Past practices of sucker removal included mechanically removing, then applying glyphosate to prevent the development of new suckers. When Roundup lost its' patent in 2000, many new formulations flooded the market. The concurrent trend for glyphosate-containing products includes the increased technologies of surfactants.

The site of action for glyphosate is the EPSP-synthate (5-Enolpyruvylshikimate 3-phosphate synthase), which is located in the shikimic acid pathway. This pathway is vital for production of the precursors to lignin, tannins, IAA, and phenolic compounds (Weaver and Herrmann, 1997). Previous research has shown that these phenolic compounds, or secondary metabolites, provide defenses for the plant, such as environmental, insects and/or disease, and antioxidants (Close and Mcarthur, 2002; Rivero et. al., 2001). Chalker-Scott (1992) indicated that there is a direct relationship between cold hardiness and phenolic compounds.

Glyphosate is a very hydrophilic chemical. For the chemical to pass through the plasma membrane of the cell walls into the phloem, a surfactant must be mixed with the glyphosate. With new formulations' increased penetrant factor, more of the active ingredient is going into the vascular system. Companies that produce glyphosate containing products utilize different surfactant packages, differing rates, and carriers, thus the need for research to determine the product with least phytotoxicity and most efficacy on weeds. The objectives of this study include: 1) Evaluate the effects of chemical vs. mechanical control of sucker removal/injury in four species of trees on North and South sides. 2) Evaluate cold hardiness with regard to sucker removal/injury and postemergent herbicides.

Materials and Methods.

Field Treatments: At The Ohio State University (OSU) on October 5, 2003 Waterman Farm, Columbus, OH (latitude 40.0085, longitude -83.0368), four species of tree liners, *Acer* x *freemanii* 'Jeffersred' (Autumn Blaze™ red maple), *Malus* 'Prairifire' (Prairifire crabapple), *Cercis canadensis* (Eastern redbud) and *Quercus rubra* (red oak) were planted in the field. On July 27, 2007 the average calipers were 62, 38, 51, and 33 mm and average heights were 431, 279, 273, and 275 cm, respectively. Six treatments were imposed; Roundup Original Max (Monsanto, 800 St. Louis, MO) (48.7% glyphosate), Roundup Pro (Monsanto, St. Louis, MO) (41% glyphosate), Kleen-up Pro (Loveland Products, Inc., Greeley, Colorado) (41% glyphosate), Scythe (Dow AgroSciences, Indianapolis, IN) (57% pelargonic acid), mechanical (no herbicide), and a control (no injury, no herbicide). The herbicides were applied at a 5% solution of product, or 6.5 oz/gal of product. All herbicide treatments were applied using a five gallon backpack sprayer (Solo, Newport News, VA) with a LFG 80^o nozzle applied directly to the trunk with a distance from the trunk of approximately 6 in. A completely randomized design with six single plant replications was utilized.

Trees had suckers removed mechanically in June 2007 and 2008 via Felco (Felco, Kirkland, WA) pruning shears. Trees that lacked suckers, such as oak, had an incision made 2.5 cm wide x 5 cm in length at approximately 10 inches from the base of the tree. Sucker removal and one incision made were conducted on the north and the south sides of each tree. Immediately after sucker removal and incisions herbicide treatments where applied according to Kuhns (1992) via a direct application immediately after injury.

Spad 502 chlorophyll meter (Konica Minolta, Tokyo, Japan) readings were obtained September 21, 2007. Shigometer (Osmos, Buffalo, NY) readings were taken on January 16, 2008 to assess trunk cambial resistance, according to Okie and Nyczepir (2004). Starch ratings were obtained on February 4, 2009 using Lugol's solution (Sigma Aldrich, St. Louis, MO). Lugol's solution was applied to one centimeter pieces of detached stem and analyzed visually under a 4x microscope (Fisher Scientific, Hampton, NH). Starch ratings were conducted on a 1-5 scale, with one being 0% starch and five being 100% starch, according to Pemberton and Schuch (2007).

Freezing Treatments: Detached terminal shoots of approximately 4 in. were collected January 7, 2008 and January 22, 2009 to assess cold hardiness. Shoots were placed in a walk-in cooler overnight, 5^0 C following removal from trees and held in Columbus, Ohio. The detached shoots were placed on tape and labeled by treatment and replication, and put in aluminum foil by temperature. The plants were then transferred to an ultra-low freezer (Forma Scientific Inc., Marietta, OH) and frozen to nine set point temperatures (-6^o, -9^o, -12^o,-15^o, -18^o, -21^o, -24^o, -27^o, and -30^o C). The ultra low chest freezer was programmed using a 1/8 DIN Microprocessor-Based, Ramping Series 982 Watlow Controller (Watlow, St. Louis, MO) to lower the temperature at a rate of 3^o C/hr. The aluminum foil, by temperatures, were monitored using an AM16/32 data logger with a CR10X wiring panel (Campbell Scientific, Logan, UT). Shoots were removed at each set point and transferred to the 5^o C according to Mathers (2004). Two viability methods, visual (tissue browning) and electrical conductivity according to and Howell (1973) and Calkins and Swanson (1990) conducted. For the visual evaluations of detached shoots followed their incubation in a 100 percent humidity chamber for 7 days following freezing according to Mathers (2004). Visual injury was scored on a scale of one to five (1=no damage, intact, green cambium layer; 5=brown, non-intact cambium). For electrical conductivity evaluation, immediately after freezing, 3 milliliters of distilled water was added to 13x100 mm test tubes (Fisher Scientific, Pittsburgh, PA), and shaken overnight at 200 rpm using a G10 Gyrotory Shaker (New Brunswick Scientific, Edison, NJ). An initial baseline electrical conductivity (EC) reading was recorded for all samples following freezing. The test tubes were then autoclaved using an Amsco autoclave (Steris Corporation, Mentor, OH) at 121^{o} C for 20 minutes to completely kill all tissue. The test tubes were then shaken again overnight at 200 rpm. After autoclaving and shaking, a final EC reading was obtained for all samples. The baseline EC was subtracted from the final EC and recorded as the differential EC. Higher differential EC reading represent greater tissue cold hardiness (Calkins and Swanson, 1990; Pellet and Heleba, 1998; Stergios and Howell, 1973).

Data Analysis: Visual observations, electrical conductivity, spad, starch, and shigometer data were subjected to analysis of variance (ANOVA) using the general linear models (GLM) procedure within SAS® (SAS Institute, Inc., Cary, NC, 2000). Fisher's least significance difference (LSD) test was used to compare means ($P \leq 0.05$) (SAS$^{©}$ Institute Inc.). The Type II Sum of Squares analyses was performed.

Results and Discussion. Maple exhibited the greatest number of cracks over all treatments (Figure 1). This is similar to what is being reported within the industry. Roundup Original Max produced significantly more cracks over all genus followed by Roundup Pro (Figure 2). This could be attributed to the increased concentration and/or surfactant. Control had significantly less cracking than other treatments (Figure 2). Roundup Original Max and Roundup Pro were significantly less cold hardy than control, mechanical, and Kleenup Pro treaments in both browning and electrical conductivity (Figure 3; Figure 4). The decrease in cold hardiness is attributed to the fact there is a disruption of the shikimate pathway due to the glyphosate, which causes a reduction in phenolics. Starch was not metabolized in Roundup products as compared to the control (Figure 4). Kozlowski and Pollardy (1997) indicates that simple sugars aid in cold hardiness, thus an accumulation of complex carbohydrates that are not broken down into these simple sugars indicates a reduction in cold hardiness. There was no correlation to orientation of cracking, indicating no correlation to Southwest Injury.

Redbud	Oak	Crabapple	Maple
1.9167 a	1.833 a	2.1667 a	5.333 b

Table 1: Amount of cracking on four species of nursery trees subjected to six sucker removal/injury treatments: Roundup Original Maxx, Roundup Pro, Kleenup Pro, Scythe, Mechanical, and Control. Data is combined over all treatments. Numbers indicate the number of cracks. Letters indicate significance LSMeans α=0.05.

Control	Mechanical	Kleenup Pro	Scythe	Roundup Pro	Roundup Original Maxx
0.625 a	2.375 b	2.375 b	2.75 b	3.875 c	4.875 d

Table 2: Amount of cracking of four genus of nursery trees subjected to six sucker removal/injury treatments: *Cercis canadensis, Quercus rubra, Malus* 'Prariefire'., and *Acer x freemanii* 'Jeffersred' Data is combined over all genus of trees. Numbers indicate the number of cracks. Letters indicate significance LSMeans α=0.05.

Control	Mechanical	Kleenup Pro	Scythe	Roundup Original Maxx	Roundup Pro
2.095 a	2.478 a	2.318 a	2.574 b	2.896 c	2.766 d

Table 3: Visual browning of four genus of nursery trees subjected to freezing after six field treatments: *Cercis canadensis, Quercus rubra, Malus* 'Prariefire'., and *Acer x freemanii* 'Jeffersred'. Data is combined over all genus of trees. Numbers indicate browning observation: 1=Alive, 5=Dead. Letters indicate significance LSMeans α=0.05.

Control	Mechanical	Scythe	Kleenup Pro	Roundup Original Maxx	Roundup Pro
.0583 a	.0582 a	.0538 a	.0496 ab	.0432 bc	.0371 c

Table 4: Differential electrical conductivity of four genus of nursery trees subjected to freezing after six field treatments: *Cercis canadensis, Quercus rubra, Malus* 'Prariefire'., and *Acer x freemanii* 'Jeffersred'. Data is combined over all genus of trees. Letters indicate significance LSMeans α=0.05.

Control	Mechanical	Kleenup Pro	Scythe	Roundup Original Maxx	Roundup Pro
2.5625 a	2.4348 a	.2.4375 a	2.6957 ab	3.2273 a	3.25 a

Table 5: Starch accumulation of four genus of nursery trees after six field treatments: *Cercis canadensis, Quercus rubra, Malus* 'Prariefire'., and *Acer x freemanii* 'Jeffersred'. Data is combined over all genus of trees. Letters indicate significance LSMeans α=0.05.

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Phytotoxicity of selected herbicides to containerized nursery stock in conjunction with the IR-4 program

Principle investigators: Dr. Hannah Mathers and Luke Case

Significance to the industry: Weed control is essential in containerized nursery crops and continues to be a major expense for nursery growers, with some crop species having few, if any labeled herbicides. The IR-4 program helps to alleviate problems faced by nursery growers by adding new uses to existing pesticides or new pesticides to the nursery/landscape or any 'minor use' cropping industries. It is imperative that growers use this program because it is based largely on growers' needs. Anyone can go to the website www.ir4.rutgers.edu and list the needs of the operation. The objectives of the IR-4 2009 program were to test numerous herbicides for phytotoxicity on selected ornamentals.

Materials and Methods. Ten species were selected to determine phytotoxicity of preemergence herbicides: yew (*Taxus* x*media* 'Densiformus'), sweetbay magnolia (*Magnolia virginiana*), arborvitae (*Thuja occidentalis* 'Emerald Green'), thornless honeylocust (*Gleditsia triacanthos*), portulaca (*Portulaca* 'Margarita Rosita'), cotoneaster (*Cotoneaster apiculata*), forsythia (*Forsythia x* 'Meadowlark'), dwarf Alberta spruce (*Picea glauca* 'Conica'), crabapple (*Malus domestica*), and Avondale Chinese redbud (*Cercis chinensis* 'Avondale'). Herbicides and rates tested included Freehand (dimethenamid-p + pendimethalin) (BASF Corp.) at 2.65 (1X), 5.3 (2X), and 10.6 (4X) lbs ai/ac, Tower (dimethenamid-p) (BASF Corp.) at 0.97 (1X), 1.94 (2X), and 3.88 (4X) lbs ai/ac, V-10142 (imazosulfuron) (Valent U.S.A Corp., Walnut Creek, CA) at 0.75 (1X), 1.5 (2X), and 3.0 (4X) lbs ai/ac, mesotrione 4 SC (mesotrione) (Syngenta Corp., Wilmington, DE) at 0.187 (1X), 0.25 (1.5X), and 0.37 (2X) lbs ai/ac, BroadStar 0.25G (flumioxazin) (Valent U.S.A. Corp.) at 0.375 (1X), 0.75 (2X), and 1.5 (4X) lbs ai/ac, Certainty (sulfosulfuron) (Monsanto Co., St. Louis, MO) at 0.06 (1X), 0.12 (2X), and 0.23 (4X) lbs ai/ac, F6875 0.3G (sulfentrazone + prodiamine)(FMC Co., Philadelphia, PA) at 0.375 (1X), 0.75 (2X), and 1.5 (4X) lbs ai/ac, and F6875 4SC (sulfentrazone + prodiamine)(FMC Co.) at 0.375 (1X), 0.75 (2X), and 1.5 (4X) lbs ai/ac. Tower, Certainty, and F6875 4SC are liquids which were sprayed with a CO_2 backpack sprayer with 8002 evs nozzles in a spray volume of 25 gallons per acre. All other herbicides were in the granular form and spread by shaker jars. Two applications of each herbicide were applied, approximately 6 weeks apart with the exception of BroadStar. The protocol indicated that BroadStar only be applied twice to species with larger than a 4 in (10 cm) diameter root ball at planting, only once at the second application timing to species with less than a 4 in diameter root ball. BroadStar was applied twice to magnolia and once to honeylocust, spruce, and crabapple. Immediately after each application, ½ acre-inch irrigation was applied. Phytotoxicity evaluations were performed at 1 WA1T (week after first treatment), 2 WAT, 4 WAT, 1 WA2T (week after second treatment), 2 WA2T, and 4 WA2T. Visual ratings were performed on a scale of 0-10 with 0 being no phytotoxicity, 10 being dead, and ≤3 commercially acceptable. Growth was also assessed by measuring at the first and last evaluations. Growth for crabapple, magnolia, and honeylocust were determined by height only; growth for cotoneaster was determined by (width+width)/2; growth for forsythia, spruce, portulaca, arborvitae, and yew were determinded by (height+width+width)/3.

Results and discussion.

FreeHand. FreeHand was safe at all rates on 'Avondale' redbud, honeylocust, and crabapple (Table 1). FreeHand was injurious at the 4X rate on forsythia, and at the 2X and 4X rates on portulaca. In previous trials (2008 Yearly Research Summary Report), honeylocust was stunted by a 3X rate of FreeHand; however, this was not the case in this year's trial. Injury to forsythia was in the form of death; when applied at the first application, forsythia was under some water stress, which indicates that FreeHand should not be applied at the 4X rate to forsythia when under stress. FreeHand caused stem brittleness to portulaca at the 2X and 4X rates. At first glance, portulaca seemed to be doing fine with all rates, but when touched, stems seemed to break much more easily than compared to the untreated controls or portulaca treated with the 1X rate. In previous trials (2008 Yearly Research Summary Report), portulaca 'Hot Shot Rose' was also injured by a 3X rate of FreeHand. FreeHand has good weed control and based on this research and previous research (data not shown), it can be applied to a wide range of crop species. FreeHand is already on the market, and the label will continue to include more crop tolerant species.

Certainty. Certainty was not safe on any of the species tested (Table 1) when all rates are taken into consideration. Although Certainty did not cause visual ratings to be significantly higher than the untreated controls, the ratings still indicated above commercially acceptable levels to the crabapple. Yew was tolerant at the 1X and 2X rates. Cotoneaster was injured by all rates of Certainty, with the 2X and 4X rates severely injuring cotoneaster. Portulaca was extremely sensitive to the rate of Certainty. The 1X rate caused just a slight injury level (stunting), but many of the plants sprayed with the 2X and 4X rates died or almost died. Certainty did cause higher visual ratings to the honeylocust when compared to controls, but not past commercially acceptable levels. Certainty does not have the weed control (data not shown) that would be desirable for nursery growers until the 0.24 lb ai/ac rate, which at this rate, most species tested are not tolerant of.

V-10142. Crabapple and spruce were not affected by any rate of V-10142 (Table 1). However, the 2X and 4X rates did injure cotoneaster. Growth of cotoneaster was severely affected by the V-10142. V-10142 has a similar chemical compound as Certainty, but it does not have quite the injury associated with it as does the Certainty. V-10142 also has acceptable weed control, even at the low rates (data not shown). V-10142 would have applications for the nursery industry, but labeled species would be more limited.

F-6875. Two formulations of F-6875 were tested, a granular and a sprayable. The granular was tested on cotoneaster and spruce. Growth index indicated that the 2X and 4X did stunt the cotoneaster, with the 2X rate being significantly different from the control at the $\alpha = 0.10$ level. However, injury ratings on cotoneaster were still commercially acceptable. The spruce was unaffected by any rate of the granular formulation of F-6875. The sprayable formulation of F-6875 was applied to arborvitae and magnolia. Magnolia was not affected by the sprayable formulation of F-6875, but arborvitae did show slight stunting at the 2X and 4X rates; however, not beyond commercially acceptable levels. F-6875, like FreeHand, is a combination herbicide that controls a broad spectrum of weeds. Based on our research (all data not shown), it does not have as broad a range for crops, but it would still work well for a number of species.

BroadStar. BroadStar was applied to magnolia, crabapple, spruce, and honeylocust and was safe at all species at all the rates tested. Valent recently came out with a new formulation of

BroadStar in order to increase the amount of crops that can be labeled. The new formulation does seem to be safer than the old formulation; however, great care must be taken to ensure that the new formulation is watered in to get the same amount of efficacy as the old formulation.

Tower. Tower was not injurious at any rate when applied to crabapple. Tower was slightly injurious to honey locust, but not beyond commercially acceptable levels, and only right after the first application. Tower is a sprayable formulation of dimethenamid-p, which is one of the chemical compounds in FreeHand. Tower has caused burning of young tissue, especially right after bud break, which is what the honeylocust showed. However, the honeylocust was not that effected. Tower would be a cheaper alternative to FreeHand, but the amount of weed control is not as good.

Mesotrione. Spruce was severely injured by all rates of mesotrione 4SC. Based on research conducted at The Ohio State University, mesotrione has limited application for nursery production. Deciduous (e.g. *Quercus, Acer*) trees seem to be the most tolerant of mesotrione (2008 Yearly Research Summary Report), and future research should be concentrated on those species. Mesotrione does have very good preemergence *and* postemergence weed control (data not shown).

Table 1. Phytotoxicity of containerized ornamentals to selected herbicides for the IR-4 Program in 2009

Cercis chinensis 'Avondale'				Phytotoxicity Ratings[z]				
Treatment	Rate	1 WA1T[y]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI[x]
FreeHand 1X	2.65 lb ai/ac	1[w]	1	1	1.5	1.5	1.4	7
FreeHand 2X	5.3 lb ai/ac	1	1	1	1.2	2.1	1.6	13.2
FreeHand 4X	10.6 lb ai/ac	1	1	1	1.6	1.8	1.6	5.8
Untreated	--	1	1	1	1.5	1.9	1.8	7.2
Cotoneaster apiculata								
Treatment								
V-10142 1X	0.75 lb ai/ac	1	1	1	2.9	1.5	3.6	-3.6
V-10142 2X	1.5 lb ai/ac	1	1	1	4.4**	3.5**	5.7	-11.1*
V-10142 4X	3.0 lb ai/ac	1.2	1	1	3.5*	4.1**	5	-10.8*
Certainty 1X	0.06 lb ai/ac	1.1	1	1	1.4	2.2	3.5	4.8
Certainty 2X	0.12 lb ai/ac	1	1	1	2.1	2.9*	4.2	-0.8
Certainty 4X	0.24 lb ai/ac	1	1	1	4.2**	5.3**	6.9**	-13**
Untreated	--	1	1	1	1.1	1.1	2.7	5.1
F6875 .3G	0.375 lb ai/ac	1.2	1.1	1	1.6	1.8	1.8	4.6
F6875 .3G 2X	0.75 lb ai/ac	1.3	1.2	1	1.8	2.1	1.8	-1.4*
F6875 .3g 4X	1.5 lb ai/ac	1	1.2	1	1.3	2.5	2.3	1.4
Untreated	--	1	1	1	1.2	1.3	1	6.1
Forsythia x 'Meadowlark'								
Treatment								
FreeHand 1X	2.65 lb ai/ac	1.2	1.2**	1.2**	1.4**	1.2**	1.2**	15.2
FreeHand 2X	5.3 lb ai/ac	1.9	1.8**	1.8**	2.2**	2.2*	2**	13.8
FreeHand 4X	10.6 lb ai/ac	3.2	6.3	6.9	7.8	7.8	7.7*	-4**
Untreated	--	3.1	4.8	4.8	5.5	4.8	5.1	5.2
Magnolia virginiana								
Treatment								
BroadStar 1X	0.375 lb ai/ac	1	1	1	1	1.1	1	1.6
BroadStar 2X	0.75 lb ai/ac	1	1	1	1.2	1	1	2.5
BroadStar 4X	1.5 lb ai/ac	1	1	1	1.1	1.1	1	2.2
Untreated	--	1	1	1	1	1.1	2.2	0
F6875 4SC 1X	0.375 lb ai/ac	1.1	1.1	1	1.1	1.2	1.1	0.2
F6875 4SC 2X	0.75 lb ai/ac	1	1	1.2	1.3	1.4	1.1	3.2
F6875 4SC 4X	1.5 lb ai/ac	1.3	1.2	1.3	1.2	1.2	1.2	-3.5
Untreated	--	1	1	1	3.2	3.2	3.2	-30.9

z = Visual ratings based on a 1-10 scale with 1 being no phytotoxicity and 10 death with ≤3 commercially acceptable.

y = WA1T: weeks after first treamtent application; WA2T: weeks after second treatment application

x = GI: growth of species during the trial from growth indices. Growth for crabapple, magnolia, and honeylocust were determined by height only; growth for cotoneaster was determined by (width+width)/2; growth for forsythia, spruce, portulaca, arborvitae, and yew were determinded by (height+width+width)/3.

w = Ratings marked with ** within the same column are significantly different from the control, based on Dunnett's t-test (α = 0.05); those marked with a * within the same column are significantly different at the α = 0.10 level

Phytotoxicity of containerized ornamentals to selected herbicides for the IR-4 Program in 2009, cont.

Malus domestica		Phytotoxicity Ratings^z						
Treatment	Rate	1 WA1T^y	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI^x
FreeHand 1X	2.65 lb ai/ac	1	1.2	1.5	2.2	2.4	2.2	18.8
FreeHand 2X	5.3 lb ai/ac	1	1	1	1.5	1.7	2	24
FreeHand 4X	10.6 lb ai/ac	1	1	1	1.8	2	2.2	21.6
Untreated	--	1	1.4	1.4	2.3	2.7	3.1	8
V-10142 1X	0.75 lb ai/ac	2	1.7	4.1	2.8	3.2	2.7	16.1
V-10142 2X	1.5 lb ai/ac	2.2	1.9	3.5	2.9	3.1	2.2	19.2
V-10142 4X	3.0 lb ai/ac	2.6	2.4	3.2	3.6	2.9	4	13.5
Tower 1X	0.97 lb ai/ac	1.9	1.8	3.2	3.2	2.7	2.9	20
Tower 2X	1.94 lb ai/ac	1.9	1.4	1.6	3	3.1	2.6	17.9
Tower 4X	3.88 lb ai/ac	1.6	1.3	2.7	4.3	4.2	3.1	17.8
Certainty 1X	0.06 lb ai/ac	2.7*	2.2	2.4	3.8	3.8	3.9	15.7
Certainty 2X	0.12 lb ai/ac	2.7*	2.2	1.8	3.8	4	4.2	13.8
Certainty 4X	0.24 lb ai/ac	2.9**	2.2	3.1	3.8	4.3	4.3	12.6
Untreated	--	1.4	1.7	2.5	2.9	3.1	2.9	12.2
BroadStar 1X	0.375 lb ai/ac				2.9	3.5	2.9	5.5
BroadStar 2X	0.75 lb ai/ac				2.6	2.6	2.5	7.7
BroadStar 4X	1.5 lb ai/ac				3.6	4.5*	4.4	3.8
Untreated	--				2.1	2.4	2.8	2

Portulaca 'Margarita Rosita' Treatment								
FreeHand 1X	2.65 lb ai/ac	1	1	1.2	1.1	1.1	1.6	10.6
FreeHand 2X	5.3 lb ai/ac	1	1.2	1.2	1.2	1.4**	4.5**	7.6
FreeHand 4X	10.6 lb ai/ac	1	2.2**	1.7**	2.1**	2.1**	4.7**	5.4**
Untreated	--	1	1	1	1.1	1	1.2	11.6
Certainty 1X	0.06 lb ai/ac	1.5	3.5**	3.2**	3.3**	3.3**	2.7	7
Certainty 2X	0.12 lb ai/ac	3.4**	4.2**	3.8**	4.4**	3.8**	3.4	7.6
Certainty 4X	0.24 lb ai/ac	6.2**	6.8**	7.3**	6.5**	6.6**	6.5**	-0.03**
Untreated	--	1	1	1	1.2	1.2	1.2	6.8

Taxus densiformus Treatment								
Certainty1X	0.06 lb ai/ac	1.2	1.3	1	2.1	2	2.9	0.9
Certainty 2X	0.12 lb ai/ac	1.4	1.1	1	1.6	1.3	2.2	5.6
Certainty 4X	0.24 lb ai/ac	1.4	1.2	1.5	3.2**	4.1**	5.6**	-0.4
Untreated	--	1	1	1	1.3	1.2	1.3	3.2

z = Visual ratings based on a 1-10 scale with 1 being no phytotoxicity and 10 death with ≤3 commercially acceptable.

y = WA1T: weeks after first treamtent application; WA2T: weeks after second treatment application

x = GI: growth of species during the trial from growth indices. Growth for crabapple, magnolia, and honeylocust were determined by height only; growth for cotoneaster was determined by (width+width)/2; growth for forsythia, spruce, portulaca, arborvitae, and yew were determinded by (height+width+width)/3.

w = Ratings marked with ** within the same column are significantly different from the control, based on Dunnett's t-test (α = 0.05); those marked with a * within the same column are significantly different at the α = 0.10 level

Phytotoxicity of containerized ornamentals to selected herbicides for the IR-4 Program in 2009, cont.

Picea glauca 'Conica'		Phytotoxicity Ratings^{z}						
Treatment	Rate	1 WA1T^{y}	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI^{x}
V-10142 1X	0.75 lb ai/ac	1.2	1	1.2	1.2	1.3	1.2	0.4
V-10142 2X	1.5 lb ai/ac	1.2	1	1.2	1.2	1.3	1.2	0.2
V-10142 4X	3.0 lb ai/ac	1.1	1	1	1.2	1.2	1.2	0.4
Mesotrione 1X	0.187 lb ai/ac	1.2	1	3**	3.7**	4.1**	4.2**	0.2
Mesotrione 1.5X	0.25 lb ai/ac	1.1	1.2*	2.8**	3.6**	4**	3.7**	0.1
Mesotrione 2X	0.37 lb ai/ac	1	1.6**	3.3**	4.5**	4.8**	4.8**	0.1
Untreated	--	1	1	1.2	1.3	1.6	1.8	0.3
F6875 .3G	0.375 lb ai/ac	1	1	1.2	1.2	1.4	1.8	0.4
F6875 .3G 2X	0.75 lb ai/ac	1	1	1.1	1.3	1.3	1.4	0
F6875 .3g 4X	1.5 lb ai/ac	1	1	1.1	1.1	1	1.4	0.5
Untreated	--	1	1	1.2	1.6	1.7	2.1	0.2
BroadStar 1X	0.375 lb ai/ac				1.2	1.3	1.3	-0.1
BroadStar 2X	0.75 lb ai/ac				1.1	1.4	1.3	-0.3
BroadStar 4X	1.5 lb ai/ac				1	1.2	1.1	0.3
Untreated	--				1.5	1.8	1.8	-0.2
Gleditsia triacanthos								
Treatment								
FreeHand 1X	2.65 lb ai/ac	1	1.1	1.1	1.7	1.2	1.4	3.4
FreeHand 2X	5.3 lb ai/ac	1.1	1.1	1.3	1.6	1.2	1.5	6
FreeHand 4X	10.6 lb ai/ac	1.3	1.3	1.4	1.7	1.4	1.4	4.4
Certainty 1X	0.06 lb ai/ac	2.2**	1.8**	2.3	1.9	1.6	1.7	5.2
Certainty 2X	0.12 lb ai/ac	1.8	1.6	2.7**	1.7	1.8	1.9	5.5
Certainty 4X	0.24 lb ai/ac	2.9**	1.9**	2.9**	1.9	1.5	1.6	6.2
Tower 1X	0.97 lb ai/ac	2.2**	1.7	1.4	1.6	1.3	1.7	5.3
Tower 2X	1.94 lb ai/ac	1.9	1.2	1.1	1.3	1.2	1.4	7.9
Tower 4X	3.88 lb ai/ac	2.4**	1.9**	1.5	1.7	1.6	1.6	7.2
Untreated	--	1	1.1	1.2	1.3	1.3	1.3	3.3
BroadStar 1X	0.375 lb ai/ac				1.3	1.5	1.4	0.3
BroadStar 2X	0.75 lb ai/ac				2.2	1.8	2.2	-0.7
BroadStar 4X	1.5 lb ai/ac				1.6	1.8	1.4	0.4
Untreated	--				1.2	1.3	1.2	-0.6
Thuja occidentalis 'Emerald Green'								
Treatment								
F6875 4SC 1X	0.375 lb ai/ac	1.1	1.2	1.9**	1.7	1.7	1.6	3.5
F6875 4SC 2X	0.75 lb ai/ac	1.2	1.3	1.7	1.8*	1.5	2**	2.8
F6875 4SC 4X	1.5 lb ai/ac	1	1.2	2.1**	1.5	1.7	1.7	3.1
Untreated	--	1	1	1.1	1	1.2	1.2	3.5

z = Visual ratings based on a 1-10 scale with 1 being no phytotoxicity and 10 death with ≤3 commercially acceptable.

y = WA1T: weeks after first treamtent application; WA2T: weeks after second treatment application

x = GI: growth of species during the trial from growth indices. Growth for crabapple, magnolia, and honeylocust were determined by height only; growth for cotoneaster was determined by (width+width)/2; growth for forsythia, spruce, portulaca, arborvitae, and yew were determinded by (height+width+width)/3.

w = Ratings marked with ** within the same column are significantly different from the control, based on Dunnett's t-test (α = 0.05); those marked with a * within the same column are significantly different at the α = 0.10 level

Efficacy of Pre-emergence Sedge Control Materials

Principle investigators: Dr. Hannah Mathers, Dania Rivera, Luke Case

Significance to the Industry. Controlling sedge in nursery production has been one of the leading objectives of the IR-4 Ornamental weed control program. Yellow nutsedge (*Cyperus esculentus*) is a common perennial weed in Ohio, and few known chemical controls exist. SedgeHammer (halosulfuron) (Gowan Co., Yuma, AZ) and Pennant Magnum (s-metolachlor) (Syngenta Corp., Wilmington, DE) are two products that will control yellow nutsedge preemergence. There is a need for other preemergence herbicides that will effectively control yellow nutsedge. The objective of this study is to compare efficacy of preemergence herbicides on yellow nutsedge and total weed control.

Materials and Methods. This experiment was conducted at Klyn Nursery near Perry, Ohio. The plots utilized were in between rows of *Salix* and *Taxodium* trees; the plots were about 3 feet (0.9 m) wide by 3 feet (0.9 m) long in size. The trial was set up in a randomized complete block design with four replications. One tree-row was a replication. The treatments included the following: Tower (dimethenamid-p) (BASF Corp., Research Triangle Park, NC) at 1.5 lb ai/ac (1.7 kg/ha), FreeHand (dimethenamid-p + pendimethalin) (BASF Corp.) at 3.5 lb ai/ac (3.9 kg/ha), Eptam G (eptc) (Gowan Co.) at 3.0 lb ai/ac (3.4 kg/ha), F6875 4SC (sulfentrazone + prodiamine) (FMC Corp., Philadelphia, PA) at 0.375 lb ai/ac (0.4 kg/ha), F6875 0.3G (sulfentrazone + prodiamine) (FMC Corp.) at 0.375 lb ai/ac (0.4 kg/ha), Pennant Magnum (s-metolachlor)(Syngenta Corp.) at 2.0 lbs ai/ac (2.24 kg/ha), V-10142 75WG (imazosulfuron) (Valent U.S.A. Corp., Walnut Creek, CA) at 0.75 lb ai/ac (0.8 kg/ha), V-10142 0.5G (imazosulfuron) (Valent U.S.A. Corp.) at 0.75 lb ai/ac (0.8 kg/ha), Casoron G (diclobenil)(Chemtura U.S.A. Corp., Middlebury, CT) at 4.0 lbs ai/ac (4.5 kg/ha) and SedgeHammer (halosulfuron) (Gowan Co.). Sprayable formulations were applied with a backpack sprayer equipped with 8002 evs nozzles with a spray volume of 25 gal/ac (234 l/ha). The products were applied on March 27, 2009. Visual data was collected on May 7, 2009 and July 1, 2009. The visual ratings were based on a scale of 0-10 with 0 for no control and 10 for total control. We collected data for the sedge control and total weed control.

Results and Discussion. The incidence of sedge was higher in the replication that was in *Taxodium*; very little sedge was located in the other replications, which were located in the *Salix*. Visual ratings indicate that the untreated control had substantial weed control, especially in May. Ratings were performed “blindly”, with no knowledge of actual treatments. In May, there was no significant difference in the control for all the weeds. There was very little weed growth in May, which is evident by the untreated control (Table 1). Also in May, the visual ratings indicate there was no significant difference for the sedge control for most of the herbicides. FreeHand had the highest sedge control rating in May, with Casoron G providing the highest overall weed control (Table 1). F6875 (both formulations) and Tower provided the poorest ratings for sedge control in May. In July, SedgeHammer provided the best sedge control (9.3) and Casoron again had the best overall weed control (7.0)

Many of the products showed good sedge control one month following application with the exception of Tower and F6875 0.3G. Preemergence weed control normally last approximately 60 days in Ohio; this is highly dependent on a number of factors including compound used, weather, type of soil, and microbial action. However, SedgeHammer controlled sedge out to 3 months after application, which is evident by the July ratings. FreeHand, a combination herbicide, also shows promise, which had a visual rating of 10 in the May evaluation and 6.7 in the July evaluation, which is just below commercially acceptable.

Table 1. Efficacy visual ratings for sedge control and overall weed control for various compounds at Klyn Nursery in 2009.

	May			July		
Treatment	Sedge		Total	Sedge		Total
Tower	6.7[z]	ab[y]	7.3[x]	3.2	b	4.6
FreeHand	10	a	7	6.7	ab	4.3
Eptam G	9.8	a	6.2	6	ab	4
F6875	8	ab	7	5	ab	5
Pennant Magnum	9.8	a	7.2	5.3	ab	5
F 6875 0.3G	6	b	7	5.3	ab	3.7
V 10142	9.2	ab	7.5	4	ab	2.7
V 10142 0.5G	9.8	a	7.2	5.7	ab	4.7
Casoron G	9.5	ab	8.2	6	ab	7
Sedgehammer	9.5	ab	8	9.3	a	6.3
Untreated	8.25	ab	7.5	5.3	ab	5.3

z = Visual ratings based on a 0-10 scale with 0 being no weed control and 10 perfect weed control

y = Visual ratings within the same column followed by the same letter are not significantly different based on lsd ($\alpha = 0.05$).

x = no significant differences were found for total weed control for May or July

Development of a RRG Double Crop Production System and GeoHumus amendments

Principle investigators: Dania Rivera and Dr. Hannah Mathers

Significance to the industry. 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. Increasing restriction being placed on natural resources, especially with 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, 1989) the influence of the roots on plant survival far-surpasses their contribution in mass. More than 50% of the $26 billion wholesale production of woody nursery crops in the US is produced in containers (Mathers et al., 2007). 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 and 2007). 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., 2007) versus conventional container or bare-root grown plants. Root dormancy as a physiological process to manipulate plant growth is unexplored in ornamentals. Media GeoHumus amendments that increase plant water use efficiency during production and could potential carry through production to increase transplant survival in landscapes has not been explored (Hummel et al. 2007); including, the impact on multiple container up-shifts, with 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. The goal of this project is to accelerate nursery tree production via innovative processes of root manipulation and GeoHumus media amendments to advance the industry. The objectives of this study are: 1) evaluate root growth of three landscape trees from cell (plugs) to 3-, 7- or 15-gallon black rounded pot when grown double cropped (6-month) versus a twelve- month-cycle in a RRG; 2) evaluate the time of up-shift and out-planting fall versus summer on root growth; and 3) explore root dormancy and GeoHumus media amendments at up-shifting as means of manipulating plant growth to significantly reduce production times and increase transplant landscape survival and 4) evaluate transplant survival from various amended medias, pot sizes and dates of planting.

Materials and Methods.

Double- vs Single cropping. At The Ohio State University, Columbus, Ohio, three landscapes tree species, Red Maple ([A] *Acer rubrum* 'October Glory®'), Avondale Redbud ([C] *Cercis* *chinensis* ‘Avondale’) and Littleleaf Linden ([T] *Tilia cordata* ‘Greenspire®’)were selected for double cropping production in retractable roof greenhouses (RRG’s). The trees were planted from tissue culture into 3 gallon containers (black rounded pots) with a soilless mix [60% pine bark, 20% rice hulls, 10% sand, 5% comtil (composted sewage sludge), and 5% stone aggregate]. For the first experiment with GEOHummus, the substrate was amended with 1% GeoHumus by volume (1G) for half of the plants and the others remained without GeoHumus (0G). The double cropping system started with a fall planting in October 2008 and is ongoing, with the double crop planting starting in June 2009. The roof and sidewalls of the OSU, RRG is controlled by a MicroGrow control system (MicroGrow Systems, Temecula, Calif.) set to operate according to outside air temperatures. The roof and sidewalls are programmed to close at 70° F during the day and 50° F during the night during the growing season (March through November). All plants were irrigated using cyclic-micro-irrigation. The plants are receiving the same water frequency two times/day, applying 500 ml of water per day during the growing season. Supplemental irrigation was applied as needed during the winter months. Plants were fertilized using a 40g of control release (CR) fertilizer (Osmocote 19-5-8, Scott’s Co., Marysville, OH) applied at potting.

October plantings were further divided into two groups; one group received no bottom heat [ambient temperature (AT)] and the other group received 42°F (6 °C) bottom heat (BH) from December to March (during dormancy) to compare effects on root growth before spring. In late January the temperature of the bottom heat mat was increased to 70°F (21 °C). The sidewalls of the RRG were set to open at 40°F (5 °C) during winter cropping. If temperatures dropped below 28 °F (-2 °C), the RRG was warmed with supplemental heated. Measurements of height, caliper (taken at 2.4 cm), leaf area, root deformations evaluation and shoot and root dry weights were taken in beginning of April (after bud break) and then again in late June. The Red Maples (A) were received as small size plugs (North American Plants (NAP), Oregon, USA) and were not harvested in April due to some death during overwintering. The Avondale Redbud (C) were received as medium size plugs and the Littleleaf Linden (T) were received as large size plugs. The measures will be analyzed in ANOVA using PROC GLM at a least significant differences with $\alpha = 0.05$ using SAS software (SAS Institute, Inc., Cary, NC).

Future methods and materials to include the double crop. As previously stated, double cropping involves two plantings within the same year, one if fall (September – October), and one in early summer (June). Subsamples from each planting will be harvested at the onset of the new crop, kept in 3 gallon pots, or up shifted into 7- or 15 gallon pots and transferred to a PIP system. Once in the PIP system, the trees will be harvested in six or twelve months after the upshift.

Results and Discussion

April 2009 Harvest. Plant shoot dry weights were greater with BH than with AT (Fig. 1). Shoot dry weights were similar for both species in the bottom heat treatment even though the Tilia were larger plants at the initiation of the trial. Root weights were not affected by bottom heat unlike the shoot dry weights (Fig. 2). Root masses of T were greater initially than C and remained so after BH treatments. Plants of both species in the BH treatments broke bud dormancy about a week before AT plants. This could account for the increase in shoot mass but not root mass. No increase in root mass supports the conclusion that C and T have true root dormancy and can not be forced to grow regardless of warm temperature manipulations during dormancy. We have also observed this with Cornus (Daniel and Mathers, 2008).

Shoot dry weights with (1G) and without GeoHumus (0G) were not significantly different (Fig. 3). During the winter, water was supplied only as needed. Since March plants have been watered using cyclic-micro-irrigation, two times/day, for 500 ml total. Similar to the results of the shoot dry weight, there was no significantly difference in root dry weights (Fig. 4). We can conclude from this data collected April 2009 that shoots are positively impacted by the bottom heat used during winter dormancy. Plants achieve an earlier bud break providing them with a growth advantage early in the season.

June 2009 Harvest. The data collected in June shows that the bottom heat temperature promotes the growth of the plant after bud break. Across species and GeoHumus treatment, plants grown in BH were taller and had increased caliper than plants grown in AT. Leaf area measures were not significantly different (Table 1). The data collected of dry weight do not show a significant difference for the root or shoot dry weight. The species were started from different sizes and they have different growth rates and root dormancy. When comparing the temperature by specie there are interactions in height and caliper (Table 2). For A and C there was an increase in height and caliper with the BH treatment (Table 3). For T there was a decrease in height and caliper when plants were in BH treatment. No interaction was found for the other measures.

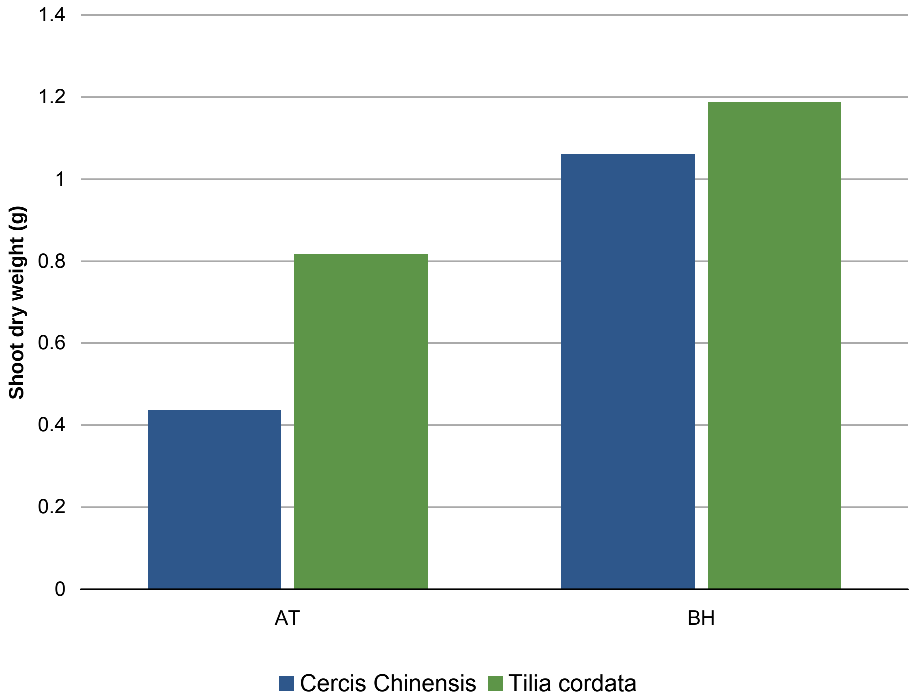
In April no significant differences were found with the Geohumus amendment main effect. The data collected in June show that also there is no significant difference for the height, caliper, leaf area and shoot dry weight measures. However, the root dry weight was significantly different (Table 4). The visible parts of the plants (shoots) did not have a significant growth but the roots that were in contact with the Geohumus were growing faster than without it. When we compare this by specie, there were no interactions found (Table 5).

When the temperature and Geohumus amendment is combined, height and caliper measures show an interaction. Plants with BH were taller without Geohumus than with it (Table 6). But when Geohumus was present in AT the height was greater than without GeoHumus. Averaged across species, plants without BH *and* Geohumus had the smallest calipers. Root dry weight data followed the same trends as the height data.

Plant growth is important for growers at the liner level. The plants need a better root system to grow higher with better calipers and adapt to future conditions (e.g. transplanting). According to this data, addition of bottom heat promotes the growth of the plants after bud break and continues to carry the difference during production. Geohumus also promotes growth, especially to the root mass. This was not observed at the beginning of the experiment, right after dormancy, but plants had a larger root mass during production time. This could promote the height and caliper later. The interaction between the BH and Geohumus suggests that different species are affected differently by the BH. Future harvest comparisons in which trees were upshifted to a pot in pot system with bigger pot sizes will contribute to these conclusions.

This data also suggests that tree liners can be grown in Ohio in RRG's starting in fall, with possible upshifts by June into PIP systems. June plantings into soil (field) are not advised for most species. Future data will include growth from trees started in June and harvested in fall to support of disprove the double cropping system.

Figure 1. The effect of bottom heat during dormancy on shoot dry weights of Cercis chinensis 'Avondale' and Tilia cordata 'Greenspire'. Plants were potted in September, 2008 and harvested April, 2009.



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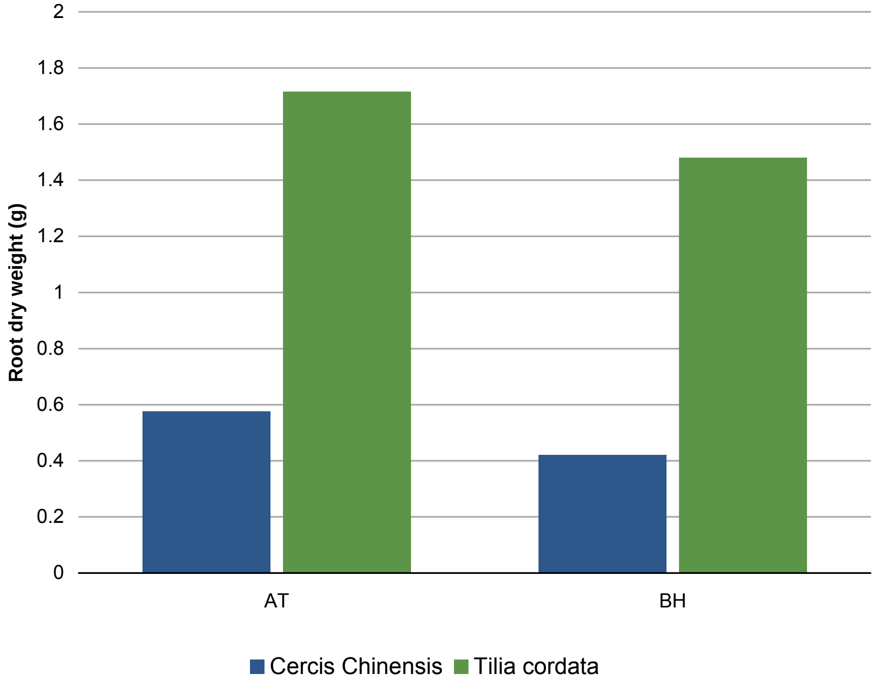
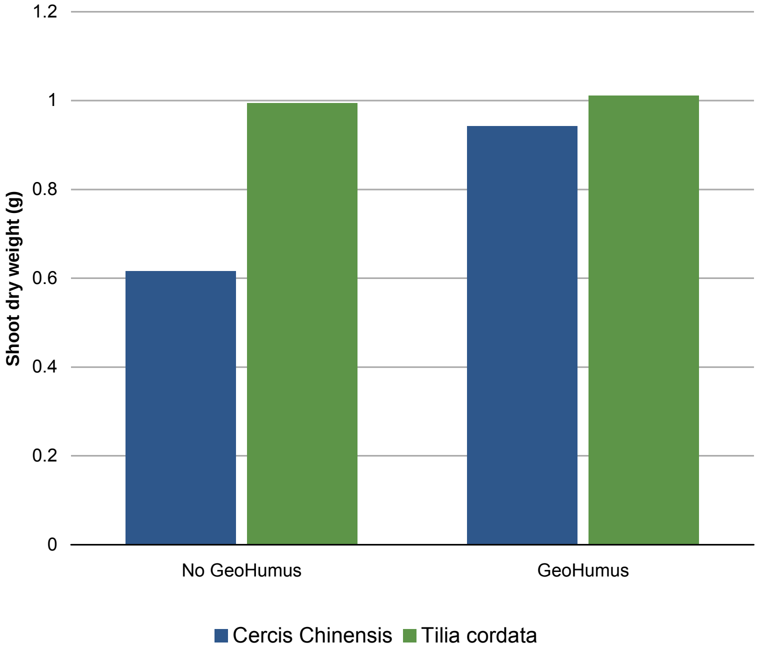


Figure 3. The effect of GeoHumus on shoot dry weight of *Cercis chinensis* 'Avondale' and *Tilia cordata* 'Greenspire'. Plants were potted October, 2008 and harvested April, 2009



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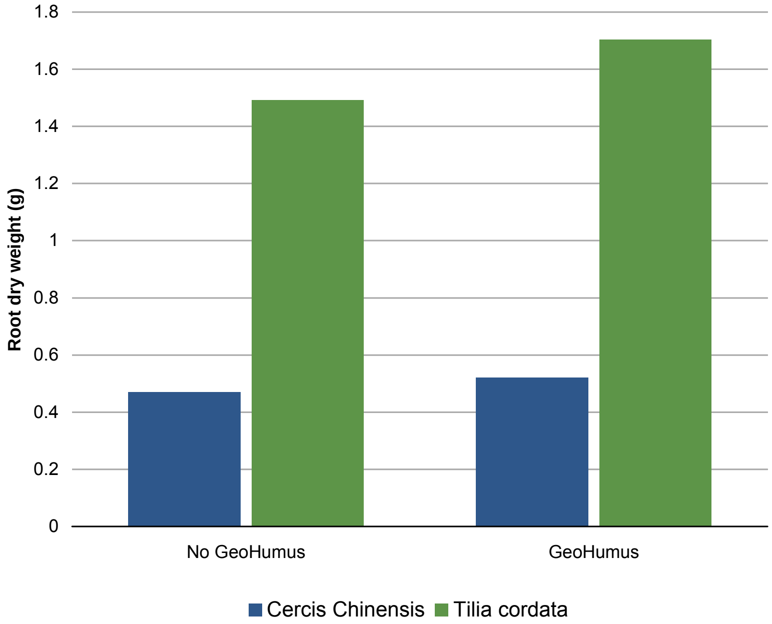


Table 1. Effect of bottom heat during dormancy on growth measurements across GeoHumus treatment and three species; *Acer rubrum* ‘October Glory’, *Cercis chinensis* ‘Avondale’, and *Tilia cordata* ‘Greenspire’. Plants were potted October, 2008 and harvested June, 2009.

Temperature	Height (cm)	Caliper (mm)	Leaf area (mm2)	Roots Dry Weight (g)	Shoot Dry Weight (g)
Bottom Heat	90.2 a^{z}	6.1 a	1604.2 a	3.4 a	13.4 a
No bottom heat	87.1 b	5.4 b	1536.8 a	3.3 a	12.8 a

z = measures followed by the same letter in the same column are not significantly different, based on LSmeans (α = 0.05)

Table 2. Growth measurements averaged across bottom heat treatments and GeoHumus treatment. Plants were potted October, 2008 and harvested June, 2009.

Specie	Height (cm)	Caliper (mm)	Leaf area (mm2)	Roots Dry Weight (g)	Shoot Dry Weight (g)
Acer rubrum 'October Glory'	111.8 b	6.6 b	2567.1 a	3.6 a	22.4 a
Cercis chinensis 'Avondale'	51.5 c	4.1 c	1184.0 b	2.3 b	7.6 bc
Tilia cordata 'Greenspire'	113.4 a	7.1 a	1213.8 b	4.2 a	11.1 b

z = measures followed by the same letter in the same column are not significantly different, based on LSmeans (α = 0.05)

Table 3. Interaction of bottom heat during dormancy and species on growth measurements averaged across GeoHumus treatment of three species. Plants were potted October, 2008 and harvested June, 2009.

Temperature	Specie	Height (cm) *	Caliper (mm) *	Leaf area (mm2)	Roots Dry Weight (g)	Shoot Dry Weight (g)
No bottom heat	*Acer rubrum* 'October Glory'	94.5 c	5.6 b	2837.9 a	4.1 a	24.7 a
Bottom heat	*Acer rubrum* 'October Glory'	115.0 ab	7.0 a	2373.7 a	3.4 ab	20.9 a
No bottom heat	*Cercis chinensis* 'Avondale'	47.1 e	3.7 c	1000.3 b	2.0 c	6.4 c
Bottom heat	*Cercis chinensis* 'Avondale'	55.6 d	4.5 c	1367.6 b	2.5 bc	8.8 c
No bottom heat	*Tilia cordata* 'Greenspire'	118.7 a	7.3 a	1260.2 b	4.5 a	11.8 c
Bottom heat	*Tilia cordata* 'Greenspire'	107.9 b	6.9 a	1167.3 b	4.0 a	10.4 c

z = measures followed by the same letter in the same column are not significantly different, based on LSmeans (α = 0.05)

Table 4. Main effect of GeoHumus averaged over bottom heat treatments and three species on growth measurements; *Acer rubrum* 'October Glory', *Cercis chinensis* 'Avondale', and *Tilia cordata* 'Greenspire'. Plants were potted October, 2008 and harvested June, 2009.

	Height (cm)	Caliper (mm)	Leaf area (mm2)	Roots Dry Weight (g)	Shoot Dry Weight (g)
GeoHumus	89.7 a	6.0 a	1604.2 a	4.3 a	14.5 a
No Geohumus	87.8 a	5.7 a	1539.9 a	2.3 b	11.7 a

z = measures followed by the same letter in the same column are not significantly different, based on LSmeans (α = 0.05)

Table 5. Interaction of GeoHumus and species averaged over bottom heat treatments on growth measurements. Plants were potted October, 2008 and harvested June, 2009

Geohumus	Specie	Height (cm)	Caliper (mm)	Leaf area (mm2)	Roots Dry Weight (g)	Shoot Dry Weight (g)
No GeoHumus	*Acer rubrum* 'October Glory'	102.4 b	5.8 c	2368.8 a	2.6 bc	18.5 ab
GeoHumus	*Acer rubrum* 'October Glory'	107.0 ab	6.4 bc	2765.4 a	4.6 ab	25.7 a
No GeoHumus	*Cercis chinensis* 'Avondale'	51.0 c	4.1 d	1221.1 b	1.3 c	6.9 c
GeoHumus	*Cercis chinensis* 'Avondale'	52.1 c	4.1 d	1146.8 b	3.2 bc	8.3 c
No GeoHumus	*Tilia cordata* 'Greenspire'	112.3 ab	6.9 ab	1236.9 b	3.1 bc	11.3 bc
GeoHumus	*Tilia cordata* 'Greenspire'	114.4 a	7.3 a	1190.6 b	5.2 a	11.0 bc

z = measures followed by the same letter in the same column are not significantly different, based on LSmeans (α = 0.05)

Table 6. Interaction of bottom heat treatment and GeoHumus treatment on growth measurements averaged across three species; *Acer rubrum* 'October Glory', *Cercis chinensis* 'Avondale', and *Tilia cordata* 'Greenspire'. Plants were potted October, 2008 and harvested June, 2009.

Temperature	Geohumus	Height (cm)	Caliper (mm)	Leaf area (mm2)	Roots Dry Weight (g)	Shoot Dry Weight (g)
No bottom heat	No GeoHumus	82.4 c	5.1 b	1522.6 a	2.2 a	11.6 a
No bottom heat	GeoHumus	93.0 ab	5.8 a	1549.8 a	4.3 b	14.0 a
Bottom heat	No GeoHumus	96.3 a	6.2 a	1554.3 a	2.3 a	11.8 a
Bottom heat	GeoHumus	89.2 b	6.1 a	1658.5 a	4.3 b	15.0 a

z = measures followed by the same letter in the same column are not significantly different, based on LSmeans (α = 0.05)

Efficacy of Dimension 2EW With and Without Gallery as a Tank Mix Partner

Principle investigators: Dr. Hannah Mathers and Luke Case

Significance to the Industry. Preemergence herbicides continue to be the “backbone” of the nursery industry, and weed control methods are always improving. The expense for developing new herbicides is very large, and many times, industry will not develop herbicides specifically for the ornamental market. Most of the ornamental herbicides actually come from row crop production. However, industry also sees a large need by the ornamental industry for good weed control, and they are proactive to find weed control solutions. One of the ways to expand labels and increase worker safety is to alter the formulation (e.g. liquids into granulars). Dimension 2EW is an emulsifiable liquid that has the same active ingredient as Dimension WSP, which is a water soluble powder. The objective of this study is to compare efficacy of Dimension 2EW and Dimension 2EW in combination with Gallery to competitive standards.

Materials and Methods. Herbicide treatments consisted of Dimension 2EW (dithiopyr) (Dow AgroSciences, Indianapolis, IN) at 0.5 lb ai/ac, Dimension 2EW + Gallery (isoxaben) (Dow AgroSciences) at 0.5 + 1.0 lb ai/ac, respectively, Gallery at 1.0 lb ai/ac, Barricade (prodiamine) (Syngenta Corp., Wilmington, DE) at 0.85 lb ai/ac, Barricade + Gallery at 0.85 + 1.0 lb ai/ac, respectively, and Dimension Ultra WSP (Dow AgroSciences) at 0.5 lb ai/ac. Each treatment was applied to six replications of one-gallon (#1) containers with a CO_2 backpack sprayer 8002 evs nozzles delivering 25 gal/ac. Just prior to herbicide application, 1/8 teaspoon equal ratio of annual bluegrass (*Poa annua*), common groundsel (*Senecio vulgaris*), bittercress (*Cardamine hirsute*), prostrate spurge (*Chamaesyce prostrata*), and common yellow woodsorrel (*Oxalis stricta*) was spread over the six replications. Treatments were applied on 6 July 2009. Evaluations of efficacy were conducted at 30 and 60 DAT (days after treatment) by visual ratings using a 0-10 scale with 0 being no control and 10 perfect weed control. The study was set up in a randomized complete block design. A visual rating of each weed specie was conducted at each evaluation, and an overall weed control rating was also conducted at the 60 DAT evaluation.

Results and Discussion. Common groundsel, common yellow woodsorrel, and bittercress had poor germination and will not be discussed. However, other weed species, like spiny sowthistle (*Sonchus asper*) and purslane germinated from the media. At 30 DAT, the spurge was controlled very well by the Gallery (8.2), Dimension 2EW + Gallery (9.2), and Barricade + Gallery (9.0) (Table 1). The annual bluegrass was controlled to commercially acceptable levels as 30 DAT by Dimension 2EW (8.5), Dimension 2EW + Gallery (9.3), Barricade + Gallery (9.8), and Dimension Ultra (7.5). At 60 DAT, the only treatments controlling spurge to commercially acceptable levels were the combination treatments, which were Dimension 2EW + Gallery (7.3) and Barricade + Gallery (8.2) (Table 1). The annual bluegrass was controlled at 60 DAT to acceptable levels by the Dimension 2EW (7.0), Dimension 2EW + Gallery (7.3), and Barricade + Gallery (9.2). Overall, the best weed control at 60 DAT was from the Barricade + Gallery (8.2), but the Dimension 2EW + Gallery also had acceptable levels of control (7.3). For broad spectrum weed control, it is best to use a combination of products, which is evident in this trial. However, depending on weed species present in the nursery, a combination treatment may not be warranted, which is why it is essential to scout and know which weeds are present. The combination products also were effective through 60 DAT, but the single chemical treatments were not.

Table 1. Efficacy of Dimension 2EW and Dimension 2EW + Gallery to Dimension Ultra, Barricade, and Barricade + Gallery.

	Spurge		Annual bluegrass		Overall
Treatment	30 DAT[z]	60 DAT	30 DAT	60 DAT	60 DAT
Dimension 2EW	3.2 B[yx]	2.2 bc	8.5 ab	7 ab	3.7 bc
Dimension 2EW + Gallery	9.2 a	7.3 a	9.3 a	7.3 ab	7.3 a
Gallery	8.2 a	3.5 b	3.7 c	2 de	3.3 bcd
Barricade	2 b	6 a	6.3 b	3.8 cd	4.2 b
Barricade + Gallery	9 a	8.2 a	9.8 a	9.2 a	8.2 a
Dimension Ultra	2 b	2.3 bc	7.5 ab	5.3 bc	2.5 cd
Untreated control	0 c	0 c	0 d	0 e	0 e

z = days after treatment

y = Visual ratings based on a 0-10 scale with 0 being no control and 10 perfect weed control

x = Ratings within each column followed by the same letter are not significantly different, based on lsmeans (α = 0.05)

Evaluation of the invasive and noxious weed species propagule-bank in nurseries and natural areas

Principle Investigators: Dr. Hannah Mathers, Luke Case, and Jason Parrish

Significance to the Industry: The ornamental industry thrives on new introductions, most of which are harvested from other countries and cultivated in North America. CFIA has stated that a PRA will be required to introduce new plants into Canada and that the grower will have to pay part of the costs of the PRA and wait until it is completed before getting permission to cultivate introduced plants (2007 Annual Report to Ontario Agricultural Services Coordinating Committee). There is a need to develop research data regarding plant groups (e.g. deciduous trees, value, acreage and pests) to help quantify the impacts of Invasive Alien Species, trade (etc.) on nursery stock. No studies have been conducted of the Propagule-bank in nurseries and/or landscapes. This lack of investigation is surprising considering the intense interest in invasive species and their spread from the ornamental industry. The objectives of this research is to characterize the movement, diversity and abundance of invasive and weedy plants present in propagule-banks at different stages of nursery production and plant use by consumers, and to determine what role nurseries are actually playing in invasive species spread.

Materials and Methods: A total of 6 nurseries, 3 in Lake County, Ohio and 3 in Ontario, Canada were surveyed beginning in 2008 for populations of vegetation and weed propagule-banks. 10 – 1-m^2 plots were surveyed at each site, with 6 plots “on-site” in active nursery fields and 4 plots in “wild areas” bordering the nursery. Samples were taken in July 2008. In each of the plots, actively growing plant species were identified and their presence recorded, and multiple soil cores were taken to obtain an approximate volume of 1.5-L of soil per plot. These samples were taken back to the greenhouse in Columbus, OH to allow growth of the propagules. Plants were identified, counted, and removed to allow for subsequent flushes of germination. The samples also received a prolonged cold treatment during Winter 2008-2009, to provide stratification of ungerminated seeds. Weeds growing within the plots at the time of the survey are only reported as the number of plots in which they were identified, whereas weeds growing from the greenhouse samples are reported as total number of plants.

Results and Discussion:. In both Ohio and Ontario, the most common species germinating from the on-site soil samples were bluegrass (*Poa spp.*) and common purslane (*Portulaca oleracea*) (Tables 1 and 2). These species were also commonly found actively growing in our July survey, in Ohio, but less commonly in Ontario (Tables 3 and 4). There are several factors which could account for this, including timing of our visit and weed control actions taken by the nurseries. *Oxalis* species were found in many areas, both within and outside of the nurseries, and in both Ohio and Ontario (Tables 3 and 4). Woody species including brambles (*Rubus spp.*), maple (*Acer spp.*), and cherry (*Prunus spp.*) were frequently noted in the seed bank from the areas outside of the nursery, though more likely because of the existing vegetation than from the nursery production. The primary weed species identified from within the nurseries are generally annual weeds commonly found in nursery production. While there is currently no conclusive evidence regarding spread of nursery plants into wild areas, this information does allow for more specific weed control recommendations to participating nurseries. By identifying the most prevalent weeds, shortfalls in the current practices can be spotted and improved. At the present time, there is not enough data to suggest that invasive plants may be encroaching from the nurseries into surrounding areas.

Table 1. The most numerous weeds that germinated from the soil cores from 3 nurseries in Ohio by germination count.

Wild		On-Site	
Rubus spp.	42	Poa spp.	121
Oxalis spp.	33	Portulaca oleracea	80
Acer spp.	9	Cardamine spp.	37
Poa spp.	8	Stellaria media	27
Rhus spp.	8	Chamaesyce prostrata	19
Galium mollugo	7	Oxalis spp.	14
Cardamine spp	4	Galium mollugo	13
Rumex obtusifolius	3	Rorippa islandica	11
Portulaca oleracea	3	Senecio vulgaris	5
Daucus carota	3	Cerastium vulgatum	4

Table 2. The most numerous weeds that germinated from the soil cores from 3 nurseries in Ontario, Canada by germination count.

Wild		On-Site	
Veronica spp.	44	Portulaca oleracea	74
Poa spp.	18	Poa spp.	36
Solanum ptycanthum	15	Veronica spp.	27
Portulaca oleracea	14	Lepidium spp.	6
Daucus carota	9	Cardamine spp.	4
Oxalis spp.	8	Stellaria media	4
Galium aparine	5	Geranium spp.	4
Polygonum spp. (smartweed)	5	Capsella bursa-pastoris	4
Chenopodium album	5	Solanum ptycanthum	3
Bromus tectorum	4	Chenopodium album	3

Table 3. Weeds with the most number of occurrences (out of 30 possible) that were found in sample areas from three Ohio nurseries.

Wild		On-Site	
Parthenocissus quinquefolia	6	Portulaca oleracea	8
Acer spp.	5	Poa spp.	6
Oxalis spp.	5	Senecio vulgaris	5
Prunus spp.	5	Oxalis spp.	5
Solidago spp.	4	Polygonum aviculare	5
Vitis spp.	4	Malus spp.	3
Toxicodendron radicans	4	Amaranthus spp.	3
Alliaria petiolata	3	Trifolium repens	3
Lonicera spp.	3	Epilobium spp.	3
Malus spp.	3	Echinochloa crus-galli	2

Table 3. Weeds with the most number of occurrences (out of 30 possible) that were found in sample areas from three Ohio nurseries.

Wild		On-Site	
Solidago spp.	4	Chenopodium album	5
Polygonum spp. (smartweed)	3	Stellaria media	4
Lonicera spp.	3	Ambrosia artemisiifolia	4
Poa spp.	2	Erigeron spp.	4
Acer spp.	2	Poa spp.	3
Malus spp.	2	Lepidium spp.	3
Taraxacum spp.	2	Capsella bursa-pastoris	3
Glechoma hederacea	2	Senecio vulgaris	2
Conyza canadensis	2	Polygonum aviculare	2
Dactylis glomerata	2	Matricaria matricariodes	2

BIO-HERBICIDES WEED CONTROL INITIATIVE FOR NURSERY AND LANDSCAPE INDUSTRIES

Principle Investigator: Dr. Hannah Mathers

Significance to Industry. Nursery growers spend $967 to $2,228/A for supplemental hand weeding over -and above herbicide application costs, in addition three to four yearly herbicide applications costing on average $1200.00 per acre are made. Economic losses due to improperly controlled weed infestations have been estimated at approximately $9000/acre. Thus, the expense of traditional weed control in nursery crop production and landscape management far surpasses all other forms of pest control. New weed control methods that are effective, economical and have reduced environmental impact are required. Access to the latest herbicides and comprehension of up to date practices and systems are essential to ensure the economic survival of the nursery/landscape industry. Ornamental weed control is critical for several reasons. Weeds detract from the appearance of the plants, harbor pests, and reduce plant size, quality, and marketability. Thresholds weed populations are not acceptable (unlike other commodities) because of the competitive nature of the weeds with the ornamental crop, nursery shipping regulations, devaluing of the market potential and the possibility of weeds introducing insect and disease pressure. Therefore, herbicide applications for weed control are preventative controls that are normally calendar based not just part of IPM programs. Lack of safe post-emergent applied herbicides currently prevents weed management strategies based on economic thresholds, as is common with disease and insect control strategies. The objective of this study is to investigate strategies for controlling weeds with non-chemical practices, such as bio-herbicide mulch combinations and bio-rational approaches to reduce overall costs and amounts of herbicides applied. This report discusses only Bio-herbicides.

Introduction: This study utilizes research from Ohio State University (OSU), Dr. Mathers' and colleagues have conducted for nine years with herbicide and mulch combinations. This research has resulted in many interesting discoveries of value in the landscape and nursery industry. These combinations, however, were not picked up for commercialization until 2006. Many companies felt homeowners would be reluctant to purchase mulch with herbicide and that potential safety issues posed to small children and pets factored too high in the consumers mind to consider development. In 2006, the tremendous success of a new home-landscape weed control product combining mulch and a granular herbicide, *Vigoro: Premium Mulch Plus Weed Stop,* proved consumers did not have these fears. Product acceptance wand sales were significantly higher than ever expected. This has resulted in another mulch plus granular herbicide product being developed, *Lebanon Seaboard Corporation: Preen Garden Weed Preventer with Mulch* (available Spring 2007) and *United Phosphorus, Inc.* is working on the formulation of mulch plus a new granular Surflan + Gallery (available Spring 2009). The time for development of other organic carriers for herbicides and bio-herbicides is right. The Ohio State University ornamental weed program is best position to research these new carriers and combinations. Our research has lead to the creation of the new products listed above and we have evaluated more mulch and herbicide combinations than any other program in the US. Based on our research results from past experiments pelletized bark dust, dried distilled grains (DDG's) and paper waste will be created containing specific amounts of optimal traditional and bio-herbicides discovered in our program. These will be evaluated over mulch applications and pre-incorporated into bagged mulches for efficacy and phytotoxicity.

Materials and Methods. Pine bark mulches of >1” and <1” and herbicide treated barks were applied to #1 containers filled with Gro-Bark nursery substrate. Herbicide and bio-herbicide treatments were applied once at the label rate of pounds of active ingredient per acre or at concentrations of 5, 10 and 15% (for the bioherbicides). Mulches were also applied untreated, as single layers, over the top of media surfaces.

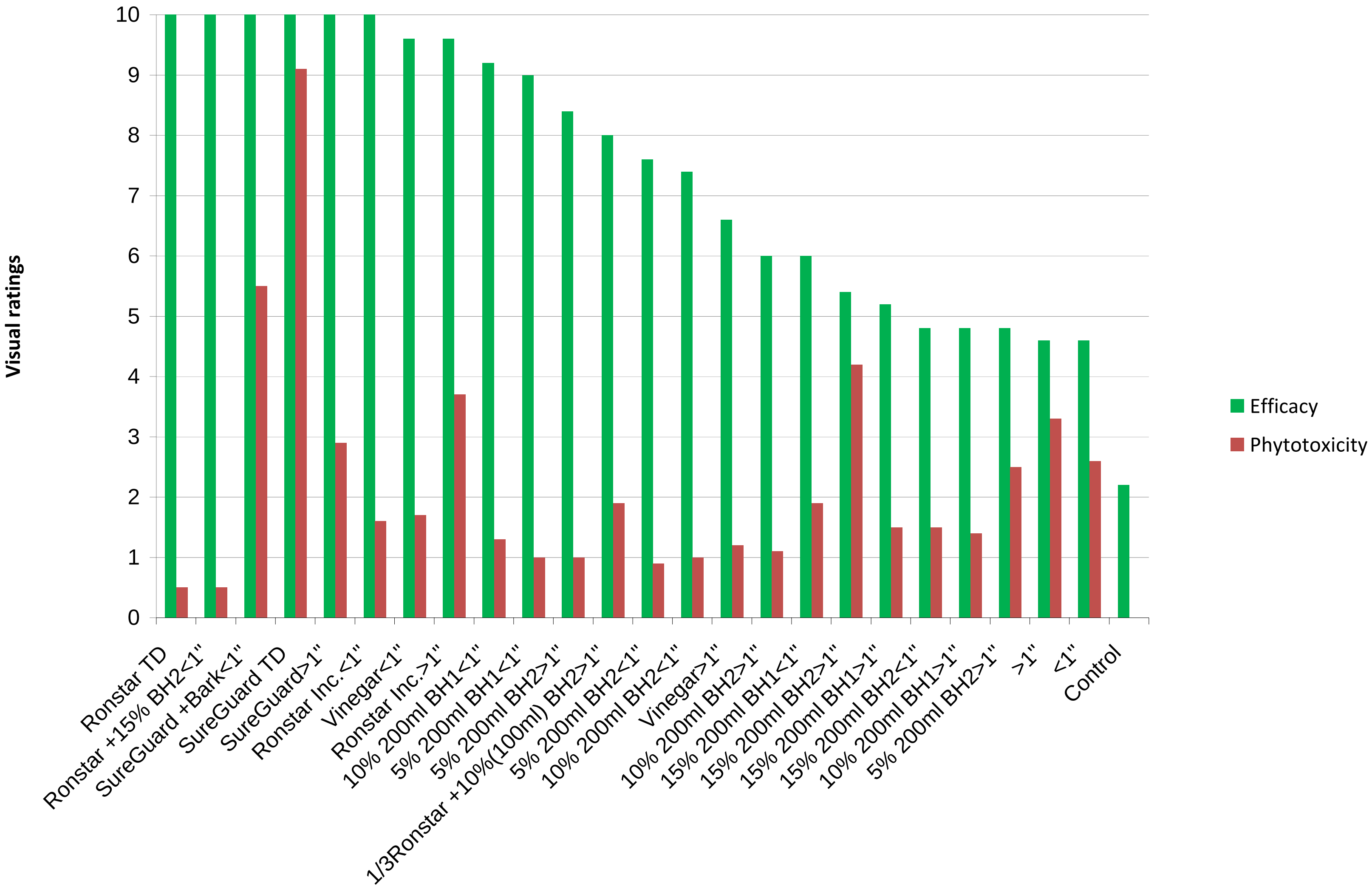
A completely randomized design with five replications and an unbalanced factorial treatment arrangement was used. There were 25 treatments. The SAS© procedure GLM will be used to perform the analyses. Fisher’s least significance difference test will be used to compare means (SAS© Institute Inc. 1989). Timeline: *The research was begun May 19, 2009 at Sheridan Nursery, Georgetown, Ontario*.

Phytotoxicity evaluations with three species of plants will be evaluated, one deciduous shrub and one broadleaf evergreen at 90 and 120 DAT. A visual rating score of 1 (no injury) to 10 (complete kill) will be used for the shoots. The mulches and herbicide treated mulches will be compared to sprays of chemicals applied directly to the surfaces of the plots, the two untreated mulches applied to the plots and a weedy check (no herbicide, no mulch) as in the efficacy evaluations.

A visual rating of weed control 0 (no control) to 10 (complete control) and 7 (commercially acceptable) was used. All liquid treatments were applied with GS CO_2 sprayer on 16" centers, with 8002VS medium droplet nozzles spraying at 45-50 psi.

Results and Discussion. At 90 DAT there were 14 treatments or 25 with efficacy ratings of >7 (commercially acceptable (Fig.1). Of those 14, only eight had phytotoxicity ratings of $\leq$ 3. Of those eight, seven were bio-herbicide treatments (Fig. 1). The vinegar applied to pine bark mulch <1” had the highest efficacy rating (9.6) with a corresponding low phytotoxicity of (1.67). Of the two bio-herbicides used in this study (BH1 and BH2), developed at Ohio State University, BH1with bark <1” was involved in two of the top 7 treatments and (BH2) was involved in four. One of the top BH2 treatments did utilize a 1/3 rate of Ronstar; however, there was no significant increase in efficacy with the Ronstar addition only an increase in phytotoxicity. This study indicates especially BH2 shows promise at 5 or 10% concentrations applied on either <1” or >1” of pine bark in ornamental weed control. 15% concentrations did not supply greater efficacy than untreated barks. Phytotoxicity of the untreated barks was much higher than expected. All of the best 7 bio-herbicide treatments had significantly lower phytotoxicity than the untreated barks (Fig. 1).

Efficacy of various organically herbicide treated mulches in comparison to untreated control and herbicide standard



Appendix

Weather data for the 2009 growing year, showing high, low, and average temperatures and total precipitation for that day, data are in English units.

March	Precip	Max Air Temp	Min Air Temp	Avg Rel. Hum	April	Precip	Max Air Temp	Min Air Temp	Avg Rel. Hum	May	Precip	Max Air Temp	Min Air Temp	Avg Rel. Hum
15	0	61.6	34.4	50	1	0.06	62.4	32	58	1	1.2	73	50.4	90
16	0	66.3	41.3	55	2	0	74.1	37.1	56	2	0.01	65.5	43.3	76
17	0	70.8	32.3	63	3	0.88	62.6	39.9	85	3	0	67.3	49.5	70
18	0.09	74.5	41.7	67	4	0	57.2	33.4	68	4	0	69.9	54.1	60
19	0.01	54.9	34.7	64	5	0.16	64.8	34.9	68	5	0	69.2	50.1	72
20	0	45.5	26.5	62	6	0.05	50.9	34.2	88	6	0.25	62.9	52.4	92
21	0	55	27	54	7	0	39.3	29.9	73	7	0	71.6	48.3	87
22	0	62.7	28.2	53	8	0	55.8	32.6	60	8	0.01	72.3	56.5	87
23	0	57.1	34.3	48	9	0	63.8	32.3	58	9	0	72	51	77
24	0	67.7	37.2	33	10	0.28	54.6	45.2	84	10	0	68.8	47.3	67
25	0.41	59.5	49.3	80	11	0.01	51.8	35	68	11	0	68.2	48.8	64
26	0.27	55.3	38.4	89	12	0	54.1	27.5	57	12	0	67.8	37.6	58
27	0	57.9	33.3	78	13	0.34	48.4	38.4	69	13	0.37	69.8	51.6	69
28	0	61.2	40.2	77	14	0.65	56	44.7	94	14	0.14	76.2	53	76
29	0.1	60.3	35.1	82	15	0.02	46.6	41	94	15	0	79.5	44.9	67
30	0.01	55.5	32.5	66	16	0	64.2	38.3	65	16	0	76.4	51.2	76
31	0	64.9	36.1	56	17	0	71.6	33.5	54	17	0	61.5	44.3	50
					18	0	77.6	37.8	61	18	0	66.3	35.1	52
					19	0.42	65.8	51.5	73	19	0	74.4	38.1	54
					20	0.4	60	43.4	90	20	0	82.7	45.2	52
					21	0.05	51.9	40.2	84	21	0	85.1	50.3	55
					22	0	60.7	37.4	71	22	0	85.2	56.4	61
					23	0	64	34	55	23	0	89	59.6	60
					24	0	85.9	52.5	48	24	0	85.4	65.3	75
					25	0	87.2	62.8	49	25	0	80.7	62.8	62
					26	0	86.2	55.7	54	26	0.09	83.1	63.9	75
					27	0	84.6	57.8	55	27	0.02	82.7	66.2	82
					28	0.17	73.9	50.5	75	28	0.04	77.4	62	88
					29	0	65.6	49	85	29	0.01	80.6	55.6	70
					30	0.23	70.1	57.9	86	30	0	77	51.5	57
										31	0	73.2	55.4	65

Weather data for the 2009 growing year, showing high, low, and average temperatures and total precipitation for that day, data are in English units.

June	Precip	Max Air Temp	Min Air Temp	Avg Rel. Hum	July	Precip	Max Air Temp	Min Air Temp	Avg Rel. Hum	Aug	Precip	Max Air Temp	Min Air Temp	Avg Rel. Hum
1	0.05	82.7	54.1	65	1	0	74.1	62	77	1	0	80.5	57.5	81
2	0.01	85.2	61.3	80	2	0.01	71.8	58.2	80	2	0.11	78.3	60.4	80
3	0.23	66.9	53.1	88	3	0	77.4	58.6	75	3	0	79.6	53.8	75
4	0	69.7	53.5	62	4	0	77.5	56.1	77	4	0.01	79	65.6	84
5	0	76.1	49.1	62	5	0	81.4	63.1	73	5	0	79.1	65.1	86
6	0	82.5	47.5	57	6	0.02	84.3	57.1	64	6	0	78	55.8	73
7	0	84.8	54.5	64	7	0	83.8	59.2	59	7	0	81.5	57.6	68
8	0.02	84.3	63.6	71	8	0	83.1	58.6	56	8	0	83.8	65.2	75
9	0	87.9	68.6	69	9	0	81.8	63.8	60	9	0	91.1	69.8	78
10	0	77.7	62.3	79	10	0	87.8	58.3	70	10	0	87.5	70.2	85
11	0.35	73.6	62.3	92	11	1.03	77	67.6	89	11	0	86.6	67.6	79
12	0	77.3	62	79	12	0	83.4	58.3	71	12	0	82.4	64.1	74
13	0	78.8	53.9	66	13	0	79.5	59	57	13	0	85.1	57.1	73
14	0	80.3	52.4	69	14	0	79.9	54.2	58	14	0	87.5	61.1	73
15	0	82.2	59.4	68	15	0	82.5	56.8	68	15	0	88.8	60.6	73
16	0.01	83.5	60	60	16	0	85	67.5	71	16	0	91.7	68.6	73
17	0.53	85.3	66.8	81	17	0.02	81	62.1	70	17	0	89.8	68.5	76
18	0	84.9	59	81	18	0	71.7	59.5	78	18	0	84.9	70.3	83
19	0.36	90.5	66.7	83	19	0	76.2	55.4	76	19	0.86	80.7	69.3	91
20	0.14	87.4	68.7	74	20	0	78	55.7	75	20	0.06	84.2	69	85
21	0	86.3	63.7	73	21	0	82.7	56	73	21	0	81.5	68.1	74
22	0	84.7	61.8	77	22	0.8	69.9	63.4	88	22	0	78.6	59.5	81
23	0	85.8	63.1	66	23	0.11	79.1	64	88	23	0	71.5	52.9	79
24	0	90.6	64	68	24	0	81.8	59.3	75	24	0	78	54.4	81
25	0.92	96.1	68.1	71	25	0.1	77.1	64.9	87	25	0	84.1	56.5	77
26	0	88	67.8	78	26	0	82.4	61.8	77	26	0	87.4	60.4	77
27	0	83.6	62	68	27	0.01	83.8	59.5	78	27	0	86.5	66.8	80
28	0	87.8	62.5	67	28	0	83.5	63.1	78	28	0.38	78.1	66.4	89
29	0	83.9	62.8	57	29	0.46	82	65.2	91	29	0.1	78.2	61.4	79
30	0	77.2	62.4	68	30	0	79.5	63	89	30	0	69.5	51.3	80
					31	0.55	81.7	63.3	80	31	0	70.4	46.1	72

Weather data for the 2009 growing year, showing high, low, and average temperatures and total precipitation for that day, data are in English units.

September	Precip	Max Air Temp	Min Air Temp	Avg Rel. Hum
1	0	78.9	50.1	65
2	0	81.1	50.6	65
3	0	79.6	52.7	70
4	0	81.1	52	71
5	0	84	55.8	65
6	0.15	75.9	65.4	85
7	0.02	76.8	63.8	91
8	0.01	82.3	61.7	82
9	0	80.2	58.4	73
10	0	76.3	54.1	67
11	0	76.5	51.4	72
12	0	78.2	46.6	74
13	0	84	55.2	76
14	0	83.5	57.1	74
15	0.58	75.1	58.1	73
16	0	78.9	49.4	69
17	0	76.8	52.2	69
18	0	76.5	51.3	67
19	0.08	73.8	54.7	80
20	0.16	73.5	66.7	91
21	0.01	83.4	68.5	84
22	0.06	81.2	66.2	88
23	0.2	72.6	62.7	92