Yearly Research Summary Report
2010 Ornamental Research

Dr. Hannah Mathers
Luke Case
Kyle Daniel
Lynne Sage
Dania Rivera

THE OHIO STATE UNIVERSITY EXTENSION

We would like to acknowledge the following companies for their support of our program:

Klyn Nursery
J. Frank Schmidt and Sons Nursery
Herman Losely and Son Nursery
A. Brown and Sons Nursery
North American Plants
Buckeye Resources
April's Greenhouse
J.C. Bakker Nurseries
WillowBrook Nurseries
Connan AVK Nursery
Sheridan Nursery
Braun Nursery
Gilson Gardens
Art Form Nurseries
Springbrooke Gardens, Inc.
Kurtz Bros., Inc.

We would also like to acknowledge support from the Department of Horticulture and Crop Science, The Ohio State University

We would also like to thank Denise Johnson, Program Coordinator, for all her help and behind-the-scenes activities.

Table of Contents

Container weed control of various Anderson's experimental DG products

Dr. Hannah Mathers and Luke T. Case

Significance to the industry. Weed control in containers is a major expense, which is usually accomplished by multiple applications of preemergence herbicides, up to four or five times per year. Escaped weeds are then handweeded. Any way to reduce cost would be very beneficial for growers. The Anderson's DG products are designed as chemical carriers that release the chemical over time, and could be a cheaper alternative to products already on the market. The objective of this trial is to determine weed control of Anderson's DG products in comparison to a few industry standards.

Materials and methods. The trial was started on July 13, 2010. One-gallon (3.8 l) trade-size pots were filled with soilless mix containing approximately 85% pine bark, 10% comtil (composted sewage sludge), and 5% pea gravel. Treatments were then applied, which included a sprayable application of SureGuard (flumioxazin) at a rate of 0.25 and 0.375 lb ai/ac and Barricade + Gallery (prodiamine + isoxaben) at a rate of 0.75 lb ai + 0.75 lb ai/ac, respectively, which were applied using a CO_2 backpack sprayer calibrated to deliver approximately 30 gal/ac. Treatments also included BroadStar at 0.375 lb ai/ac, Snapshot (isoxaben + trifluralin) at 2.0 + 0.5 and 4.0 + 1.0 lb ai/ac, respectively, FreeHand (dimethenamid + pendimethalin) at 1.125 + 1.5, 1.5 + 2.0, and 2.25 + 3.0 lb ai/ac, respectively, Snapshot DG (60% oryzalin + 20% isoxaben) at 2.0 + 0.5 and 4.0 + 1.0 lb ai/ac, respectively, prodiamine 0.24% + flumioxazin 0.125% DG at 0.24 +0.125, 0.48 + 0.25, and 0.94 + 0.5 lb ai/ac respectively, Dimension (dithiopyr) 0.25% DG at 0.375 and 0.5 lb ai/ac, Dimension 0.27% G at 0.375 and 0.5 lb ai/ac, and untreated control. One tablespoon (app. 16g) Scott's Osmocote Pro 15-9-12, 8-9 month formulation was applied immediately after treatment application. A mixture of 0.06 ml (1/8 tsp) of equal portions of prostrate spurge (*Chamacyse maculata*), bittercress (*Cardamine hirsuta*), annual bluegrass (*Poa annua*), common yellow woodsorrel (*oxalis stricta*), and common groundsel (*Senecio vulgaris*) were applied evenly across the six reps of each treatment. Immediately after treatments, weed seed, and fertilizer were applied, pots were laid out in a completely randomized design with six replications per treatment. Efficacy visual ratings were taken at 30, 60, and 90 DAT (days after treatment) and were based on a 0-10 scale with 0 being no weed control, 10 perfect weed control and ≥7 commercially acceptable. Water was applied daily throughout the test period using overhead irrigation delivering at least 0.25 ac-in/day, regardless of rainfall.

Results and discussion. Common groundsel and annual bluegrass failed to germinate. Bittercress and common yellow woodsorrel had erratic germination, but still provided some insight as to what treatments controlled them. Only one treatment (not including the control) did not provide commercially acceptable control at 30 DAT (lowest rate of Dimension 0.25 DG), with seven treatments providing perfect weed control (Table 1). At 60 DAT, nine treatments failed to provide commercially acceptable control, but two treatments still provided perfect control, which were both rates of SureGuard. At 90 DAT, only six treatments provided commercially acceptable control. Prostrate spurge was the most predominant species, but it was also apparent that some of the treatments failed to provide acceptable control of other weed species. Most of the treatments provided 100% control of prostrate spurge at 30 DAT, but those that did not provide 100% control were Snapshot DG at both rates and all Dimension DG products (data not shown). Prostrate spurge is harder to control than many other species in containers, but flumioxazin is one compound that does a good job of controlling prostrate spurge. That is reinforced in this trial; all treatments that contained flumioxazin controlled prostrate spurge to acceptable levels, even out to 90 DAT (Table 1). Treatments that failed to control bittercress at 90 DAT were Snapshot at both rates, FreeHand at the lowest rate, Snapshot DG at both rates, and Dimension 0.27 DG at both rates (data not shown). Barricade + Gallery provided poor control of goosegrass (*Eleusine indica*), which was a volunteer weed (data not shown). In this trial, the DG formulation of Snapshot was slightly less efficacious than the commercially available formulation of Snapshot (Table 1). Of the Dimension products, the 0.27 DG formulation had a slight advantage, but both formulations only provided acceptable control out to 30 DAT, primarily due to the poor spurge control. From this study, flumioxazin + prodiamine DG at the medium rate would be a very good weed control product in containers; however, flumioxazin does injure many ornamental species, and research should be done to see if the AGT formulations can decrease the phytotoxicity of flumioxazin. The Dimension and Snapshot DG products may be used on species from which the prodiamine + flumioxazin formulation cannot be used.

Table 1. Overall weed control at 30, 60, and 90 DAT and Prostrate spurge control at 90 DAT from Anderson's DG products in comparison to several industry standards and untreated control in 1-gallon containers.

Treatment	Rate (ai/ac)	30 DAT[z]		60 DAT		90 DAT		P. spurge 90 DAT	
SureGuard	0.25	10[yx]	a	10.0	a	9.2	a	9.5	a
SureGuard	0.38	10.0	a	10.0	a	9.2	a	9.2	a
Barricade + Gallery	0.75 + 0.75	9.7	ab	6.8	bcd	4.8	def	4.0	cd
BroadStar	0.25	10.0	a	9.7	a	8.7	a	8.8	a
Snapshot	2.0 + 0.5	9.7	ab	6.1	cde	4.0	defg	3.0	de
Snapshot	4.0 + 1.0	9.8	ab	6.0	cdef	3.2	fgh	2.3	def
FreeHand	1.125 + 1.5	10.0	a	8.3	ab	5.5	de	5.3	bcd
FreeHand	1.5 + 2.0	10.0	a	7.8	abc	5.7	cd	5.0	bcd
FreeHand	2.25 + 3.0	9.8	ab	9.2	a	5.8	bcd	5.8	bc
Snapshot DG	2.0 + 0.5	8.2	d	3.8	fg	2.8	gh	3.7	cd
Snapshot DG	4.0 + 1.0	9.3	abc	4.5	efg	3.0	fgh	2.5	def
Prodiamine + Flumioxazin DG	0.24 + 0.125	10.0	a	9.5	a	7.5	abc	7.5	ab
Prodiamine + Flumioxazin DG	0.48 + 0.25	9.7	ab	8.8	ab	7.8	ab	9.4	a
Prodiamine + Flumioxazin DG	0.96 + 0.5	10.0	a	9.8	a	9.3	a	9.2	a
Dimension 0.25 DG	0.375	6.8	e	3.5	g	2.2	gh	3.0	de
Dimension 0.25 DG	0.5	8.5	cd	3.7	g	1.7	hi	1.3	ef
Dimension 0.27 DG	0.375	8.7	cd	5.0	defg	3.7	efg	4.2	cd
Dimension 0.27 DG	0.5	9.0	bcd	5.3	defg	3.0	fgh	2.5	def
Untreated	0	0.5	f	0.0	h	0.0	i	0.0	f

z = Days after treatment

y = Visual ratings based on a 0-10 scale with 10 being perfect weed control and 0 no weed control and ≥7 commercially acceptable

x = Visual ratings followed by the same letter in the same column are not significantly different based on lsmeans (α = 0.05)

Evaluation of experimental formulations of preemergence herbicides applied on top of hardwood mulch for phytotoxicity and efficacy

Dr. Hannah Mathers and Luke Case

Introduction. Preemergence herbicides are the backbone of any ornamental program which includes the nursery and landscape sectors. Landscape contractors have few herbicide options that are labeled for a wide range of landscape species. For this reason, Snapshot (isoxaben + trifluralin) (Dow AgroSciences, Indianapolis, IN) along with Treflan (trifluralin) (numerous manufacturers) and Pendulum 2G (pendimethalin) (BASF Corp., Research Triangle Park, NC) are the most widely used because of the crop safety. Combination products, such as Snapshot, have a wider range of weed control than formulations with only a single active ingredient (e.g. Treflan). There are other preemergence herbicides labeled for nursery use, but because landscapes often have a wide range of species in very small areas, companies fear labeling herbicides for landscape use. However, BroadStar (Valent U.S.A, Walnut Creek, CA), a preemergence herbicide that had a nursery label is now also labeled for landscape use. BroadStar contains the active ingredient flumioxazin, which controls a number of grass and broadleaf species and is a great herbicide when combined with mulch (Case and Mathers, 2006a; Mathers, 2003).

Increasing soil residual of preemergence herbicides has been a topic of research basically since preemergence herbicides were invented. Mulches can enhance the longevity of herbicide residual (Case and Mathers, 2006a; Mathers, 2003); however, it varies with the mulch and herbicide used. A proprietary dispersible granule invented by The Anderson's (Toledo, OH) is a granule developed to break down over a period of time by soil microbes. The theory is that it releases the herbicide as it is being broke down and there are a number of formulations (i.e. release patterns) being trialed for herbicides. The objectives of this trial were to determine the efficacy and phytotoxicity of various active ingredients with The Anderson's dispersible granule on top of hardwood mulch in comparison to industry standards and untreated control.

Materials and methods. On June 2, 2010, four ornamental species, including *Ligustum xvicarii*, *Buxus* 'Winter gem', *Salvia*, and *Rudbeckia* 'Goldquelle' were planted in 3' x 6' (0.9 m x 1.8 m) plots that were previously tilled to a depth of 4". Immediately after planting, shredded hardwood mulch was applied to a depth of 1.5 to 2" (5 cm) around the plants. Treatments were applied on June 2, 2010. Treatments included a sprayable application of SureGuard (flumioxazin) at a rate of 0.25 and 0.375 lb ai/ac and Barricade + Gallery (isoxaben) at a rate of 0.75 lb ai + 0.75 lb ai/ac, respectively, which were applied as directed sprays using a backpack pump type sprayer to replicate the landscape industry. Treatments also included BroadStar at 0.375 lb ai/ac, Snapshot (isoxaben + trifluralin) as the industry standard at 2.0 + 0.5 and 4.0 + 1.0 lb ai/ac, respectively, FreeHand (dimethenamid + pendimethalin) at 1.125 + 1.5, 1.5 + 2.0, and 2.25 + 3.0 lb ai/ac, respectively, Snapshot DG (60% oryzalin + 20% isoxaben) at 2.0 + 0.5 and 4.0 + 1.0 lb ai/ac, respectively, prodiamine 0.24% + flumioxazin 0.125% DG at 0.24 +0.125, 0.48 + 0.25, and 0.94 + 0.5 lb ai/ac respectively, Dimension (dithiopyr) 0.25% DG at 0.375 and 0.5 lb ai/ac, Dimension 0.27% G at 0.375 and 0.5 lb ai/ac, BroadStar (flumioxazin) DG at 0.375 lb ai/ac, and untreated control (mulch only). Approximately four hours after treatment application, 1.1 inches rain fell. On June 3, 2010, a controlled release (8-9 month) 15-9-12 fertilizer was applied to each plot at a rate of approximately 200 lbs/ac. Evaluations of phytotoxicity were conducted at 15, 30, 60, and 90 DAT (days after treatment), and efficacy evaluations were conducted at 30, 60, and 90 DAT. Efficacy visual ratings were based on a 0-10 scale with 0 being no weed control and 10 perfect weed control, and $\geq$7 commercially acceptable. Phytotoxicity visual ratings were based on a 0-10 scale with 0 being no phytotoxicity and 10 death, and $\leq$3 commercially acceptable. Growth index was also taken at 90 DAT which was assessed by the formula: (height+width+width)/3.

Results and discussion.

Efficacy. Predominant weed species included green and giant foxtail (*Setaria viridis* and *Setaria faberi*, respectively), hairy galinsoga (*Galinsoga ciliata*), common lambsquarters (*Chenopodium album*), lady's thumb (*Polygonum persicaria*), large crabcrass (*Digitaria sanquinalis*), marestail (*Conyza canadensis*), Eastern black nightshade (*Solanum ptycanthum*), and prickly lettuce (*Lactuca serriola*). Many of the treatments performed well at 30 DAT, with only six treatments (including the untreated control) not providing commercially acceptable control (Table 1). By 60 DAT, only 11 treatments provided commercially acceptable control, and at 90 DAT, the number of treatments providing commercially acceptable control had been reduced to four. Snapshot, the industry standard, did provide acceptable control through 90 DAT, but only at the highest rate (which is equal to 200 lbs product/ac). FreeHand, a relatively new product from BASF, provided acceptable control with the medium and high rates through 60 DAT, and with the highest rate at 90 DAT. The highest rate of FreeHand was also the best treatment through 90 DAT (Table 1). The DG formulations of Snapshot did not do quite as well as the commercially available formulation of Snapshot through 90 DAT, but when comparing by rate, they were not significantly different. From the DG products, the combination of prodiamine + flumioxazin was the best treatment, with the medium and high rates both providing acceptable control through 90 DAT (Table 1). The two dimension formulations were about equal, but the 0.25% formulation had a slight advantage. The BroadStar DG product provided the poorest visual ratings, but the commercially available BroadStar also did poor. Neither treatment provided acceptable control at any of the evaluation dates (Table 1). BroadStar has performed poorly in a landscape setting in recent trials performed by The Ohio State University (data not shown). SureGuard, the sprayable formulation of flumioxazin that is commercially available (but not labeled for landscape use) has been known to provide good weed control when used with hardwood mulch in a landscape setting (Case and Mathers, 2006b). SureGuard in this study did provide good weed control, but only through 60 DAT. The combination of Barricade + Gallery only provided acceptable control through 30 DAT (Table 1).

Phytotoxicity. High weed pressure caused competition with *Ligustrum, Rudbeckia, and Salvia*, which is evident in the visual ratings of untreated controls at 60 and 90 DAT (Table 2). However, visual ratings at 15 and 30 DAT can provide valuable information as to what treatments may cause damage to the crop species selected. On *Buxus*, Barricade + Gallery consistently provided significantly higher visual ratings than the control through 60 DAT, and also the lowest growth index rating (Table 2). Four treatments provided significantly higher visual ratings than the untreated control plants through 30 DAT to *Ligustrum*; both rates of SureGuard, Barricade + Gallery, and the highest rate of the DG formulation of prodiamine + flumioxazin (Table 3). Growth index ratings of *Ligustrum* were the lowest with the lowest rate of SureGuard and the highest rate of the DG formulation of prodiamine + flumioxazin. Three treatments provide significantly higher visual ratings than the controls of *Rudbeckia* at 15 DAT;

again both rates of SureGuard and the combination of Barricade + Gallery (Table 4). Five treatments provided visual ratings significantly higher than the untreated *Salvia* at 15 DAT; the two rates of SureGuard, Barricade + Gallery, the high rate of Snapshot, and the medium and high rates of the DG formulation of prodiamine + flumioxazin (Table 5). The high rates of Snapshot and DG formulation of prodiamine + flumioxazin also provided significantly higher visual ratings at 30 DAT. Growth index values also indicate that the high rate of Snapshot was detrimental to Salvia growth (Table 5). Visual ratings indicate that there were some significant effects from FreeHand to *Buxus*, but this was only at 30 DAT and at the lowest rate (Table 2). Otherwise, FreeHand had little effect on any of the species in this trial, which the growth indices also indicate. However, it should be noted that phytotoxicity has been observed on some annuals at 400 lbs/ac (Mathers 2008; Mathers 2009) and in woody species at 600 lbs/ac (Mathers 2009).

The species in the trial were selected because they have few herbicides labeled and the low tolerance to flumioxazin. As previously stated, flumioxazin works well with mulch in a landscape setting, but phytotoxicity can generally be high when used over the top as a sprayable (SureGuard). Even though the SureGuard was used a directed spray, it is almost impossible to not get some spray drift on desirable species. Complete data is not shown, but phytotoxicity ratings varied across reps from the SureGuard applications. As indicated by phytotoxicity visual ratings, the commercially available granular formulation of flumioxazin, BroadStar, does reduce phytotoxicity in comparison to the SureGuard, even if SureGuard is a directed spray. Many species can recover from SureGuard applications, but since a large portion of the landscape industry is based on aesthetics, there is a zero tolerance policy with herbicide injury. *Salvia* and *Rudbeckia* were able to recover from the SureGuard applications; *Ligustrum* was not able to fully recover (Tables 3, 4, and 5). BroadStar is now labeled for landscape use, but as the data in this trial indicate, BroadStar has reduced weed control compared to SureGuard.

Conclusions. Based on efficacy and phytotoxicity visual ratings, some of the DG formulations performed as good as or better than the commercially available products. The medium rate of the DG formulation of prodiamine + flumioxazin provided good weed control but had low visual ratings on *Buxus* and *Rudbeckia*. The high rate of both Dimension DG formulations had low phytotoxicity ratings on all species, and provided good weed control, although not quite commercially acceptable at 90 DAT. The highest rate (300 lbs product/ac) of FreeHand was the best treatment in the trial, in terms of both weed control and low phytotoxicity to all species tested. From this trial, BroadStar alone (both formulations) does not provide adequate weed control. SureGuard is not labeled for landscape use, and the visual ratings from this trial support that. Barricade + Gallery is the worst treatment in terms of phytotoxicity, and weed control was not great either. More testing should be done with the high rate of both Dimension DG products, the medium and high rates of the DG formulation of prodiamine + flumioxazin and the high rate of the DG formulation of Snapshot.

Acknowledgments: Kyle Daniel, Phoebe Gordon, Dania Rivera, Nicholas Steller for their help in setting up the trial and data collection. We would like to thank The Anderson's Company, Valent U.S.A, and Dow AgroSciences for herbicide products. We would also like to thank Herman Losely and Son's Nursery, Klyn Nursery, April's Greenhouse, and Springbrook Gardens for plant donations.

Literature Cited

Case, L.T. and H.M. Mathers. 2006a. Herbicide treated mulches for weed control in container crops. J. Envir. Hort. 24:84-90.

Case, L. and H. Mathers. 2006b. Field evaluation of herbicide treated mulches. S. Nurserymen's Assn. Res. Conf. 51:402-405.

Mathers, H. 2003. Novel methods of weed control in containers. HortTechnology. 13:28-31.

Mathers, H. 2008. Yearly research summary report. http://basicgreen.osu.edu.

Mathers, H. 2009. Yearly research summary report. http://basicgreen.osu.edu.

Table 1. Efficacy visual ratings of various herbicide treatments when applied over hardwood mulch at 30, 60, and 90 DAT.

Treatment	Rate (ai/ac)	30 DAT[z]		60 DAT		90 DAT	
SureGuard	0.25	8.0[y]	abc	7.0	bcd	5.2	cdef
SureGuard	0.38	7.8	abc	6.2	cd	5.6	bcdef
Barricade + Gallery	0.75 + 0.75	7.0	cd	5.2	de	4.0	ef
BroadStar	0.25	4.6	e	3.6	ef	3.4	f
Snapshot	2.0 + 0.5	6.5	cd	7.2	abc	6.8	abcd
Snapshot	4.0 + 1.0	8.2	abc	8.8	ab	7.8	ab
FreeHand	1.125 + 1.5	7.8	abc	6.2	cd	6.8	abcd
FreeHand	1.5 + 2.0	7.8	abc	7.4	abc	6.0	bcde
FreeHand	2.25 + 3.0	9.0	ab	9.0	a	8.8	a
Snapshot DG	2.0 + 0.5	6.8	cd	6.2	cd	6.0	bcde
Snapshot DG	4.0 + 1.0	7.2	cd	7.0	bcd	6.6	abcd
Prodiamine + Flumioxazin DG	0.24 + 0.125	8.0	abc	6.2	cd	5.4	cdef
Prodiamine + Flumioxazin DG	0.48 + 0.25	8.0	abc	8.8	ab	7.5	abc
Prodiamine + Flumioxazin DG	0.96 + 0.5	9.4	a	8.8	ab	7.8	ab
Dimension 0.25 DG	0.375	7.0	cd	7.0	bcd	6.0	bcde
Dimension 0.25 DG	0.5	7.4	bcd	7.0	bcd	6.6	abcd
Dimension 0.27 DG	0.375	5.8	de	5.8	cd	4.5	def
Dimension 0.27 DG	0.5	8.2	abc	7.4	abc	6.2	bcde
BroadStar 0.25 DG	0.375	4.2	e	3.0	f	0.7	g
Untreated	0	0.0	f	0.0	g	0.0	g

z = days after treatment

y = visual ratings followed by the same letter in the same column are not significantly different based on lsmeans (α = 0.05)

x = visual ratings are based on a 0-10 scale with 0 being no control and 10 perfect control with ≥7 commercially acceptable.

Table 2. Phytotoxicity visual ratings of *Buxus* 'Winter gem' from various herbicide treatments when applied over hardwood mulch at 15, 30, 60, and 90 DAT.

Treatment	Rate (ai/ac)	15 DAT[z]		30 DAT		60 DAT		90 DAT	GI[y]	
SureGuard	0.25	1.2	xw	1.8		2.4		3.5	17.4[v]	abc
SureGuard	0.38	1.8		2.4		2.2		2.6	18.3	abc
Barricade + Gallery	0.75 + 0.75	3.0	**	3.8	**	3.8	**	2.6	15.5	c
BroadStar	0.25	1.2		1.6		2.2		2.8	16.4	bc
Snapshot	2.0 + 0.5	0.6		0.4		2.2		1.8	17.5	abc
Snapshot	4.0 + 1.0	1.8		2.4		3.2	*	2.6	17.4	abc
FreeHand	1.125 + 1.5	2.0		3.4	**	2.2		2.8	16.9	abc
FreeHand	1.5 + 2.0	1.6		2.4		1.8		3.2	17.5	abc
FreeHand	2.25 + 3.0	1.2		1.8		2.4		2.6	17.3	abc
Snapshot DG	2.0 + 0.5	1.2		1.2		2.0		2.8	15.2	abc
Snapshot DG	4.0 + 1.0	0.8		1.4		2.0		3.4	16.9	abc
Prodiamine + Flumioxazin DG	0.24 + 0.125	0.8		1.2		2.4		2.6	16.3	abc
Prodiamine + Flumioxazin DG	0.48 + 0.25	0.6		0.6		0.8		0.5	19.2	abc
Prodiamine + Flumioxazin DG	0.96 + 0.5	0.2		1.0		0.2		1.2	20.1	a
Dimension 0.25 DG	0.375	1.6		1.2		1.0		3.2	16.5	abc
Dimension 0.25 DG	0.5	0.2		1.0		1.0		1.2	19.4	ab
Dimension 0.27 DG	0.375	0.6		2.0		2.8		3.0	17.8	abc
Dimension 0.27 DG	0.5	0.8		1.4		2.8		2.4	17.5	abc
BroadStar 0.25 DG	0.375	1.0		1.2		2.2		3.3	15.9	abc
Untreated	0	0.4		0.0		0.4		1.2	17.4	abc

z = days after treatment

y = growth index which was assessed by (height+width+width)/3

x = visual ratings in the same column followed by ** are not significantly different than the control based on Dunnett's t-test at the $\alpha = 0.05$. Those followed by * are not significantly different from the control at the $\alpha = 0.10$

w = visual ratings are based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable

v = Growth index values followed by the same letter are not significantly different from each other, based on lsmeans ($\alpha = 0.05$)

Table 3. Phytotoxicity visual ratings of *Ligustrum x*'vicaryii' from various herbicide treatments when applied over hardwood mulch at 15, 30, 60, and 90 DAT.

Treatment	Rate (ai/ac)	15 DAT[z]		30 DAT		60 DAT	90 DAT	GI[y]	
SureGuard	0.25	7.0[xw]	**	5.0	**	5.8	6.3	7.8[v]	e
SureGuard	0.38	6.0	**	5.0	**	2.0	2.6	16.7	abc
Barricade + Gallery	0.75 + 0.75	5.0	**	5.4	**	3.8	4.6	12.3	bcde
BroadStar	0.25	0.6		1.8		2.8	3.6	14.3	abcde
Snapshot	2.0 + 0.5	1.0		1.6		1.0	2.8	15.3	abcd
Snapshot	4.0 + 1.0	2.4		3.8		4.4	3.6	14.3	abcde
FreeHand	1.125 + 1.5	0.4		1.4		2.4	2.2	21.4	a
FreeHand	1.5 + 2.0	0.4		1.4		0.6	5.0	21.5	a
FreeHand	2.25 + 3.0	1.4		2.2		2.8	1.8	19.5	ab
Snapshot DG	2.0 + 0.5	0.6		2.0		1.8	3.0	17.9	abc
Snapshot DG	4.0 + 1.0	1.8		3.4		1.8	3.4	16.0	abc
Prodiamine + Flumioxazin DG	0.24 + 0.125	2.4		2.6		2.4	3.2	15.2	abcde
Prodiamine + Flumioxazin DG	0.48 + 0.25	2.4		4.0		3.2	5.3	11.8	cde
Prodiamine + Flumioxazin DG	0.96 + 0.5	3.4	*	5.6	**	5.8	6.4	8.4	de
Dimension 0.25 DG	0.375	2.0		3.2		4.4	5.0	11.8	cde
Dimension 0.25 DG	0.5	0.8		2.0		2.2	2.8	15.2	abcde
Dimension 0.27 DG	0.375	1.6		3.2		3.6	5.0	10.6	cde
Dimension 0.27 DG	0.5	2.4		3.6		3.4	4.4	12.7	bcde
BroadStar 0.25 DG	0.375	2.2		1.8		1.4	3.3	15.2	abcde
Untreated	0	0.6		1.4		3.0	6.4	9.1	de

z = days after treatment

y = growth index which was assessed by (height+width+width)/3

x = visual ratings in the same column followed by ** are not significantly different than the control based on Dunnett's t-test at the $\alpha = 0.05$. Those followed by * are not significantly different from the control at the $\alpha = 0.10$

w = visual ratings are based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable

v = Growth index values followed by the same letter are not significantly different from each other, based on lsmeans ($\alpha = 0.05$)

Table 4. Phytotoxicity visual ratings of *Rudbeckia* 'Goldquelle' from various herbicide treatments when applied over hardwood mulch at 15, 30, 60, and 90 DAT.

Treatment	Rate (ai/ac)	15 DAT[z]		30 DAT	60 DAT	90 DAT	GI[y]	
SureGuard	0.25	2.6[xw]	**	2.8	2.8	2.5	44.2[v]	bc
SureGuard	0.38	3.0	**	3.6	3.0	1.6	46.8	abc
Barricade + Gallery	0.75 + 0.75	2.4	*	2.6	2.4	3.0	44.7	bc
BroadStar	0.25	0.6		1.8	1.6	3.6	44.5	bc
Snapshot	2.0 + 0.5	0.6		0.8	2.6	2.5	44.9	bc
Snapshot	4.0 + 1.0	2.0		3.6	3.8	3.2	42.8	bc
FreeHand	1.125 + 1.5	1.2		1.0	1.2	2.5	48.4	ab
FreeHand	1.5 + 2.0	0.8		1.6	2.4	2.6	46.5	abc
FreeHand	2.25 + 3.0	1.6		3.2	4.0	3.6	44.9	bc
Snapshot DG	2.0 + 0.5	1.2		2.4	2.0	3.0	44.7	bc
Snapshot DG	4.0 + 1.0	0.8		1.4	3.0	2.8	43.1	bc
Prodiamine + Flumioxazin DG	0.24 + 0.125	1.0		2.0	1.6	2.8	45.2	abc
Prodiamine + Flumioxazin DG	0.48 + 0.25	0.6		1.4	1.6	2.0	48.2	abc
Prodiamine + Flumioxazin DG	0.96 + 0.5	1.2		1.4	1.8	1.6	53.3	a
Dimension 0.25 DG	0.375	0.8		2.0	2.0	2.8	47.4	abc
Dimension 0.25 DG	0.5	1.6		2.6	2.2	2.6	41.3	bc
Dimension 0.27 DG	0.375	1.8		2.8	3.0	3.8	45.4	abc
Dimension 0.27 DG	0.5	0.4		2.2	2.0	2.4	45.0	bc
BroadStar 0.25 DG	0.375	0.4		1.6	2.2	2.2	38.8	c
Untreated	0	0.6		2.0	1.6	3.4	42.3	bc

z = days after treatment

y = growth index which was assessed by (height+width+width)/3

x = visual ratings in the same column followed by ** are not significantly different than the control based on Dunnett's t-test at the $\alpha = 0.05$. Those followed by * are not significantly different from the control at the $\alpha = 0.10$

w = visual ratings are based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable

v = Growth index values followed by the same letter are not significantly different from each other, based on lsmeans ($\alpha = 0.05$)

Table 5. Phytotoxicity visual ratings of *Salvia* from various herbicide treatments when applied over hardwood mulch at 15, 30, 60, and 90 DAT.

Treatment	Rate (ai/ac)	15 DAT[z]		30 DAT		60 DAT	90 DAT	GI[y]	
SureGuard	0.25	6.2[xw]	**	2.6		2.6	3.0	39.3[v]	abcd
SureGuard	0.38	4.4	**	2.2		2.4	2.8	38.1	abcd
Barricade + Gallery	0.75 + 0.75	5.2	**	3.4		4.0	4.4	30.7	bcd
BroadStar	0.25	1.2		1.0		1.2	3.8	32.3	abcd
Snapshot	2.0 + 0.5	1.0		1.6		2.4	4.0	29.8	cd
Snapshot	4.0 + 1.0	3.8	**	6.0	**	4.8	5.0	29.5	d
FreeHand	1.125 + 1.5	2.4		2.4		2.6	3.0	34.1	abcd
FreeHand	1.5 + 2.0	2.2		1.4		1.2	3.0	39.5	abcd
FreeHand	2.25 + 3.0	2.8		3.6		3.0	2.4	40.5	abcd
Snapshot DG	2.0 + 0.5	2.4		3.2		2.8	4.2	33.3	abcd
Snapshot DG	4.0 + 1.0	2.6		1.8		2.4	4.2	31.8	bcd
Prodiamine + Flumioxazin DG	0.24 + 0.125	4.2	**	3.2		2.6	2.8	32.6	abcd
Prodiamine + Flumioxazin DG	0.48 + 0.25	4.8	**	4.3	*	2.6	3.8	34.0	abcd
Prodiamine + Flumioxazin DG	0.96 + 0.5	1.4		1.0		2.2	2.6	42.5	ab
Dimension 0.25 DG	0.375	1.4		1.8		0.6	2.8	41.7	abc
Dimension 0.25 DG	0.5	1.4		1.8		1.6	2.4	41.7	abc
Dimension 0.27 DG	0.375	0.6		1.2		2.6	4.3	37.6	abcd
Dimension 0.27 DG	0.5	1.2		0.6		1.0	2.8	40.1	abcd
BroadStar 0.25 DG	0.375	1.0		1.0		1.6	2.0	45.1	a
Untreated	0	0.4		0.4		2.0	4.0	29.1	d

z = days after treatment

y = growth index which was assessed by (height+width+width)/3

x = visual ratings in the same column followed by ** are not significantly different than the control based on Dunnett's t-test at the α = 0.05. Those followed by * are not significantly different from the control at the α = 0.10

w = visual ratings are based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable

v = Growth index values followed by the same letter are not significantly different from each other, based on lsmeans (α = 0.05)

Weed Control and phytotoxicity to selected annuals from applications of FreeHand and Snapshot in a landscape setting

Dr. Hannah Mathers and Luke Case

Introduction. Weed control in landscapes is predominantly achieved by preemergence herbicides followed by directed applications of glyphosate or handweeding. However, few herbicides exist for landscapes that have good control of both grass and broadleaf weeds but are not phytotoxic to desirable plants. Snapshot (isoxaben + trifluralin, Dow AgroSciences, Indianapolis, IN) is a combination herbicide that does provide good weed control while safe to a wide range of ornamental species and is used extensively by the landscape industry because of these characteristics. However, using the same herbicide over time in the same location gives rise to weeds that are not harmed by the herbicide, which is one reason to alternate herbicide chemistries. Annual bedding plants are especially sensitive to herbicides and fewer options exist than compared to herbaceous perennials or woody species. FreeHand (dimethanid-p + pendimethalin) is a herbicide released by BASF that also has good weed control and is safe to a wide range of species, but since it is fairly new (release was in 2008), crop tolerance is not as fully understood as Snapshot. The objectives of this study were to determine phytotoxicity and efficacy of FreeHand over a variety of annual bedding plants in comparison to Snapshot and untreated control.

Materials and Methods. Two similar trials were set up in consecutive years, the first one starting on June 4, 2009, and the second starting on June 2, 2010. Ten species of annual bedding plants were planted into 4' x 6' plots of previously tilled soil. Just prior to planting, 2" (5 cm) of hardwood mulch was put down on the soil surface. Bedding plants in 2009 consisted of Ageratum 'Hawaii Royal', Alyssum 'Wonderland Citron', Coleus 'Carefree', Dianthus 'Ideal Select Salmon', Gomphrena 'Gnome Pink', Impatiens 'Xtreme Pink', Marigold 'Orange Boy', Portulaca 'Margarita Rosita', Salvia 'Vista', and Dusty Miller 'Silverdust', which all came from 2" (5 cm) pots. In 2010, bedding plant species consisted of Marigold 'Bonanza orange', Zinnia 'Profusion yellow', Dusty Miller 'Silverdust', Impatiens 'White', Begonia 'Eureka green leaf scarlet', Salvia 'Rhea', Portulaca 'Margarita banana', Agertum 'Hawaii royal', Alyssum 'Crysal clear white', and Dahlia 'Harlequin' mix. On June 15, 2009, and June 2, 2010, treatments were applied, which consisted of FreeHand (dimethenamid-p + pendimethalin) at 100, 200, and 400 lbs/ac (1.75, 3.5, and 7 lbs ai/ac, respectively) and Snapshot (isoxaben + trifluralin) (DowAgroSciences, Indianapolis, IN) at 200 lbs/ac (5.0 lb ai/ac), and these were compared to untreated control (mulch only). Immediately after treatments were applied, plots were watered with overhead irrigation in 2009, and in 2010, approximately 1.1 inches rain fell starting 4 hours after application. Treatments were arranged in a completely randomized design with four replications per treatment with two subsamples of species per replication. In 2009, growth of the plants was not deemed sufficient, so on July 15, 2009, fertilizer [33-3-9 (Scott's Co., Marysville, OH)] was applied at a rate of 100 lbs/ac. In 2010, 15-9-12 8-9 month Osmocote Pro (Scott's Co.) was applied at 200 lbs/ac on June 3. Evaluations of phytotoxicity and efficacy were conducted at 30, 60, and 90 and efficacy only at 120 DAT (days after treatment) in 2009. In 2010, evaluations of phytotoxicity were conducted at 15, 30, and 60 DAT and efficacy visual ratings were conducted at 30, 60, and 90 DAT. Phytotoxicity visual ratings were taken on each plant based on a 1-10 scale with 1 being no phytotoxicity and 10 death in 2009, and a 0-10 scale in 2010 with 0 being no phytotoxicity and 10 death. Efficacy visual ratings were taken on a whole plot basis based on a 0-10 scale with 0 being no weed control and 10 perfect weed control in both 2009 and 2010.

Results and discussion.
Efficacy. Both trials were similar in terms of weed control, but as in most multiple-year trials, some differences exist (Table 1). At the 100 lbs/ac rate, FreeHand provided weed control only up to 30 DAT, both in 2009 and in 2010. Weed control improved significantly at the 200 lbs/ac rate compared to the 100 lbs/ac rate of FreeHand in both years. In 2009, acceptable weed control was achieved through 90 DAT, and through 60 DAT in 2010. None of the treatments provided acceptable weed control at 120 DAT in 2009, although Snapshot came close (6.8). FreeHand at 400 lbs/ac provided acceptable weed control through 90 DAT in both 2009 and 2010. One of the biggest differences between years was the amount of weed control that Snapshot provided. Weed control with Snapshot was much better in 2009 than in 2010. Snapshot provided acceptable weed control through 90 DAT in 2009, but in 2010, it was acceptable only at 30 DAT. Weed pressure was much higher in the first 60 days in 2010, primarily from the amount of rain that fell during the first 30 DAT.
Phytotoxicity. Averaged over all evaluation dates, FreeHand at the 100 lb/ac rate did not cause any phytotoxicity to any of the plants evaluated in 2009 or 2010 (Table 2). At the 200 lb/ac rate, Gomphrena did show phytotoxicity in 2009 from FreeHand at 200 and 400 lbs/ac that was significantly higher than the control, but it was still commercially acceptable. In 2010, Begonia, Silverdust, and Portulaca had significantly higher visual ratings than the control at 200 and 400 lbs/ac (Table 2). Species also significantly injured by the 400 lbs/ac rate in 2010 were Salvia, Ageratum (but still commercially acceptable), Alyssum, and Dahlia. At 400 lb/ac in 2009, FreeHand caused significant injury to Coleus, Gomphrena, and Marigold; however, Marigold was the only specie to have ratings not commercially acceptable. Snapshot caused unacceptable injury to Gomphrena and Impatiens (Table 2). Some species (e.g. Alyssum) had ratings beyond commercially acceptable in 2009, but because of variance between replications (and sometimes within replications), they were not significantly different from the control. Also, because of poor growth at the start of the experiment in 2009, phytotoxicity ratings were generally high, even with the control plants (Table 2).

Conclusions. From this trial, FreeHand would be an excellent alternative/addition for weed management in landscapes. FreeHand at 200 lbs/ac is the best choice; 100 lbs/ac is not enough for weed control, and 400 lbs/ac causes more damage to the bedding plants. Although 200 lbs/ac does cause some phytotoxicity, it is evident that many species can tolerate that rate, and more research is necessary to increase the number of species that can be added to the label.

Table 1. Weed control of FreeHand and Snapshot vs. untreated control in a landscape setting in 2009 and 2010.

2009									
Treatment	Rate	30 DAT[z]		60 DAT		90 DAT		120 DAT	
FreeHand	100 lbs/ac	8.2[yx]		6.0	b	5.0	b	3.5	b
FreeHand	200 lbs/ac	9.0		8.8	ab	7.8	ab	5.5	a
FreeHand	400 lbs/ac	9.5		9.5	a	8.5	ab	5.8	a
Snapshot	200 lbs/ac	9.8		9.5	a	9.3	a	6.8	a
Untreated	--	8.3		5.8	b	5.3	b	2.8	b
2010		15 DAT		30 DAT		60 DAT		90 DAT	
FreeHand	100 lbs/ac	6.2	bc	7.3	b	5.3	c	5.7	b
FreeHand	200 lbs/ac	8.0	ab	9.0	a	8.0	ab	5.5	b
FreeHand	400 lbs/ac	9.8	a	9.8	a	9.0	a	8.3	a
Snapshot	200 lbs/ac	5.0	c	7.3	b	6.5	bc	5.0	b
Untreated	--	0.8	d	3.2	c	0.0	d	0.0	c

z = days after treatment

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

x = visual ratings in the same column followed by similar letters are not significantly different based on lsmeans ($\alpha = 0.05$)

Table 2. Phytotoxicity of several annual bedding plants from FreeHand in comparison with Snapshot and untreated control in 2009 and 2010.

2009

Treatment	Rate	Ageratum	Alyssum	Coleus	Dianthus	Gomphrena
FreeHand	100 lbs/ac	1.6[zy]	2.8	1.6	1.6	1.3
FreeHand	200 lbs/ac	2.2	4	2.2	2.2	2.5 **
FreeHand	400 lbs/ac	2.4	4.4	2.8 **	2.4	2.5 **
Snapshot	200 lbs/ac	3.1	4.6	2.1	3	3 **
Untreated	--	2	2.6	1.5	2	1.4

Treatment	Rate	Impatiens	Marigold	Portulaca	Salvia	Dusty Miller
FreeHand	100 lbs/ac	1.7	1.7	4	2.4	1.3
FreeHand	200 lbs/ac	2.1	2.4	4.9	3.6	1.5
FreeHand	400 lbs/ac	2.5	4.2 **	5	3.9	1.8
Snapshot	200 lbs/ac	3.9 **	2	4.8	4.4	1.5
Untreated	--	2	1.5	3.3	2.9	1.8

z = Visual ratings are averged over 30, 60, and 90 days after treatment and are based on a 0-10 scale with 0 being no phytotoxicity and 10 death
y = Treatment means followed by ** are not significantly different from the control based on Dunnett's t-test (α = 0.05)

2010

Treatment	Rate	Marigold	Zinnia	Silverdust	Impatiens	Begonia
FreeHand	100 lbs/ac	1.2[zy]	0.7	0.5	1.1	6.0
FreeHand	200 lbs/ac	2.3	1.3	2.2 **	3.1	8.6 **
FreeHand	400 lbs/ac	2.5	2.2	2.0 **	3.0	9.0 **
Snapshot	200 lbs/ac	0.8	1.0	1.0	1.9	2.8
Untreated	--	1.8	1.0	0.8	2.4	4.7

Treatment	Rate	Salvia	Portulaca	Ageratum	Alyssum	Dahlia
FreeHand	100 lbs/ac	1.9	2.0	1.0	1.9	2.6
FreeHand	200 lbs/ac	4.1	4.5 *	1.7	3.0	3.2
FreeHand	400 lbs/ac	6.4 **	4.9 **	2.8 *	5.2 **	4.3 *
Snapshot	200 lbs/ac	2.5	2.7	0.9	4.7 **	3.4
Untreated	--	3.5	2.6	1.3	2.0	2.6

z = Visual ratings are averged over 15, 30, and 60 days after treatment and are based on a 0-10 scale with 0 being no phytotoxicity and 10 death

y = Visual ratings in the same column followed by * and ** are significantly different from the control using Dunnett's t-test (α = 0.10 and 0.05, respectively)

Efficacy and phytotoxicity of SureGuard, V-10233, Barricade + Gallery, and BroadStar when applied around actively growing plants

Dr. Hannah Mathers and Luke T. Case

Introduction. Weed control in the landscape is very important, and in most cases, is a zero tolerance policy. New products add an extra line of defense for landscapers with the war on weeds. BroadStar (Valent U.S.A, Walnut Creek, CA) is a granular formulation of the active ingredient flumioxazin that has been recently labeled for landscape weed control. SureGuard (Valent U.S.A) also contains flumioxazin as the active ingredient, but it is a sprayable formulation and is not labeled for landscapes. SureGuard is labeled for nursery production. Sprayable formulations are more phytotoxic to desirable species than the granular counterpart, especially if the sprayable formulations are not used as directed sprays. The objectives of this study were to determine the efficacy and phytotoxicity of SureGuard and a new, experimental product in comparison to BroadStar, Barricade + Gallery, and untreated control.

Materials and methods. Three ornamental landscape species, *Buxus* 'Winter gem', *Spirea* 'Anthony waterer', and *Salvia* were planted in 3' x 6' plots on June 2, 2010. Immediately after planting, approximately 1-1.5" shredded hardwood mulch was placed around the plants. Treatments were applied on June 3, 2010 in a completely randomized design with four replications per treatment. Treatments included SureGuard at 8 oz/ac, SureGuard at 12 oz/ac, the experimental product, V-10233 at 7 oz/ac, V-10233 at 10 oz/ac, Barricade (prodiamine, Syngenta Corp., Wilmington, DE) + Gallery (isoxaben, Dow AgroSciences, Indianapolis, IN) at 1.15 + 1.0 lbs/ac, respectively, BroadStar at 150 lbs/ac, and untreated control (shredded hardwood mulch only). All treatments except BroadStar were applied with a handpump, backpack sprayer to simulate the industry. BroadStar was applied using a handheld shaker jar. On June 3, 2010, a 15-9-12, 8-9 month Osmocote Pro fertilizer was applied to each plot at a rate of 200 lbs/ac. Phytotoxicity visual ratings were taken on each plant at 15, 30, 60, and 90 DAT on a 0-10 scale with 0 being no phytotoxicity and 10 death, with $\leq$3 commercially acceptable. Efficacy visual ratings were taken on a 0-10 scale with 0 being no weed control and 10 perfect weed control, with $\geq$7 commercially acceptable.

Results and discussion.
Efficacy. SureGuard at both rates and V-10233 at both rates gave above commercially acceptable control at 30 DAT (Table 1). At 60 DAT, only the high rates of SureGuard and V-10233 gave above commercially acceptable control. Canada thistle (*Cirsium arvense*) and field bindweed (*Convolvulus arvensis*) became an increasing problem throughout the trial, and by 90 DAT, it became such a problem that many of the plots were not given ratings (data not shown). Data at 90 DAT may be somewhat misleading because of this (Table 1). However, SureGuard and V-10233 were still much better at weed control than Barricade + Gallery, BroadStar, and the untreated control. It should also be noted that all SureGuard and V-10233 treatments were not statistically different from each other at each evaluation (Table 1); however, it was apparent that the higher rates did provide better control.
Phytotoxicity. *Spirea* was the only species showing phytotoxicity significantly higher than the untreated plants, and only at the $\alpha = 0.10$ level when averaged across dates (Table 2). Several treatments, including SureGuard at the 12 oz/ac rate and both rates of V-10233 provided visual

ratings that were not commercially acceptable on *Salvia*, but were not significantly different from the untreated plants. *Buxus* did not show any phytotoxicity from any of the treatments when averaged across dates (Table 2). There was some variation across replications, especially with the untreated plants from weed competition. This is especially true for *Salvia*.

From this trial, it is evident that Barricade + Gallery and BroadStar do not adequately control weeds in a landscape setting using hardwood mulch. It should be mentioned that the minimum amount of mulch was used, and increasing the depth would greatly increase weed control of any of the treatments. However, with the depth that was used, differences can more easily be seen in terms of weed control. From previous research (data not shown), flumioxazin is a great herbicide for a landscape setting, but SureGuard (liquid) is better than BroadStar (granular), and this trial confirms those findings. But, as usual, the liquid formulation proves also to be more phytotoxic. V-10233 proves to be quite competitive with SureGuard, although there can be some phytotoxicity, especially with *Salvia* and *Spirea*. When using a handpump sprayer and directing the spray (as opposed to over-the-top or applying granulars), it is much harder to get precise applications, in terms of ai/ac. If and when liquid formulations do get labeled for landscapes, the amount of active ingredient applied should be stated as a % of total volume. This would make mixing and applying much easier. One weakness of flumioxazin is grass species; giant foxtail (*Setaria faberi*) was one of the predominant species in this study. BroadStar alone would not control it, and it also became a problematic weed in the SureGuard treatments after 60 DAT. Formulations that include a grass inhibiting herbicide in addition to flumioxazin would be very beneficial for the ornamental industry.

Table 1. Efficacy of SureGuard, V-10233, Barricade + Gallery, and BroadStar at 30, 60, and 90 DAT in a landscape setting.

Treatment	Rate	30 DAT[z]		60 DAT		90 DAT	
SureGuard	8 oz/ac	7.75[yx]	ab	6.5	ab	5.3	abc
SureGuard	12 oz/ac	9.0	a	7.3	a	5.8	ab
V-10233	7 oz/ac	7.8	ab	5.3	ab	7.0	a
V-10233	10 oz/ac	9.0	a	7.7	a	6.5	ab
Barricade + Gallery	1.15 + 1.0 lb/ac	6.5	b	3.5	b	3.5	abc
BroadStar	150 lbs/ac	4.3	c	3.5	b	2.8	bc
Untreated	--	2.8	c	0.0	b	0.0	c

z = days after treatment

y = visual ratings are based on a 0-10 scale with 0 being no weed control, 10 perfect weed control and ≥7 commercially acceptable

x = visual ratings followed by the same letter in the same column are not significantly different based on lsmeans ($\alpha = 0.05$)

Table 2. Phytotoxicity of SureGuard, V-10233, Barricade + Gallery, and BroadStar averaged across 30, 60, and 90 DAT in a landscape setting.

Treatment	Rate	*Salvia*	*Buxus*	*Spirea*
SureGuard	8 oz/ac	2.6[zy]	2.3	1.9
SureGuard	12 oz/ac	4.0	2.1	1.3
V-10233	7 oz/ac	4.6	1.6	2.0
V-10233	10 oz/ac	3.9	2.8	3.1 *
Barricade + Gallery	1.15 + 1.0 lb/ac	2.9	1.5	1.9
BroadStar	150 lbs/ac	2.8	1.4	1.6
Untreated	--	2.6	1.6	1.7

z = Visual ratings are based on a 0-10 scale with 0 being no phytotoxicity, 10 death, and ≤3 commercially acceptable

y = visual ratings followed by * are significantly higher than the untreated control based on Dunnett's t-test (α = 0.10)

Phytotoxicity of selected herbicides to ornamental plants at three Michigan nurseries

Principle investigators: Dr. Hannah Mathers and Luke Case

Significance to the industry. Weed control is a major expense faced by the ornamental industry. With the large number of species and the constant addition of new species and cultivars, chemical companies struggle to perform all the research needed for labeling. The IR-4 program was developed by the federal government in association with universities and chemical companies in order to expand pesticide labels for minor use crops, and many companies now rely on the IR-4 program for label expansion for minor use crops. Additional information is needed on the factors that impact herbicide longevity in environments where high organic substrates and irrigation is used to promote plant growth. This information may result in the development of management strategies that increase herbicide longevity. This study has shown Biathalon, FreeHand, the granular form of F6875 and Tower all merit further evaluations in MI nurseries in field and containers. SedgeHammer also merits further field testing due to its ability to deal with some of Michigan's particularly difficult weeds.

Materials and methods. Phytotoxicity trials were set up on April 29, 2010 and evaluated at three nurseries in Michigan: Lincoln Nurseries, Inc., near Grand Rapids (Fig.6a), Spring Meadow Nursery, Inc., near Grand Haven (Fig. 6b), and Zelenka Nursery, LLC, also near Grand Haven n(Fig.6c). Nine to six species were selected by the individual nurseries from the IR-4 priority 2010 list for a total of 22 container trials and one field test at Zelenka. The nine species at Lincoln were *Berberis thunbergii* 'Crimson pygmy', *Chamaecyparis* 'Golden spangel', *Clematis* 'Midnight showers', *Coreopsis* 'Crème brule', *Cornus* 'Baileyi', *Echinacea purpurea* 'White satin', *Hemerocallis* 'Strawberry candy', *Hydrangea macrophylla* 'All summer beauty', and *Potentilla fruticosa* 'Pink beauty' were selected. The eight species at Spring Meadow were *Berberis thunbergii* 'Gold pillar', *Buddelia* 'Adonis blue', *Ceanothus xpal.* 'Marie bleu', *Chamaecyparis* 'Soft serve', *Cornus sanguinea* 'Arctic sun', *Euonymus alatus* 'Fireball', *Potentilla* 'Goldfinger', and *Viburnum dentatum* 'Blue muffin'. The six species at Zelenka were *Berberis thunbergii* 'Aurea', *Buddleia davidii* 'Black night', *Coreopsis* 'Moonbeam', *Echinacea purpurea*, and *Hydrangea macrophylla* 'Mini penny' for containerized material, and *Buxus x*'Green mountain' for field phytotoxicity. Herbicides (not every herbicide was used on all species) were evaluated at their 1X, 2X and 4X label rates, respectively and included, oxyfluorfen + prodiamine (Biathalon, OHP, Mainland, PA) at 2.75, 5.5 and 11.0 lb ai/ac; dimethenamid-p + pendimethalin (FreeHand, BASF Corp., Research Triangle Park, NC) at 2.65, 5.3 and 10.6 lb ai/ac; sulfosulfuron (Certainty, Monsanto Co., St. Louis, MO) at 0.059, 0.117 and 0.234 lb ai/ac; dimethenamid-p (Tower, BASF Corp.) at 0.97, 1.94 and 3.88 lb ai/ac; sulfentrazone + prodiamine (F6875, FMC Corp., Fresno, CA), two formulations, granular and liquid, at 0.375, 0.75 and 1.5 lb ai/ac; and mesotrione (Callisto, Syngenta Corp., Wilmington, DE) at 0.187, 0.25 and 0.37 lb ai/ac. Halosulfuron-methyl (SedgeHammer, Gowan, Yuma, AZ) was applied only in the field at rates of 1.3, 2.6 and 5.2 oz/ac.

On April 29, 2010, weather conditions were generally overcast with temperatures ranging from about 46 °F at time of start to 61 °F at the end of the day. The liquid formulations of Tower, Certainty, and F6875 4SC were sprayed with a CO_2 backpack sprayer using 8003 vs.

nozzles in a spray volume of 30 gallons per acre. All other herbicides were granular formulations and spread by shaker jars. The second application of each herbicide was applied on June 24, 2010. The weather was warm, approximately 75-88 °F during the course of applications with some dew present in the morning at the first site, Lincoln. Immediately after each application, ½ acre-inch of irrigation was applied. Phytotoxicity evaluations were performed at 1 WA1T (week after first treatment), 2 WA1T, 4 WA1T, 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 of nursery stock was also assessed by measuring heights (from the ground to the tallest extended leaf) for *Hemerocallis* 'Strawberry candy' and a growth index (GI) [GI = height + width at widest point + width 90° to first width/ 3] (Keever, 1994) on the first and last evaluations. These two GI's were used to calculate a delta or change in GI (Δ GI) [ΔGI = last GI – first GI). The higher the ΔGI value the greater the growth of the plant.

Fig. 6. From left to right, Lincoln Nursery (A) vented, open ends polyhouse; Spring Meadow Nursery Westbrook roof-venting double poly greenhouse with solid ends and sides (B) and Zelenka Nursery outdoor geotextile covered growing area (C). Pictures taken 05/2010 for Lincoln and Spring Meadow and 06/2010 for Zelenka by H. Mathers.

Results and discussion. Unless otherwise specified, refer to Table 5 for all herbicides and species discussed below.
Biathalon. Biathalon was tested on *Berberis* at all three locations and *Cornus* and *Potentilla* at Lincoln and Spring Meadow. Biathalon was not injurious at any rate to any of the species tested. Biathalon is a premix of oxyfluorfen + prodiamine for grass and broadleaf control. Biathalon appears to be an excellent combination herbicide for the nursery market, at least for the woody shrubs in this trial.

Certainty. All species that received applications of Certainty were injured by at least the higher rates of Certainty, which included *Berberis* at all three locations, *Buddleia* at Spring Meadow and Zelenka, *Clematis* at Lincoln, and *Viburnum* at Spring Meadow. The *Berberis* at Lincoln was damaged by all rates of Certainty (Fig. 7A). In addition to severe stunting (Fig. 7B) Certainty also caused the plants to turn bright red (Fig. 7C). From previous research (data not shown), Certainty is injurious to a number of ornamental plants and also not very good for weed control at the lowest rate (0.059 lb ai/ac). Certainty is an acetolactate synthesis (ALS) inhibitor; the herbicides in this family are very selective, yet all the herbicides in the ALS family are very different from each other in what they injure or kill. ALS herbicides would be an option for postemergence control of weeds; however, because they are very selective, crop tolerance would be species, and sometimes cultivar dependent.

Fig. 7. A from left to right in first row *Berberis thunbergii* 'Crimson pygmy' at Lincoln Nursery two weeks after one application of sulfosulfuron (Certainty, Monsanto Co., St. Louis, MO) applied at 0.117(2X) and 0.059 (1X) lb product per 100 gal and control. In the foreground is 0.234 lb ai/ac (3X) lb product per 100 gal. **B** Note the severe stunting with even the 1X rate compared to the control four weeks after treatment. **C** In addition to stunting, the plants treated with Certainty turned bright red. The first number on the tag is the treatment rate with 1 = 1X, 2 = 2X, 3 = 4X and 4 = control.

FreeHand. FreeHand was applied to *Ceanothus xpal.* 'Marie bleu' at Spring Meadow and *Chamaecyparis* at Spring Meadow and Lincoln. FreeHand was not injurious to *Chamaecyparis* at any rate; however, at high rates, it can be injurious to *Ceanothus xpal.* 'Marie bleu' (Fig.8), although not beyond commercially acceptable. Other trials (data not shown) indicate that FreeHand will cause stunting to *Ceanothus xpal.* 'Marie bleu' especially if under stress. In this study the ΔGI does indicate a slight stunting injury to *Ceanothus xpal.* 'Marie bleu' compared to the control. FreeHand is already on the market for ornamentals and has a wide label, but caution is urged to not apply too high of a rate.

Fig. 8. Left hand picture, from left to right *Ceanothus xpal.* 'Marie bleu', two weeks after one application of dimethenamid-p + pendimethalin (FreeHand, BASF Corp., Research Triangle Park, NC) at 10.6 lb ai/ac (4X), control and 4X. Note the stunting with the 4X rate compared to the control. In the right hand picture note the stunting as a top view. The first number on the tag is the treatment rate with 1 = 1X, 2 = 2X, 3 = 4X and 4 = control.

F6875. F6875 was applied as either liquid or granular, both at the same rates of ai/ac. *Coreopsis* at Lincoln and Zelenka was not injured by the granular formulation of F6875. The liquid formulation of F6875 was applied to *Hydrangea* and *Echinacea* at Lincoln and Zelenka; both species were injured by F6875. The first application was much more injurious than the second as indicated by visual ratings on *Hydrangea*, especially at Lincoln (Fig.9C). At Zelenka, the injury included a burn and severe epinasty of the leaves and twigs (Fig.9 A-B, D). The granular formulation of F6875 appears to be more viable for the ornamental market, at least in containerized material.

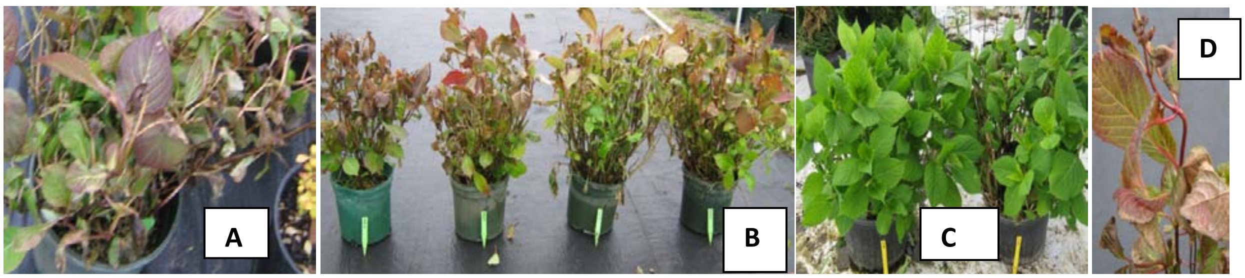


Fig. 9. A and D *Hydrangea macrophylla* 'Mini penny' two weeks after one application of sulfentrazone + prodiamine (F6875, FMC Corp., Fresno, CA) as a liquid, at 0.375, 0.75, and 1.5 lb ai/ac (1x, 2x and 3x, respectively) at Zelenka nursery. Note the twisted foliage and twigs. **B** From left to right: 4X, 2X, 1X and control with increased twisting and burn to the growth as the rate is increased at Zelenka. **C** *Hydrangea macrophylla* 'All summer beauty' from left to right: the control and the 1X rate of F6875SC. The first number on the tag is the treatment rate with 1 = 1X, 2 = 2X, 3 = 4X and 4 = control.

Tower. Tower was only applied to *Hemerocallis* at Lincoln; it caused slight stunting and yellowing, especially at the highest rate (Fig. 10). Tower is currently labeled for ornamentals, exhibits good activity on grasses, and can suppress yellow nutsedge. Tower can cause burning when applied shortly after bud break, which is indicated by the label, so caution should be used. This study indicates that Tower can be used on *Hemerocallis*, but not at high rates.

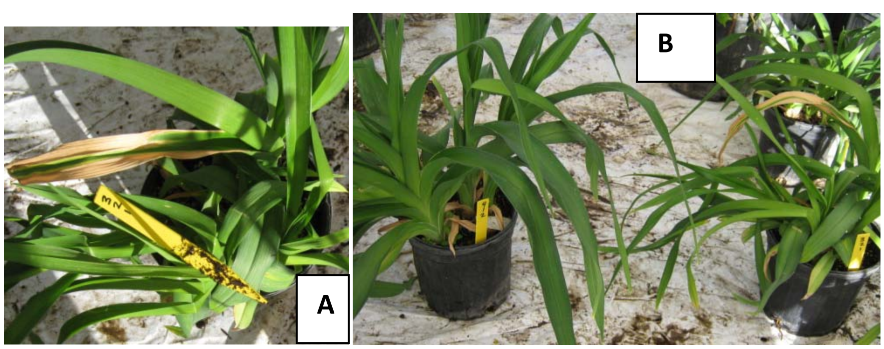


Fig. 10. A *Hemerocallis* 'Strawberry candy' at Lincoln Nursery two weeks after one application of dimethenamid-p (Tower, BASF Corp.) at 3.88 lb ai/ac; (4X). Note the stunting of the leaves and yellowing. **B** From left to right: the control and 4X. The first number on the tag is the treatment rate with 1 = 1X, 2 = 2X, 3 = 4X and 4 = control.

Mesotrione. *Euonymus* was injured at all rates by mesotrione at the Spring Meadow site. Although mesotrione provides excellent weed control, it can cause severe bleaching (i.e. whitening) to susceptible species such as *Euonymus* (Fig.11). Deciduous trees seem to be the most tolerant of mesotrione based on data from The Ohio State University (2008 Yearly Research Summary Report) (data not shown) and mesotrione should be studied for field use in deciduous trees.

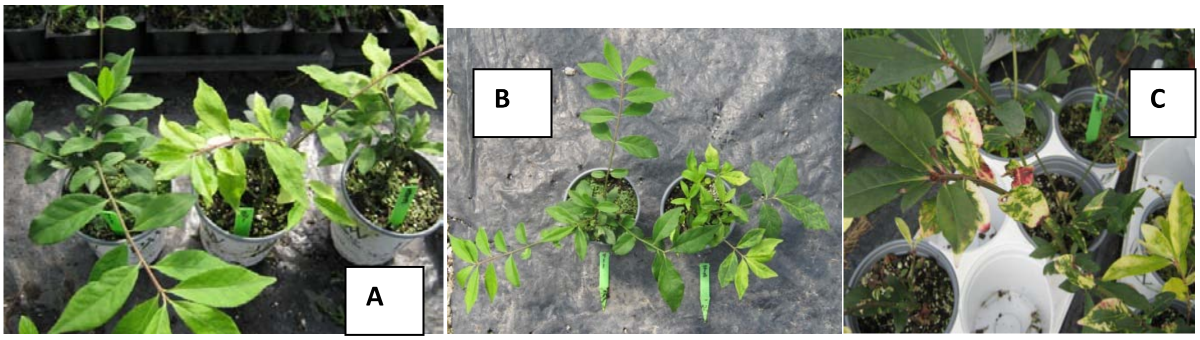


Fig. 11. A at Spring Meadow Nursery two weeks after one application of mesotrione (Callisto, Syngenta Corp., Wilmington, DE) from right to left: control and 0.37 lb ai/ac (4X). Note the stunting of the leaves and beginning of whitening. **B** From left to right: the control and 4X. **C** After the second application, bleaching of the foliage is becoming severe. The first number on the tag is the treatment rate with 1 = 1X, 2 = 2X, 3 = 4X and 4 = control.

SedgeHammer. SedgeHammer was applied only to *Buxus* 'Green Mountain' in the field at Zelenka Nursery (Table 6). For the first two evaluations after the first application of SedgeHammer, the *Buxus* appeared uninjured. SedgeHammer, with only one application was efficacious to two very invasive perennial weeds, mugwort (Fig. 12 A) (*Artemisia vulgaris*) and (Fig. 12B) Wild Garlic (*Allium vineale)*, which were growing in the fields at time of application. SedgeHammer provided stunting of both weeds and residual control, even after the plots were hand weeded (Fig. 13). Due to the invasive nature of these weeds and lack of viable control options, further exploration of SedgeHammer at the lowest rate (1X) with various timings to control these weeds is warranted. Phytotoxicity was lowest at the 1X rate and just at commercially acceptable (Fig. 13). The second application made apparent the ability of SedgeHammer to cause yellowing and stunting of the *Buxus* (Fig.13). SedgeHammer has caused injury to *Buxus* in containers (2008 OSU Nursery Yearly Research Summary Reports) (data not shown) which this trial confirms. SedgeHammer should not be applied to actively growing *Buxus* in containers or field.

Fig. 12. Halosulfuron-methyl (SedgeHammer, Gowan, Yuma, AZ) applications in the field at 1.3, 2.6 and 5.2 oz/ac suppressed the growth (A) mugwort (*Artemisia vulgaris*) and (B) Wild Garlic (*Allium vineale)*. Growth suppression was increased slightly as rate was increased with the greatest change in growth suppression occurring between the control (far right) and the 1X rate (beside control to the left).

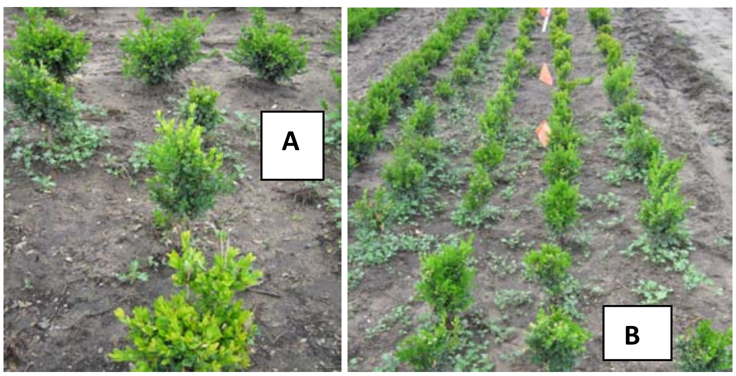


Fig. 13. A Following Halosulfuron-methyl (SedgeHammer, Gowan, Yuma, AZ) applications in the field at 1.3, 2.6 and 5.2 oz/ac, *Buxus x*'Green mountain' showed distinct yellowing and stunting by the second application. Note the two plants in the sprayed rows in the foreground with the two control rows in the background. **B** Residual weed control occurred. Note the control plot in the foreground with 4X and 2X rates in the three right rows of the plot in the background. The plots are divided by orange flags.

Table 5. Phytotoxicity of containerized ornamentals to selected herbicides for the IR-4 Program in 2010 at 3 nurseries in Michigan.

Berberis 'Crimson pygmy' — Lincoln

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI[y]
Biathalon 2.75 lb ai/ac	0.3[x] ns	5.1	0.3	0.3	0.1	0.3	20.4
Biathalon 5.5 lb ai/ac	0.9 ns	5.9	0.8	0.6	1.3	0.7	21.0
Biathalon 11 lb ai/ac	0.3 ns	6.3	0.4	1.1	0.3	1.2	19.9
Certainty 0.059 lb ai/ac	0.0 ns	4.9	3.3 *[w]	4.5 *	7.8 *	5.5 **	0.0 **
Certainty 0.117 lb ai/ac	0.2 ns	6.5 *	3.4 *	4.5 *	7.8 *	6.1 **	5.0 **
Certainty 0.234 lb ai/ac	0.0 ns	4.8	3.9 *	5.4 *	7.7 *	6.7 **	0.0 **
Untreated	0.3	3.4	0.3	0.3	0.4	0.2	18.6

Berberis 'Gold pillar' — Spring Meadow

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Biathalon 2.75 lb ai/ac	0.3	0.0	0.0	0.2	3.2	1	15.4
Biathalon 5.5 lb ai/ac	1.2 *	0.0	0.0	0.1	7.5 *	4.3 **	10.4
Biathalon 11 lb ai/ac	1.2 *	0.0	0.3	0.3	0.4	0.8	15.3
Certainty 0.059 lb ai/ac	0.3	4.5 *	4.2 *	6.1 *	8.3 *	8.1 **	-8.8 **
Certainty 0.117 lb ai/ac	0.0	5.5 *	4.0 *	6.4 *	8.0 *	8 **	-7.1 **
Certainty 0.234 lb ai/ac	0.0	4.5 *	4.3 *	6.4 *	8.6 *	9 **	-9.7 **
Untreated	0.0	0.0	0.0	0.0	2.0	1.2	12.6

Berberis 'Barberry golden' — Zelenka

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Biathalon 2.75 lb ai/ac	0.3	3.8	1.5 ns	1.8 ns	7.8 ns	1.1	1.7
Biathalon 5.5 lb ai/ac	0.8 *	5.3 *	1.9 ns	1.3 ns	5.9 ns	1.5	2.1
Biathalon 11 lb ai/ac	0.5	3.8	0.9 ns	2.1 ns	7.9 ns	1.2	3.4
Certainty 0.059 lb ai/ac	0.4	1.9	1.7 ns	2.8 ns	6.4 ns	1.7	2.7
Certainty 0.117 lb ai/ac	0.3	5.3 *	2.9 ns	2.3 ns	6.7 ns	5.1 **	-1.1
Certainty 0.234 lb ai/ac	0.3	4.2	2.9 ns	2.2 ns	8.1 ns	6.7 **	-2.3
Untreated	0.0	0.8	0.8	2.0	7.4	1.9	0.6

Buddleia 'Adonis blue' — Spring Meadow

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	3.0 **	4.0 **	3.5 **	1.1 **	6.8 ns	3.6 **	29.9
Certainty 0.117 lb ai/ac	3.4 **	6.1 **	3.6 **	1.8 **	5.2 ns	4.1 **	26.1 **
Certainty 0.234 lb ai/ac	4.3 **	5.7 **	5.0 **	3.8 **	5.3 ns	5.3 **	20.2 **
Untreated	0.0	0.0	0.0	0.0	7.4	0.0	36.4

Buddleia 'Black night' — Zelenka

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	3.6 **	2.9	4.0	1.1 **	1.5	3.1 **	22.6
Certainty 0.117 lb ai/ac	4.6 **	3.3 *	4.3	2.8 **	4.8	3.9 **	18.7 *
Certainty 0.234 lb ai/ac	4.6 **	3.3 *	5.1 **	3.8 **	5.3 *	4.8 **	12.9 **
Untreated	0.0	0.5	3.8	0.0	2.0	0.6	28.1

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

y = Growth indices

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

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

Table 5., Continued

Ceonothus xpal. 'Marie Bleu' — Spring Meadow

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI[y]
FreeHand 2.65 lb ai/ac	0.2[x] ns	1.8	0.2 ns	0.0	0.3 ns	0.8	13.7 *[w]
FreeHand 5.3 lb ai/ac	0.1 ns	3.0 **	0.0 ns	0.8	0.3 ns	0.2	16.0
FreeHand 10.6 lb ai/ac	0.2 ns	2.8 **	0.1 ns	1.0 **	0.0 ns	1.5 **	14.9
Untreated	0.2	1.0	0.1	0.0	0.8	0.0	17.6

Chamaecypari s 'Golden spangel' — Lincoln

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
FreeHand 2.65 lb ai/ac	1.7 ns	1.1	1.1 ns	0.4 ns	0.0 ns	0 ns	4.8 ns
FreeHand 5.3 lb ai/ac	2.2 ns	1.7 **	1.3 ns	0.2 ns	0.5 ns	0 ns	4.9 ns
FreeHand 10.6 lb ai/ac	1.8 ns	0.3	1.0 ns	0.2 ns	0.0 ns	0 ns	6.8 ns
Untreated	2.1	0.3	1.0	0.3	0.3	0	4.4

Chamaecyparis 'Soft serve' — Spring Meadow

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
FreeHand 2.65 lb ai/ac	0.4	0.0 ns	0.3 ns	0.0	0.0 ns	0.0 ns	10.4 ns
FreeHand 5.3 lb ai/ac	0.1	0.0 ns	0.4 ns	0.8 *	0.0 ns	0.4 ns	11.2 ns
FreeHand 10.6 lb ai/ac	0.2	0.0 ns	0.3 ns	0.1	0.0 ns	0.2 ns	11.3 ns
Untreated	0.2	0.0	0.1	0.0	0.0	0.0	11.1

Clematis 'Midnght showers — Lincoln

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	3.2	4.9 **	3.6 **	3.4 **	3.2	4.2 **	17.1
Certainty 0.117 lb ai/ac	5.3 **	4.6 **	4.4 **	4.1 **	5.3 **	5.3 **	7.8 **
Certainty 0.234 lb ai/ac	5.6 **	5.2 **	4.3 **	5.1 **	5.6 **	5.8 **	2.3 **
Untreated	1.3	0.0	0.2	0.2	1.3	0.4	34.5

Coreopsis 'Crème brule' — Lincoln

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 0.3G 0.375 lb ai/ac	0.0 ns	0.0 ns	0.0	0.2 ns	0.0 ns	0.3 ns	17.1 ns
F6875 0.3G 0.75 lb ai/ac	0.3 ns	0.0 ns	0.0	0.9 ns	0.0 ns	0.4 ns	23.0 ns
F6875 0.3G 1.5 lb ai/ac	2.2 ns	0.0 ns	1.0 *	0.9 ns	0.0 ns	0.8 ns	19.0 ns
Untreated	0.1	0.0	0.3	0.3	0.0	1.1	13.0

Coreopsis 'Moonbeam' — Zelenka

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 0.3G 0.375 lb ai/ac	0.3	0.0 ns	0.5 ns	0.0 ns	0.5 ns	0.0 ns	29.4 ns
F6875 0.3G 0.75 lb ai/ac	0.9 **	0.0 ns	0.6 ns	0.2 ns	2.6 ns	0.0 ns	27.1 ns
F6875 0.3G 1.5 lb ai/ac	0.7 **	0.0 ns	0.7 ns	0.2 ns	0.5 ns	0.0 ns	24.5 ns
Untreated	0.0	0.0	0.1	0.0	0.5	0.0	27.8

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

y = Growth indices

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

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

Table 5., Continued

Cornus 'Baileyi' — Lincoln

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI[y]
Biathalon 2.75 lb ai/ac	0.2[x] ns	1.9 ns	0.2	0.0 ns	0.0 ns	0.0 ns	ns
Biathalon 5.5 lb ai/ac	0.0 ns	4.1 ns	0.2	0.3 ns	0.0 ns	0.0 ns	ns
Biathalon 11 lb ai/ac	0.1 ns	4.0 ns	0.4 *[w]	0.3 ns	0.0 ns	0.0 ns	ns
Untreated	0.0	2.9	0.0	0.4	0.0	0.0	

Cornus sanguinea 'Arctic sun' — Spring Meadow

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Biathalon 2.75 lb ai/ac	0.2 ns	0.5 ns	0.1 ns	1.8 ns	7.0 ns	2.8 ns	17.2 ns
Biathalon 5.5 lb ai/ac	0.2 ns	1.0 ns	1.0 ns	1.5 ns	6.8 ns	3.2 ns	16.8 ns
Biathalon 11 lb ai/ac	0.1 ns	0.5 ns	2.0 ns	0.3 ns	7.8 ns	2.8 ns	16.5 ns
Untreated	0.3	1.0	1.3	1.2	7.0	3.8	17.8

Echinacea purpurea 'White satin' — Lincoln

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 4SC 0.375 lb ai/ac	7.4 **	8.9 **	8.8 **	8.8 **	9.7 **	8.0 **	-6.6 *
F6875 4SC 0.75 lb ai/ac	8.3 **	9.3 **	9.2 **	9.7 **	10.0 **	9.7 **	-7.8 **
F6875 4SC 1.5 lb ai/ac	8.7 **	9.3 **	9.3 **	10.0 **	10.0 **	10.0 **	-4.4 *
Untreated	1.1	1.3	2.1	0.6	5.4	4.4	5.8

Echinacea purpurea — Zelenka

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 4SC 0.375 lb ai/ac	4.5 **	6.0 **	4.3 **	3.5 **	7.1 **	5.3 **	-1.2
F6875 4SC 0.75 lb ai/ac	4.6 **	7.3 **	5.1 **	3.9 **	7.8 **	4.8 **	-3.6 *
F6875 4SC 1.5 lb ai/ac	5.4 **	8.1 **	6.5 **	6.7 **	8.4 **	7.3 **	-7.0 **
Untreated	0.3	0.2	0.0	0.0	0.2	0.0	6.1

Euonymus alatus 'Fireball' — Spring Meadow

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Mesotrione 4SC 0.187 lb ai/ac	1.1 **	3.0	3.8 **	2.8 **	5.5 **	3.3 *	-2.1 ns
Mesotrione 4SC 0.25 lb ai/ac	0.6 **	4.7 **	3.7 **	3.3 **	6.3 **	5.1 **	-4.5 ns
Mesotrione 4SC 0.5 lb ai/ac	1.7 **	6.0 **	4.9 **	5.3 **	8.2 **	6.2 **	-2.3 ns
Untreated control	0.0	0.0	0.0	0.7	0.3	0.5	-1.3

Hemerocallis 'Strawberry candy' — Lincoln

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Tower 0.97 lb ai/ac	0.8 ns	3.7	0.1 ns	0.7	2.5	1.3 ns	2.2
Tower 1.94 lb ai/ac	0.6 ns	3.1	0.1 ns	1.2 *	2.9	1.4 ns	-2.8
Tower 3.88 lb ai/ac	1.1 ns	4.0 *	0.1 ns	0.9	3.6 **	1.6 ns	-0.7
Untreated	0.7	1.2	0.3	0.0	1.0	0.6	6.4

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

y = Growth indices

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

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

Table 5., Continued

Hydrangea macrophylla 'All summer beauty'	Lincoln						
Treatment	**1 WA1T**[z]	**2 WA1T**	**4 WA1T**	**1 WA2T**	**2 WA2T**	**4 WA2T**	**GI**[y]
F6875 4SC 0.375 lb ai/ac	3.9[x] **[w]	5.8 **	2.7 **	0.5	0.0 ns	0.0 ns	ns
F6875 4SC 0.75 lb ai/ac	3.4 **	6.2 **	3.0 **	0.8	0.3 ns	0.0 ns	ns
F6875 4SC 1.5 lb ai/ac	4.2 **	6.9 **	3.8 **	1.6 **	0.0 ns	0.0 ns	ns
Untreated	0.6	1.5	0.6	0.2	0.0	0.0	
Hydrangea macrophylla 'Mini penny'	Zelenka						
Treatment	**1 WA1T**	**2 WA1T**	**4 WA1T**	**1 WA2T**	**2 WA2T**	**4 WA2T**	**GI**
F6875 4SC 0.375 lb ai/ac	3.1 **	6.6 **	4.2	0.6	4.5	2.0 *	-3.8 ns
F6875 4SC 0.75 lb ai/ac	3.7 **	7.1 **	4.7 **	1.4 **	6.0 **	2.5 **	-4.4 ns
F6875 4SC 1.5 lb ai/ac	4.6 **	8.3 **	5.5 **	2.1 **	5.3	3.2 **	0.1 ns
Untreated	1.3	3.9	3.7	0.4	3.2	0.3	-5.7
Potentilla fruticosa 'Pink beauty'	Lincoln						
Treatment	**1 WA1T**	**2 WA1T**	**4 WA1T**	**1 WA2T**	**2 WA2T**	**4 WA2T**	**GI**
Biathalon 2.75 lb ai/ac	0.0 ns	0.2	0.2 ns	0.1 ns	0.0 ns	0.0 ns	ns
Biathalon 5.5 lb ai/ac	0.0 ns	0.5	0.6 ns	0.4 ns	0.0 ns	0.0 ns	ns
Biathalon 11 lb ai/ac	0.0 ns	1.0 *	0.2 ns	0.1 ns	0.0 ns	0.0 ns	ns
Untreated	0.0	0.0	0.2	0.1	0.0	0.0	
Potentilla fruticosa 'Goldfinger'	Spring Meadow						
Treatment	**1 WA1T**	**2 WA1T**	**4 WA1T**	**1 WA2T**	**2 WA2T**	**4 WA2T**	**GI**
Biathalon 2.75 lb ai/ac	0.0	0.0 ns	0.0 ns	0.0 ns	0.0 ns	0.0 ns	ns
Biathalon 5.5 lb ai/ac	0.4	0.0 ns	0.0 ns	0.0 ns	0.0 ns	0.0 ns	ns
Biathalon 11 lb ai/ac	1.0 **	0.3 ns	0.0 ns	0.0 ns	0.0 ns	0.0 ns	ns
Untreated	0.0	0.0	0.0	0.0	0.0	0.0	
Viburnum dentatum 'Blue muffin'	Spring Meadow						
Treatment	**1 WA1T**	**2 WA1T**	**4 WA1T**	**1 WA2T**	**2 WA2T**	**4 WA2T**	**GI**
Certainty 0.059 lb ai/ac	2.8 **	5.8 **	4.5 **	3.6 **	4.0	5.5	6.8 *
Certainty 0.117 lb ai/ac	4.5 **	6.1 **	5.0 **	5.1 **	6.0	7.5 **	0.0 **
Certainty 0.234 lb ai/ac	4.5 **	7.1 **	5.8 **	7.8 **	8.8 **	9.7 **	-12.0 **
Untreated	0.0	0.0	0.0	0.0	5.4	4.8	12.0

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

y = Growth indices

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

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

Table 6. Phytotoxicity of *Buxus* 'Green mountain' to SedgeHammer herbicide at Zelenka Nursery in the field.

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI[y]
SedgeHammer 0.31 lb ai/ac	0.0[x]	--	3.3 ns	1.1 *[w]	3.3 **	4.0 **	4
SedgeHammer 0.62 lb ai/ac	0.0	--	3.3 ns	1.6 **	4.5 **	4.3 **	4.4
SedgeHammer 0.125 lb ai/ac	0.0	--	3.5 ns	2.3 **	4.5 **	4.7 **	5.4
Untreated	0.0	--	3.1	0.0	0.0	0.0	4.2

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

y = Growth indices

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

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 and efficacy of several products to control liverwort

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 nursery growers' problems by adding new uses to existing pesticides or new pesticides for nursery/landscape use and other 'minor use' cropping industries. Growers should use the IR-4 program because it is based largely on growers' needs. Anyone can go to the website www.ir4.rutgers.edu and list the needs of their operation. The objectives of this trial were to look at phytotoxicity and efficacy of a number of pesticides for control of liverwort. Plant forms such as silver thread mosses (*Bryum argenteum*) and common liverwort (*Marchantia polymorpha*) are problematic in container production (Mathers, 2003) and have spread throughout the United States nursery industry at an alarming rate (Fausey, 2003). Both are considered highly invasive and difficult to control pests in containerized ornamentals (Fausey, 2003). Reasons for their spread are not always clear. Ornamental liners commonly infested with liverwort or moss are produced in one region of the country and then shipped to another for finishing, and shipped again for retail. Liverwort is in the division Bryophyta. They are very primitive plants that have no leaves, roots, stems or vascular tissue and reproduce vegetatively and/or by spores. Products that have performed well in this study merit further testing are Scythe, SureGuard and TerraCyte.

Materials and methods. To complete these studies we have used USDA Inter-regional project 4(IR-4) program protocols. Three cooperating nurseries were selected as sites to test the liverwort protocol, which were Lincoln Nurseries (Grand Rapids, MI), Zelenka Nursery (Grand Haven, MI), and Spring Meadow Nursery, Inc. (Grand Haven, MI). Species selected for phytotoxicity ratings at Lincoln Nurseries included *Buxus* x 'Green Velvet', *Berberis thunbergii* 'Crimson Pygmy', *Ilex* x *merservea* 'China Girl', and *Thuja occidentalis* 'Nigra'. Species selected for phytotoxicity at Zelenka Nursery included *Euonymus* x 'White Album', *Juniperus horizontalis* 'Hughes Gold', *Chaenomeles* x 'Double Take Pink Storm', and *Viburnum dentatum 'Double Pink'*. Species selected for phytotoxicity at Spring Meadow Nursery included *Syringa meyeri* 'Paliban' and *Hydrangea amorences* 'Invincibelle'. Phytotoxicity visual ratings were taken on a 0-10 scale with 0 being no phytotoxicity, 10 death, and ≤3 commercially acceptable. Efficacy visual ratings were taken on the liverwort on a 0-10 scale with 0 being no liverwort control, 10 perfect liverwort control, and ≥7 commercially acceptable. Phytotoxicity and efficacy visual ratings were taken at one, two (03/04/10), and four weeks (03/18/10) after first treatment (WA1T) and one, two, and four weeks after the second treatment (WA2T). The IR-4 protocol indicated a second application was to be made after one month if there was less than 80% reduction in liverwort from the first application. Liverwort control treatments consisted of (Oregano Oil Extract) Bryophyter™ at 1% v/v, (Copper hydroxide) Champ DP™ at 5.5 lb./100 gal, (Ammonium nononanoate) Racer™ at 0.2% v/v, (Pelargonic acid) Scythe™ at 10% v/v, flumioxazin (SureGuard, Valent U.S.A.) at 12 oz./ac + nonionic surfactant at 0.25% v/v, dimethenamid-p (Tower, BASF Corp.) at 32 oz/ac, (Sodium carbonate peroxyhydrate) TerraCyte Pro™ at 0.5 lb/gal, and (20% acetic acid) WeedPharm™ at 10% v/v (Pharm Solutions Inc., Port Townsend, WA) at Spring Meadow Nursery and Lincoln Nurseries. Only the Bryophyter and SureGuard at the rates described previously were tested at Zelenka Nursery because of the lack of liverwort. Treatments were applied using a CO_2 backpack sprayer with 8004 VS nozzles (Teejet Co.) delivering a spray volume of 45 gal/ac on February 18, 2010. Because the protocol required 90 gal/ac, two passes were conducted. Irrigation of ½ inch was applied within four hours after treatments were applied. Treatments were applied in the morning, with temps ranging from 45 to 55 °F at all locations, under sunny conditions in greenhouses. Plants were well watered at time of application but foliage was dry. Container substrates varied over sites. Lincoln Nursery used a Renewed Earth Media LC1 mix; the other sites used Fafard greenhouse mixes. Greenhouse environments are described in site photos (Fig. 1).

Fig. 1. From left to right, Spring Meadow Nursery Westbrook roof-venting double poly greenhouse with solid ends and sides, heated with forced air furnaces and Zelenka Nursery double poly greenhouse end venting inflated tube supplemental heat greenhouse. Pictures taken 03/04/2010 during 2WA1T evaluation by H. Mathers.

Results and discussion.

Phytotoxicity.

Spring Meadow. At 1 and 2 WA1T, it was difficult to distinguish phytotoxicity because plants were either still dormant or just coming out of dormancy at all locations. This is evident in the visual ratings from one evaluation to the next (Tables 1, 2, and 3). At Spring Meadow Nursery, phytotoxicity was not evaluated at 1 and 2 WA1T (Table 2). However, by 4 WA1T, all species had come out of dormancy. *Syringa* expressed phytotoxicity from applications of Bryophyter and Scythe; many of the treatments, including the controls, had visual ratings higher than commercially acceptable due to death unrelated to the treatments (Table 1). Hydrangea was unacceptably injured by Scythe, SureGuard, and Terracyte.

Lincoln. At 2 WA1T, the only treatment not phytotoxic to any of the species at Lincoln Nurseries was the WeedPharm (Table 2). *Buxus* was unacceptably injured by Champ, Scythe, SureGuard, and Tower and also by Bryophyter and Racer at 2 WA1T. Bryophyter and Racer may have just caused a delay in bud break, as these two treatments did not cause harm at any other evaluation date. *Berberis* was unacceptably injured by Scythe, SureGuard, Tower, and

Terracyte, and by 4 WA2T, many were dead from these treatments (Table 2). There were only two treatments that did not affect *Ilex* at any evaluation date, Racer and WeedPharm (Table 2). All other treatments injured *Ilex* at some point; however, Scythe, SureGuard, and Tower consistently provided unacceptable ratings across evaluation dates, starting with 2 WA1T. *Buxus* and *Ilex* were affected by application timing, and the timing also seemed to affect bud break (Fig. 2). The effect of early applications on delaying bud break could explain some of the variation in visual ratings across dates. *Thuja* was injured significantly by a few treatments in comparison to the control, but once again, Scythe caused commercially unacceptable ratings (Table 2).

Zelenka. Only two treatments, SureGuard and Bryophyter, were applied at Zelenka due to the small amount of liverwort present. SureGuard injured all species tested; however, *Viburnum* and *Juniperus* were injured only briefly after the first application and fully recovered by the end of the trial (Table 3). *Euonymus* and *Chaenomeles* were significantly injured by SureGuard and did not recover.

Efficacy.

Scythe is a nonselective, "contact" type herbicide that is very fast acting on susceptible species; it quickly kills liverwort. However, Scythe does not provide residual control, so frequent applications are necessary. This is evident in the evaluation ratings for Scythe across dates (Table 4). By 4 WA1T, liverwort in the Scythe treatment had begun to re-infest, especially at Spring Meadow (Fig. 3). SureGuard is primarily a preemergence herbicide, although it does have some activity on small weeds. SureGuard acts differently on liverwort, killing it slowly with high efficacy (Table 4). SureGuard by 4 WA1Tprovided 100% control of liverwort at Lincoln and Spring Meadow and almost 100% control at Zelenka (Fig. 4). In previous research at OSU, liverwort has been controlled postemergence by SureGuard, and SureGuard also has provided up to 6 months of residual control of liverwort (data not shown). Tower provided some control of liverwort, but not as well as SureGuard or Scythe. Tower is very slow acting, and the second application seemed to help increase control of liverwort (Table 4). The only other treatment providing acceptable levels of control was Terracyte, and only at Spring Meadow at 4 WA2T (Table 4). Other treatments provided little control of liverwort at the rates tested.

SureGuard and Scythe were the only treatments that consistently controlled liverwort, but they also caused the highest levels of phytotoxicity. Scythe killed or injured *everything*. These trials demonstrate that Scythe can be used for spot treatments or as a direct spray, which is indicated on the label. The other treatments provided inconsistent levels of control; i.e. there was some control in some pots, but no control in others. We speculate that increasing the rates of these treatments could provide additional control. From these trials, SureGuard could be used over the top of *Thuja*, V*iburnum*, and *Juniperus*, and possibly *Syringa*. As previously stated, from earlier trials at OSU, SureGuard has provided long residual control of liverwort at the same rates used in this trial. Decreasing the rate could provide acceptable control while also decreasing phytotoxicity. Although Tower did suppress liverwort postemergence, it did not provide complete control (Fig. 5). Tower should be studied further to see if it could provide preemergence control of liverwort. Increasing the rate of Tower would not be advised, especially during bud break.

Fig. 2. Tower will delay bud break if applied at bud break. On the left are pictures of *Buxus* at 3 WA1T, with the untreated on top and those treated with Tower on the bottom. Tower treated *Buxus* are behind in growth. On the right are plants at 4 WA2T, with the untreated *Buxus* in the top picture. There are no other symptoms of phytotoxicity with the *Buxus* that were treated with Tower other than that they are much smaller due to delayed growth?

Table 1. Phytotoxicity of selected herbicides on rooted cuttings of *Syringa* and *Hydrangea* at Spring Meadow Nursery.

*Syringa meyer*i 'Paliban'

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
Bryophyter			7.9 **[y]	8.3 **	8.6 **	8.6 **
Champ			2.3	3.6	4.2	4.0
Racer			5.6	5.3	6.8	6.7
Scythe			4.5	10.0 **	9.7 **	9.6 **
SureGuard			4.2	4.1	6.0	5.9
Tower			4.5	5.3	5.2	5.3
Terracyte			3.6	4.8	6.8	6.5
WeedPharm			3.6	3.6	3.8	3.6
Untreated			1.7	2.9	3.7	3.9

Hydrangea amorences 'Invincibelle '

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
Bryophyter			1.2	1.3	1.6	1.6
Champ			1.5	2.1 **	1.4	1.2
Racer			1.1	0.7	0.8	1.3
Scythe			2.3	9.9 **	8.8 **	9.6 **
SureGuard			9.4 **	9.1 **	8.8 **	8.8 **
Tower			1.8	1.8	0.5	0.3
Terracyte			2.4 *	5.4 **	3.8 **	1.8
WeedPharm			1.0	0.3	0.1	0.0
Untreated			0.0	0.0	1.0	0.4

z = WA1T: weeks after first treatment; WA2T: weeks after second treatment

y = visual ratings in the same column followed by ** are significantly different from the control based on Dunnett's t test ($\alpha = 0.05$), and ratings followed by * are different at the $\alpha = 0.10$ level

Table 2. Phytotoxicity of selected herbicides on rooted cuttings of *Buxus*, *Berberis, Ilex,* and *Thuja* at Lincoln Nursery.

Buxus microphylla 'Green velvet'

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
Bryophyter	0.5	8.0 **[y]	0.8	0.5	1.5	1.8
Champ	2.8 **	8.0 **	4.8 **	2.3 **	2.5 **	0.3
Racer	1.0	4.0 **	0.5	1.0	0.5	0.0
Scythe	2.8 **	7.0 **	4.0 **	5.0 **	4.5 **	5.3 **
SureGuard	0.5	5.0 **	2.0 *	2.8 **	3.0 **	3.0 **
Tower	1.8 **	5.0 **	1.5	3.3 **	1.8 **	2.0 **
Terracyte	0.0	2.5	0.8	1.3	0.5	0.0
WeedPharm	0.0	1.0	0.5	1.0	1.3	0.3
Untreated	0.0	0.0	0.0	0.0	0.0	0.0

Berberis thunbergii 'Crimson Pygmy'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
Bryophyter	0.0	0.0	0.0	0.5	0.5	0.5
Champ	0.0	1.3	1.8	0.8	2.5	2.5
Racer	0.0	0.0	0.0	0.5	0.8	0.0
Scythe	0.0	7.0 **	10.0 **	10.0 **	10.0 **	10.0 **
SureGuard	0.0	6.8 **	2.5 **	4.0 **	6.3 **	6.8 **
Tower	0.0	6.3 **	3.0 **	8.0 **	8.5 **	10.0 **
Terracyte	0.0	6.5 **	3.5 **	8.3 **	9.3 **	10.0 **
WeedPharm	0.0	0.0	0.0	3.0 **	2.3	0.5
Untreated	0.0	0.0	0.0	0.0	0.0	0.8

Ilex merservea 'China Girl'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
Bryophyter	0.0	6.5 **	1.8	1.5	1.3	2.3
Champ	0.3	2.8	2.5 **	3.8 **	2.3	1.8
Racer	0.0	1.5	0.0	0.3	0.0	1.0
Scythe	0.5	4.0	2.0 **	2.8 **	3.5 **	4.5 *
SureGuard	0.0	5.0 *	0.5	3.0 **	3.3 **	3.8
Tower	1.0	3.8	1.5	2.3 *	2.3	3.5
Terracyte	0.5	1.8	0.0	1.3	1.3	5.0 **
WeedPharm	0.0	0.8	0.3	1.5	1.0	1.8
Untreated	0.0	0.0	0.0	0.0	0.5	1.0

z = WA1T: weeks after first treatment; WA2T: weeks after second treatment

y = visual ratings in the same column followed by ** are significantly different from the control based on Dunnett's t test ($\alpha = 0.05$), and ratings followed by * are different at the $\alpha = 0.10$ level

Table 2, cont.

Thuja 'Techny'

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
Bryophyter	0.8	0.0	0.3	0.0	0.0	1.5 **[y]
Champ	0.8	0.0	1.0	1.8 **	1.0	0.5
Racer	2.3 **	0.0	0.5	2.0 **	1.3 **	2.8 **
Scythe	0.0	0.0	2.0 **	4.0 **	4.0 **	4.3 **
SureGuard	0.0	0.0	0.0	0.0	0.0	0.3
Tower	2.0 **	0.0	0.0	1.3 **	1.0	2.3 **
Terracyte	1.3	0.0	0.0	0.0	0.0	0.5
WeedPharm	0.3	0.0	0.0	0.3	0.0	0.0
Untreated	0.0	0.0	0.0	0.0	0.0	0.0

z = WA1T: weeks after first treatment; WA2T: weeks after second treatment

y = visual ratings in the same column followed by ** are significantly different from the control based on Dunnett's t test (α = 0.05), and ratings followed by * are different at the α = 0.10 level

Table 3. Phytotoxicity of selected herbicides on *Euonymus, Viburnum, Juniperus,* and *Chaenomeles* at Zelenka Nursery.

Euonymus x 'White Album'

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
SureGuard	1.8 *[y]	0.0	3.0 **	2.3 **	2.8 **	3.0 **
Bryophyter	1.8 *	0.0	0.0	0.0	0.0	0.0
Untreated	0.0	0.0	0.0	0.0	0.0	0.0

Viburnum dentatum 'Double pink'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
SureGuard	3.3 **	0.0	0.0	1.3	0.5	1.3
Bryophyter	1.8 **	0.0	0.0	0.0	0.0	0.5
Untreated	0.0	0.0	0.0	0.0	0.0	0.8

Juniperus horizontalis 'Hughes Gold'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
SureGuard	2.0 **	0.0	0.0	0.0	0.0	0.0
Bryophyter	1.3	0.0	0.0	0.0	0.0	0.3
Untreated	0.0	0.0	0.0	0.0	0.0	0.0

Chaenomeles x ' Double Take Pink Storm'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
SureGuard	2.8	8.5 a	5.3	3.8	3.3	3.0
Bryophyter	2.3	0.0 b	2.0	1.8	2.0	1.5

z = WA1T: weeks after first treatment; WA2T: weeks after second treatment

y = visual ratings in the same column followed by ** are significantly different from the control based on Dunnett's t test ($\alpha = 0.05$), and ratings followed by * are different at the $\alpha = 0.10$ level

Table 4. Efficacy of selected herbicides on liverwort at Spring Meadow Nursery, Lincoln Nursery, and Zelenka Nursery.

Spring Meadow Nursery

Treatment	1 WA1T[z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
Bryophyter	2.3 e[y]	1.5 e	1.3 f	2.6 d	2.3 c	1.7 c
Champ	3.9 d	2.7 d	0.8 fg	5.2 c	3.1 c	2.8 c
Racer	0.6 f	0.4 f	0.5 fg	2.0 d	2.3 c	2.3 c
Scythe	9.6 a	8.5 a	7.2 b	9.8 a	9.9 a	7.0 b
SureGuard	4.9 c	6.3 b	10.0 a	10.0 a	9.9 a	10.0 a
Tower	3.6 d	3.4 d	6.1 c	7.5 b	6.6 b	9.9 a
Terracyte	4.8 c	3.0 d	2.5 e	5.4 c	6.1 b	9.2 a
WeedPharm	6.6 b	4.4 c	3.9 d	5.7 c	3.1 c	6.1 b
Untreated	0.0 f	0.0 f	0.0 g	2.0 d	0.8 d	2.3 c

Lincoln Nursery

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
Bryophyter	1.2 c	4.2 cd	1.6 c	2.4 cd	4.0 cd	5.0 b
Champ	2.3 bc	2.8 d	2.6 c	3.5 cd	5.0 cd	4.1 b
Racer	2.1 c	3.8 d	1.7 c	2.0 de	3.1 e	4.1 b
Scythe	9.7 a	10.0 a	8.9 a	10.0 a	10.0 a	10.0 a
SureGuard	1.2 c	7.3 b	9.8 a	9.9 a	10.0 a	10.0 a
Tower	1.9 c	5.2 b	6.4 b	6.7 b	7.9 b	8.8 a
Terracyte	3.1 b	2.7 d	1.3 cd	3.6 c	3.5 de	3.8 b
WeedPharm	3.7 b	5.1 c	1.4 cd	5.6 b	5.7 c	4.1 b
Untreated	0.1 d	5.4 b	0.0 d	0.7 e	1.3 f	1.8 c

Zelenka Nursery

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T
SureGuard	0.9	4.1 a	6.3 a	9.1 a	8.4 a	9.3 a
Bryophyter	0.5	0.0 b	3.8 b	3.1 b	1.9 b	1.3 b
Untreated	0.0	1.9 b	0.0 c	1.4 c	1.2 b	0.3 c

z = WA1T: weeks after first treatment; WA2T: weeks after second treatment

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

Fig. 3. Scythe on *Syringa meyeri* ‘Paliban’ at Spring Meadow Nursery.

Fig. 4. SureGuard on *Syringa meyeri* ‘Paliban’ at Spring Meadow Nursery.

Fig. 5. Tower on *Syringa meyeriI* ‘Paliban’ at Spring Meadow Nursery.

Phytotoxicity of selected herbicides to containerized ornamentals

Principle investigators: Dr. Hannah Mathers and Luke Case

Significance to the industry. Weed control is a major expense faced by the ornamental industry. With the large number of species and the constant addition of new species and cultivars, it is hard for chemical companies to perform all the research needed for labeling. The IR-4 program was developed by the federal government in association with universities, chemical companies, and the USDA in order to expand pesticide labels for minor use crops, and many companies now rely on the IR-4 program for label expansion for minor use crops. The objective of these trials was to evaluate the phytotoxicity of selected herbicides to ornamental plants that are important to the nursery industry in Michigan.

Materials and methods. Phytotoxicity trials were performed on the following species: Japanese maple (*Acer palmatum* 'Bloodgood'), agastache (*Agastache* 'Black adder'), running serviceberry (*Amelanchier stolonifera*), false spirea (*Astilbe xarendsii* 'Final' & 'Bridal veil'), Azalea 'Bollywood star' (*Rhododendron* 'Farrow'), Crimson pygmy barberry (*Berberis thunbergii* 'Crimson pygmy'), butterfly bush (*Buddleia davidii* 'Black night'), ceanothus (*Ceanothus xpallidus* 'Marie bleu'), Japanese false cypress (*Chamaecyparis pisifera* 'Filifera golden mops'), tickseed (*Coreopsis verticillata* 'Moonbeam'), flowering dogwood (*Cornus florida*), kousa dogwood (*Cornus kousa var. chinensis* 'Milky way'), delphinium (*Delphinium* 'Connecticut yankee'), purple coneflower (*Echinacea purpurea* 'Bravado'), burning bush (*Euonymus alatus* 'Compacta'), daylily (*Hemerocallis* 'Stella d'Oro), hydrangea (*Hydrangea* 'Annabelle'), bush cinquefoil (*Potentilla fruticosa* 'Goldfinger'), and viburnum (*Viburnum carlcephalum*). Herbicides tested (although not every herbicide was used on all species selected) were oxyfluorfen + prodiamine (Biathalon, OHP, Mainland, PA) at 2.75, 5.5, and 11.0 lb ai/ac, dimethenamid-p + pendimethalin (FreeHand, BASF Corp., Research Triangle Park, NC) at 2.65, 5.3, and 10.6 lb ai/ac, sulfosulfuron (Certainty, Monsanto Co., St. Louis, MO) at 0.059, 0.117, and 0.234 lb ai/ac, dimethenamid-p (Tower, BASF Corp.) at 0.97, 1.94, and 3.88 lb ai/ac, sulfentrazone + prodiamine (F6875, FMC Corp., Fresno, CA) in two formulations, granular and liquid, at 0.375, 0.75, and 1.5 lb ai/ac, isoxaben + trifluralin (Snapshot, DowAgrosciences, Indianapolis, IN) at 2.5, 5.0 and 10.0 lb ai/ac, and mesotrione (Syngenta Corp., Wilmington, DE) at 0.187, 0.25, and 0.37 lb ai/ac. Tower, Certainty, and F6875 4SC are liquids which were sprayed with a CO_2 backpack sprayer with 8003 vs nozzles in a spray volume of 30 gallons per acre. All other herbicides were in the granular form and spread by shaker jars. Some of the herbicides were applied on May 7, 2010, and the rest of the herbicides were applied on May 20, 2010, with second applications being applied on June 23, 2010, and July 6, 2010, respectively. Immediately after each application, approximately 0.5 acre-inch irrigation was applied. Phytotoxicity evaluations were performed at 1 WA1T (week after first treatment), 2 WA1T, 4 WA1T, 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 $\leq$3 commercially acceptable. Growth was also assessed by measuring heights and widths at the first and last evaluations.

Results and discussion.

Certainty. All species that received applications of Certainty were injured, except *Acer* (Table 1), with rate having little effect. From previous research conducted at The Ohio State University (OSU), (2008- and 2009 Yearly Research Summary Reports), Certainty is injurious to a number of ornamental plants and also not very good for weed control at the lowest rate (0.059 lbs ai/ac). Certainty is an acetolactate synthesis (ALS) inhibitor; the herbicides in this family are very selective, yet all the herbicides in the ALS family are very different from each other in what they injure or kill. ALS herbicides would be an option for postemergence control of weeds; however because they are very selective, crop tolerance would be species, and sometimes cultivar dependent.

FreeHand. FreeHand is a herbicide now labeled for ornamentals from BASF and is safe on many types of genera. In this trial, FreeHand is safe to all the species tested at the lowest rate; however, at the higher rates, it becomes more phytotoxic, which is generally in the form of general yellowing and stunting. *Amelanchier* was the most sensitive, with phytotoxicity showing up to beyond commercially acceptable at the 5.3 lb ai/ac rate (Table 1). At 10.6 lb ai/ac, *Astilbe*, *Ceanothus*, *Chamaecyparis*, and *Cornus kousa* were all injured, either by visual ratings or growth indices. From trials at OSU, FreeHand is an excellent preemergence herbicide for ornamentals, but caution should be followed to not apply too high of rates.

F6875. One of the chemical components of F6875 is sulfentrazone, which is a PPO herbicide. PPO herbicides, when applied as a postemergence cause "contact" type of death, and can also cause the same type of burning of foliage of desirable plants. In this study, when applied as a liquid, it caused injury, and sometimes death, to *Buddleia*, *Echinacea*, and *Hydrangea* (Table 1). However, when applied to the *Rhododendron* (azalea), it had the opposite effect. For some reason, many of the untreated azaleas died presumably from upshifting and shock, but those treated with the liquid formulation of F6875 had far fewer casualties, with the middle rate (0.75 lb ai/ac) being the best treatment. Coreopsis was the only species receiving applications of the granular formulation, with no injury observed from any of the rates tested.

Biathalon. Biathalon was not injurious to any of the species and rates tested, which included *Berberis*, *Cornus florida*, and *Potentilla* (Table 1). . Biathalon is a premix of oxyfluorfen + prodiamine for grass and broadleaf control, although it is a little weak on grass species. Biathalon looks to be an excellent combination herbicide for the nursery market, at least for the woody shrubs in this trial.

Tower. Tower was applied to *Cornus kousa* and *Hemerocallis*, and was only injurious to *Cornus kousa* to beyond commercially acceptable visual ratings at the highest rate (Table 1). Growth index scores for *Cornus kousa* indicate that plants that were treated with Tower grew better than plants that were left untreated. This was due to the competition with weeds in the untreated pots. This is also indicated by visual ratings; many of the untreated plants died or were severely stunted from the competition with weeds. Tower is currently labeled for ornamentals and has good activity on grasses and can suppress yellow nutsedge. Tower can cause burning when applied shortly after bud break, which is indicated by the label, so caution should be used. From this study, it could be used on *Hemerocallis* and *Cornus kousa*.

Snapshot. Snapshot was applied to *Delphinium* in this study, and due to death in many of the controls for unknown reasons, it is hard to decipher whether or not Snapshot is injurious to *Delphinium* in containers (Table 1). There was some injury early on, so there may be some injury to *Delphinium*; however, more research needs to be done on Snapshot and *Delphinium*. Snapshot is a widely used herbicide in the ornamental industry and is very good for preemergence weed control for many ornamental species.

Mesotrione. *Euonymus* was the only species receiving applications of mesotrione, and was injured by the medium and high rates (Table 1). In other trials (data not shown), mesotrione had caused injury on *Euonymus* from mesotrione, and the amount of injury is highly impacted by the rate. The 0.187 lb ai/ac rate seems to be the *highest* possible rate to use on *Euonymus*. Mesotrione has caused significant injury to a number of ornamental species in the form of whitening, yellowing, and bronzing of the leaves (2007-, 2008-, and 2009 Research Summary Reports).

Table 1. Phytotoxicity of selected herbicides on containerized ornamentals for the IR-4 program.

Acer palmatum 'Bloodgood'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	1.4	1.2	0.3	0.5	0.8	1.4	-1.9 *
Certainty 0.117 lb ai/ac	0.7	1.0	0.0	0.4	0.1	0.7	-1.1 **
Certainty 0.234 lb ai/ac	1.6	1.3	0.2	0.6	0.7	1.6	-1.3 *
Untreated	3.9	1.3	0.2	2.2	3.8	3.9	-10.1

Agastache 'Black Adder'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	2.0 **	4.5 **	5.5 **	5.1 **	6.0 **	4.9 **	13.2 **
Certainty 0.117 lb ai/ac	2.5 **	6.7 **	8.3 **	7.7 **	8.3 **	7.8 **	2.2 **
Certainty 0.234 lb ai/ac	3.3 **	8.2 **	9.3 **	9.4 **	9.7 **	9.4 **	-5.1 **
Untreated	0.0	0.0	0.0	0.3	1.1	1.5	23.6

Amelanchier stolonifera

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
FreeHand 2.65 lb ai/ac	1.0	1.1	0.8	1.1	1.5 *	1.5	12.5
FreeHand 5.3 lb ai/ac	0.9	1.0	0.9	1.6	2.7 **	3.2 *	13.7
FreeHand 10.6 lb ai/ac	1.0	1.0	1.0	2.2 **	3.3 **	4.3 **	5.6
Untreated	0.8	0.8	0.8	0.3	0.1	0.5	15.4

Astilbe xarendsii 'Final' & 'Bridal veil'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	2.1	3.7 **	2.7	6.5 **	8.8 **	9.0 **	-26.7 *
Certainty 0.117 lb ai/ac	1.8	3.8 **	4.2 **	5.3	8.1 **	8.0 **	-28.2 **
Certainty 0.234 lb ai/ac	2.0	4.3 **	3.9 **	5.7 *	8.3 **	9.8 **	-31.7 **
FreeHand 2.65 lb ai/ac	1.4	2.1	2.3	3.8	6.1	2.8	-18.2
FreeHand 5.3 lb ai/ac	2.3 *	2.8	2.9	3.6	5.9	2.8	-14.9
FreeHand 10.6 lb ai/ac	1.4	1.9	2.2	4.4	7.8 **	6.9 *	-26.9 *
Untreated	0.8	1.6	1.6	3.5	5.3	3.3	-18.0

Rhododendron 'Farrow'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 4SC 0.375 lb ai/ac	2.2 **	2.8 **	2.8 **	3.8 **	4.8 **	4.9 **	-2.3
F6875 4SC 0.75 lb ai/ac	0.1 **	0.3 **	0.9 **	0.9 **	1.2 **	1.6 **	0.0 **
F6875 4SC 1.5 lb ai/ac	1.5 **	2.9 **	3.5 **	5.9 **	5.2 **	5.3 **	-4.4
Untreated	7.7	10.0	10.0	10.0	9.2	10.0	-6.2

Berberis thunbergii 'Crimson pygmy'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	1.0	0.6	2.5	4.5 **	4.7 **	6.6 **	-2.2 **
Certainty 0.117 lb ai/ac	1.0	0.8	2.2	4.4 **	5.0 **	6.8 **	-1.9 **
Certainty 0.234 lb ai/ac	1.0	0.8	2.7	4.7 **	4.8 **	7.2 **	-2.4 **
Biathalon 2.75 lb ai/ac	1.1	0.0	1.8	0.5	1.3	1.0	7.0
Biathalon 5.5 lb ai/ac	1.0	0.2	0.8	0.5	0.9	1.1	8.7
Biathalon 11 lb ai/ac	1.0	0.2	1.8	0.0	0.3	0.5	10.1
Untreated	1.0	0.3	1.4	0.3	1.3	1.3	7.3

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

y = Growth indices; values indicate difference from first to last evaluation

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

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

Table 1., cont.

Buddleia davidii 'Black night'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	4.4 **	4.5	2.5	2.8 *	3.2 **	4.4 **	16.2
Certainty 0.117 lb ai/ac	4.7 **	6.1 **	5.7 **	3.8 **	4.7 **	4.7 **	11.7
Certainty 0.234 lb ai/ac	6.6 **	5.3 *	5.9 **	5.9 **	6.7 **	6.6 **	9.3 **
F6875 4SC 0.375 lb ai/ac	8.3 **	7.2 **	6.6 **	7.3 **	7.6 **	8.3 **	2.0 **
F6875 4SC 0.75 lb ai/ac	9.8 **	8.3 **	8.1 **	8.7 **	9.3 **	9.8 **	-5.2 **
F6875 4SC 1.5 lb ai/ac	10.0 **	9.0 **	9.4 **	9.6 **	9.8 **	10.0 **	-2.8 **
Untreated	2.2	3.1	0.6	0.2	0.4	2.2	21.0

Ceanothus xpal. 'Marie bleu'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
FreeHand 2.65 lb ai/ac	0.1	0.1	0.1	0.6	0.4	1.0	6.3
FreeHand 5.3 lb ai/ac	0.2	0.2	0.3	1.2	0.8	0.8	6.6
FreeHand 10.6 lb ai/ac	0.5	0.3	2.2 **	3.6 **	3.0 **	3.7 **	4.4
Untreated	0.3	0.3	0.1	0.4	0.4	0.5	7.7

Chamaecyparis pisifera 'Filifera golden mop'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
FreeHand 2.65 lb ai/ac	0.2	0.1	0.2	0.1	0.1	0.2	7.8
FreeHand 5.3 lb ai/ac	0.3	0.3	0.3	0.4	0.4	0.7	7.1
FreeHand 10.6 lb ai/ac	0.4	0.3	0.6	1.5	1.3	1.3	4.8 *
Untreated	0.2	0.2	0.3	0.9	1.0	0.8	8.9

Coreopsis verticillata 'Moonbeam'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 0.3G 0.375 lb ai/ac	0.2	0.0	0.0	0.3	0.0	0.0	25.6
F6875 0.3G 0.75 lb ai/ac	0.9	1.0	0.0	0.8	0.0	0.0	24.8
F6875 0.3G 1.5 lb ai/ac	0.5	0.0	0.0	0.8	0.0	0.0	25.4
Untreated	0.6	0.7	0.3	0.2	0.0	0.0	26.9

Cornus florida

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Biathalon 2.75 lb ai/ac	0.0	0.0	0.2	0.1	0.1	0.0	8.3
Biathalon 5.5 lb ai/ac	0.0	0.0	0.3	0.2	0.2	0.0	11.8
Biathalon 11 lb ai/ac	0.0	0.0	0.8	0.1	0.3	0.0	10.1
Untreated	0.0	0.0	0.3	0.3	0.3	0.0	8.4

Cornus kousa 'Milky way'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Tower 0.97 lb ai/ac	1.7	1.4	1.4	2.3	2.9	2.5	-6.1 **
Tower 1.94 lb ai/ac	2.0	2.6	1.8	1.5	2.9	2.2	-3.6 **
Tower 3.88 lb ai/ac	1.7	1.6	2.4	3.3	4.8	4.3	-14.3
FreeHand 2.65 lb ai/ac	1.5	1.1	2.0	2.3	2.3	2.6	-3.5 **
FreeHand 5.3 lb ai/ac	1.0	1.4	1.5	1.7	1.9	2.2	-4.5 **
FreeHand 10.6 lb ai/ac	2.2	1.8	2.2	1.4	3.0	2.9	-4.5 **
Untreated	2.3	2.3	2.6	4.5	6.0	6.7	-23.5

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

y = Growth indices

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

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

Table 1, cont.

Delphinium 'Connecticut yankee'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	3.4	5.6 *	3.8	6.0	7.3	8.3	7.1
Certainty 0.117 lb ai/ac	3.4	6.6 **	7.6 **	9.0 **	9.6 *	9.8	0.8
Certainty 0.234 lb ai/ac	3.9	7.1 **	9.3 **	10.0 **	10.0 **	10.0	0.0
Snapshot 2.5 lb ai/ac	3.3	5.1 **	4.0	6.0	7.6	8.9	6.6
Snapshot 5.0 lb ai/ac	2.9	6.1 **	5.3 **	6.3	7.7	8.3	6.8
Snapshot 10 lb ai/ac	1.6	3.7	4.8	7.3	8.6	9.6	0.8
Untreated	2.3	1.1	2.5	5.0	6.8	7.6	7.2

Echinacea purpurea 'Bravado'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 4SC 0.375 lb ai/ac	7.1 **	6.8 **	6.0 **	6.2 **	6.9 **	6.3 **	4.6
F6875 4SC 0.75 lb ai/ac	6.9 **	7.3 **	6.9 **	7.3 **	7.6 **	7.9 **	-4.5
F6875 4SC 1.5 lb ai/ac	8.0 **	9.3 **	9.3 **	9.6 **	9.7 **	9.8 **	-6.3
Untreated	0.6	0.3	0.1	0.0	1.6	0.3	4.0

Euonymus alatus 'Compacta'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Mesotrione 4SC 0.187 lb ai/ac	1.3	3.1	2.0	1.7	1.1	1.3	0.5
Mesotrione 4SC 0.25 lb ai/ac	1.7	3.5	2.9 **	3.6 **	2.9 **	4.0 *	-2.9
Mesotrione 4SC 0.5 lb ai/ac	1.9	3.5	4.2 **	5.4 **	5.2 **	6.5 **	-1.1
Untreated control	1.3	3.3	1.0	1.6	0.8	1.7	-0.1

Hemerocallis 'Stella d' Oro'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Tower 0.97 lb ai/ac	0.1	0.0	0.0	0.2	0.8	1.0	6.1
Tower 1.94 lb ai/ac	0.0	0.0	0.1	0.1	0.7	1.0	5.7
Tower 3.88 lb ai/ac	0.0	0.0	0.2	0.3	0.7	1.2	3.8
Untreated	0.1	0.0	0.0	0.3	0.5	1.3	6.9

Hydrangea 'Annabelle'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 4SC 0.375 lb ai/ac	6.9 **	6.5 **	8.3 **	8.3 **	8.3 **	7.6 **	3.4 **
F6875 4SC 0.75 lb ai/ac	8.8 **	8.1 **	9.9 **	10.0 **	10.0 **	10.0 **	-1.9 **
F6875 4SC 1.5 lb ai/ac	9.8 **	9.1 **	9.8 **	10.0 **	10.0 **	10.0 **	-0.9 **
Untreated	3.2	2.8	0.4	0.0	0.0	0.0	11.8

Potentilla 'Goldfinger'

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Biathalon 2.75 lb ai/ac	0.4	0.3	0.6	0.1	--	0.0	13.1
Biathalon 5.5 lb ai/ac	0.5	0.8 *	0.6	0.2	--	0.8	11.9
Biathalon 11 lb ai/ac	1.0 **	0.8	0.3	0.1	--	0.0	13.4
Untreated	0.3	0.2	0.3	0.3	--	0.0	13.1

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

y = Growth indices

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

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

Comparison of fertilizers using Advanced Granule Technology with industry standards

Dr. Hannah Mathers, Kyle Daniel, and Luke Case

Significance to the industry. Fertilizers are essential for container production; controlled release fertilizers are the norm for most container nurseries. The amount of nutrients needed varies from species to species, and there is no single type of fertilizer for every ornamental species, which is why there are so many different types of fertilizer on the market. In a perfect world, nutrition would be applied to the plants on an as-needed basis; however, not only the amount of nutrients varies from species to species but also the timing of when the plant uptakes nutrients varies. Most nurseries don't specialize in any one type of crop (although there are a few). There are some formulations available for specific genus (e.g. *Rhododendron*) and many formulations have different release patterns; for example, 1) quick release (exponential type of release curve), 2) constant release, or 3) slow release at first with a larger release at the end (logarithmic type of release curve). Using the right type of release and nutrient load requirements can be quite cumbersome and difficult for nursery growers and many growers prefer to use a "standard" for many of their crops.

Another problem with fertilizers is that prices are highly variable from year to year. From 2007 to 2008, spring nitrogen prices increased by a third, and phosphate and potash prices doubled. In 2009, spring potash prices again continued to climb, but in 2010, more manageable prices prevailed. With the recession still lingering in 2010, the nursery industry has also suffered and any way to save money or cut spending would be highly beneficial to the nursery industry. The Anderson's Company was interested in using the Advanced Granule Technology (AGT) for fertilizers to potentially create less expensive yet effective controlled release fertilizers for the nursery industry. The objectives of this study were to compare AGT formulations to industry standards on broadleaf evergreen, deciduous, and evergreen species.

Materials and Methods. Three species, *Buxus* 'Wintergem', *Juniperus chinensis*, and *Spirea nipponica* 'Snowmound', were upshifted into 3 gallon (3.8 l) trade size pots containing 85% pine bark, 10% comtil, and 5% pea gravel on April 27, 2010 at the main campus of The Ohio State University, Columbus, OH. Fertilizer treatments consisted of 6- and 9- month formulations of Osmocote Pro (Scott's Co., Marysville, OH) 15-9-12, 6 month formulation of Harrell's (Harrell's LLC, Lakeland, FL) 16-6-11, 9 month formulation of Harrell's 15-9-12, 6 month formulation of AGT 16-5-11 (which will be referred to as AND 10119), and four 9 month formulations of AGT fertilizers, three of them were a 18-6-12 formulation (which will be referred to as AND 10115, AND 10117, and AND 10118), and one was a 18-6-11 formulation (which will be referred to as AND 10116). All the fertilizer treatments were both top dressed and incorporated for a total of 18 treatments. The amount of fertilizer added was dependent on the %N and bulk density of each of the treatments; all treatments received the same amount of nitrogen, which was based on the medium rate of the 6- and 9- month formulations of Osmocote Pro. Plants were immediately watered in at upshifting and were subsequently watered every day via overhead irrigation, regardless of rainfall with at least 0.25 ac-in/day. No other treatments were imposed, and weeds were removed from the pots via handweeding. Three subsamples of each species were selected at the beginning of the trial for foliar analysis of nutrient levels. Evaluations were taken at approximately 1, 2, 3, 4, and 5 MAT (months after treatment) and consisted of taking color and quality visual ratings on a scale of 1-5 with 1 being of excellent quality or color and 5 being dead. Color ratings were based on how "green" the plant was, and quality was based on the shape in relation to size of the plant. Evaluations also consisted of testing leachates via the pour through method for pH, electrical conductivity (Ec), and nitrate levels. Growth was evaluated by taking growth index [(height + width1 + width2)/3] at the beginning and end of the trial. Growth and visual rating means were separated using Proc mixed in SAS (SAS, Inc., Cary, NC) using LSmeans with $\alpha = 0.05$.

Results and discussion. Only one of the species had a treatment x date interaction for only quality visual ratings, so all treatments discussed are averaged over the five dates of evaluation. Each of the species behaved differently to the fertilizers (Tables 1, 2, and 3). *Buxus* did not have much growth from any of the treatments (Table 1), but *Buxus* is generally a slow growing species. In terms of growth and quality ratings, AND 10119 as a top dress was the best treatment for *Buxus*, and was second in terms of color ratings (Table 1). The worst treatment for *Buxus* was AND 10115 as a top dress treatment; it provided the worst color and quality ratings and also the least amount of growth. Color and quality ratings were all very acceptable for *Juniperus*; however, there was a large variation in growth between fertilizer treatments, with growth indices ranging from 40.6 (9 month Osmocote incorporated) to 22.3 (AND 10119 incorporated) (Table 2). *Spirea* was perhaps the most indicative species of the trial. Color and quality ratings as well as growth were highly variable (Table 3). AND 10116 incorporated killed the *Spirea*, and AND 10116 as a topdress also provided poor visual ratings and little growth (Table 3). The 9 month Osmocote top dress treatment provided the best growth for *Spirea* (Table 3).

Ec levels generally peaked in May before slowly declining, with some fertilizers declining at slower paces than others (Figs. 1, 2, and 3). Although nitrates make up a portion of the salts that contribute to Ec, soluble nitrates generally peaked in June (Figs. 4, 5, and 6). The Ec values provide one explanation as to why some of the fertilizers are better than others, especially for *Juniperus* and *Spirea*. While it is easy to look for peaks and valleys for nutrient levels, consistency is often overlooked. The worst treatment (which is somewhat subjective to the interpreter of the data) for *Juniperus* is AND 10119 incorporated, which failed to supply Ec values of over 0.5, especially through August. On the opposite end, one of the best treatments (e.g. 9 month Osmocote incorporated) provided consistently high Ec values of over 0.5 through August. Although Ec data with *Spirea* is not as clear cut as with *Juniperus*, the data still indicates that consistent Ec values may be the key. Two of the best treatments for *Spirea* (6 month Osmocote top dress and 9 month Osmocote top dress) have consistent Ec values of over 0.7. The one exception to this hypothesis is the 9 month Harrell's incorporated treatment, which has a July Ec value of 0.45 (Fig. 3); if AND 10115 is compared to that treatment, they are very close in having similar EC values, but AND 10115 has higher visual ratings and decreased growth (Tables 2 and 3). Taking Ec and nitrate levels into consideration, it seems that other soluble salts other than nitrates could be responsible for the increased growth with the better treatments since the nitrates are not limited.

The 9 month Osmocote formulation is the best overall treatment in the trial in terms of growth when averaged over all species, with the topdress application having a slight advantage over the incorporated application (Table 4). The 9 month Osmocote formulation also has a very consistent nutrient release, based on Ec data (Figures 1, 2, and 3). According to Scott's, the 6- and 9 month Osmocote formulations used in this trial have a "standard (or constant)" release rate. Results with the Osmocote are similar to the data in a similar study in 2009. In 2009, there were four locations, and when average across species, the 9 month formulation (incorporated or topdressed) was the best in two of the locations and ranked very high at the other two (data not shown). Based on the data from this trial, there seems to be a slight advantage for the AGT fertilizers to be incorporated rather than topdressed, which was also seen from trials the previous year. This is indicated by the increased quality and color visual ratings on *Buxus* and *Spirea* (Tables 1 and 3), as well as decreased growth. However, the incorporated treatments, with the exception of AND 10119 and 10116 on *Spirea*, seemed to do as well as the industry standards when incorporated. The best AGT fertilizers were the AND 10119 topdress for *Buxus*, AND 10116 (incorporated or topdressed) for *Juniperus*, and AND 10117 or 10118 incorporated for *Spirea*. Although none of the AGT fertilizers worked the same with each species, possibly the best overall fertilizers are the AND 10117 and 10118, both incorporated (Table 4). Future research should include more inclusive release patterns for AGT fertilizers and how these release patterns correspond to plant growth. Data from these types of trials could also indicate possible explanations for lower growth and higher plant injury from the AGT fertilizer topdress treatments.

Table 1. Effect of fertilizer on color and quality visual ratings and growth of *Buxus* 'Wintergem' in 3 gallon containers.

Treatment	Color[z]		Quality		Growth[y]	
6 mo. Os. Inc.	1.1	c[x]	1.5	c	3.9	ab
6 mo. Har. Inc.	1.5	ab	1.4	c	2.7	ab
6 Mo. And 10119 Inc.	1.4	bc	1.5	c	1.9	ab
6 mo. Os. Top Dress	1.1	bc	1.6	c	1.2	bc
6 mo. Har. Top Dress	1.3	bc	1.7	bc	3.2	ab
6 mo. And 10119 Top Dress	1.2	bc	1.4	c	4.8	a
9 mo. Os. Inc.	1.1	c	1.4	c	2.0	ab
9 mo. Har. Inc.	1.0	c	1.5	c	1.8	ab
9 mo. And 10115 Inc.	1.1	c	1.5	c	1.7	abc
9 mo. And 10116 Inc.	1.1	c	1.4	c	2.1	ab
9 mo. And 10117 Inc.	1.2	bc	1.7	bc	2.3	ab
9 mo. And 10118 Inc.	1.3	bc	1.6	c	3.7	ab
9 mo. Os. Top Dress	1.2	bc	1.6	c	3.3	ab
9 mo. Har. Top Dress	1.0	c	1.7	bc	1.5	abc
9 mo. And 10115 Top Dress	1.8	a	2.1	a	0.3	c
9 mo. And 10116 Top Dress	1.2	bc	1.4	c	1.2	bc
9 mo. And 10117 Top Dress	1.8	a	2.0	ab	2.0	b
9 mo. And 10118 Top Dress	1.0	c	1.6	c	2.1	ab

z = Color and quality visual ratings based on a 1-5 scale with 1 being of excellent color and quality and 5 dead. Color and quality visual ratings are averaged over 5 dates of evaluation.
y = Growth assessed by subtracting growth index at 1 MAT from growth index at 5 MAT. Growth index assessed by (height + width + width)/3.
x = Treatment means followed by the same letter in the same column are not significantly different based on lsmeans ($\alpha = 0.05$).

Table 2. Effect of fertilizer on color and quality visual ratings and growth of *Juniperus chinensis* in 3 gallon containers.

Treatment	Color[z]		Quality		Growth[y]	
6 mo. Os. Inc.	1.1	bc	1.4	bc	33.2	abcde
6 mo. Har. Inc.	1.3	a	1.1	def	32.9	abcde
6 Mo. And 10119 Inc.	1.1	bc	1.7	a	22.3	e
6 mo. Os. Top Dress	1.1	bc	1.2	cdef	36.9	abcd
6 mo. Har. Top Dress	1.1	bc	1.1	def	35.3	abcd
6 mo. And 10119 Top Dress	1.1	bc	1.4	ab	28.9	cde
9 mo. Os. Inc.	1.0	c	1.1	ef	40.6	a
9 mo. Har. Inc.	1.1	c	1.2	cdef	28.7	de
9 mo. And 10115 Inc.	1.0	c	1.2	cdef	31.0	abcde
9 mo. And 10116 Inc.	1.1	bc	1.0	f	35.7	abcd
9 mo. And 10117 Inc.	1.0	c	1.2	cdef	29.5	bcde
9 mo. And 10118 Inc.	1.0	c	1.2	bcdef	28.9	cde
9 mo. Os. Top Dress	1.0	c	1.0	f	40.1	ab
9 mo. Har. Top Dress	1.0	c	1.1	ef	34.5	abcd
9 mo. And 10115 Top Dress	1.1	bc	1.3	bcde	32.4	abcde
9 mo. And 10116 Top Dress	1.1	bc	1.4	bc	37.4	abcd
9 mo. And 10117 Top Dress	1.2	ab	1.4	b	30.3	abcde
9 mo. And 10118 Top Dress	1.1	bc	1.3	bcd	32.8	abcde

z = Color and quality visual ratings based on a 1-5 scale with 1 being of excellent color and quality and 5 dead. Color and quality visual ratings are averaged over 5 dates of evaluation.

y = Growth assessed by subtracting growth index at 1 MAT from growth index at 5 MAT. Growth index assessed by (height + width + width)/3.

x = Treatment means followed by the same letter in the same column are not significantly different based on lsmeans ($\alpha = 0.05$).

Table 3. Effect of fertilizer on color and quality visual ratings and growth of *Spirea* 'Snowmound' in 3 gallon containers.

Treatment	Color[z]		Quality		Growth[y]	
6 mo. Os. Inc.	1.3	ef	1.2	f	42.6	abc
6 mo. Har. Inc.	1.9	cde	2.1	cd	27.1	bcd
6 Mo. And 10119 Inc.	2.0	cde	1.9	de	23.6	cd
6 mo. Os. Top Dress	1.0	f	1.0	f	50.1	ab
6 mo. Har. Top Dress	1.1	f	1.0	f	40.9	abcd
6 mo. And 10119 Top Dress	1.3	ef	1.2	f	33.3	abcd
9 mo. Os. Inc.	1.0	f	1.1	f	46.0	abc
9 mo. Har. Inc.	1.2	ef	1.3	ef	55.7	a
9 mo. And 10115 Inc.	1.4	def	1.7	def	27.2	bcd
9 mo. And 10116 Inc.	5.0	a	5.0	a	--	
9 mo. And 10117 Inc.	1.1	f	1.0	f	46.3	abc
9 mo. And 10118 Inc.	1.1	e	1.2	f	42.5	abc
9 mo. Os. Top Dress	1.6	def	1.6	def	56.2	a
9 mo. Har. Top Dress	1.9	cde	1.9	de	30.8	bcd
9 mo. And 10115 Top Dress	1.0	f	1.1	f	40.3	abcd
9 mo. And 10116 Top Dress	2.4	bc	2.8	bc	22.6	cd
9 mo. And 10117 Top Dress	2.8	b	2.9	b	17.5	d
9 mo. And 10118 Top Dress	2.0	cde	2.2	cd	22.1	cd

z = Color and quality visual ratings based on a 1-5 scale with 1 being of excellent color and quality and 5 dead. Color and quality visual ratings are averaged over 5 dates of evaluation.

y = Growth assessed by subtracting growth index at 1 MAT from growth index at 5 MAT. Growth index assessed by (height + width + width)/3.

x = Treatment means followed by the same letter in the same column are not significantly different based on lsmeans (α = 0.05).

Table 4. Effect of fertilizer on five months of growth averaged across three species in 3 gallon containers.

Treatment	Growth^z	
6 mo. Os. Inc.	26.6^y	abc
6 mo. Har. Inc.	21.3	bcde
6 Mo. And 10119 Inc.	15.9	e
6 mo. Os. Top Dress	28.8	ab
6 mo. Har. Top Dress	26.5	abc
6 mo. And 10119 Top Dress	22.6	bcde
9 mo. Os. Inc.	28.9	ab
9 mo. Har. Inc.	26.5	abc
9 mo. And 10115 Inc.	20.0	bcde
9 mo. And 10116 Inc.	25.1*	bcd
9 mo. And 10117 Inc.	26.0	bc
9 mo. And 10118 Inc.	25.0	bcd
9 mo. Os. Top Dress	35.0	a
9 mo. Har. Top Dress	22.5	bcde
9 mo. And 10115 Top Dress	24.1	bcde
9 mo. And 10116 Top Dress	21.1	bcde
9 mo. And 10117 Top Dress	16.6	de
9 mo. And 10118 Top Dress	19.7	cde

y = Growth assessed by subtracting growth index at 1 MAT from growth index at 5 MAT. Growth index assessed by (height + width + width)/3.

x = Treatment means followed by the same letter in the same column are not significantly different based on lsmeans (α = 0.05).

* Only *Juniperus* and *Buxus* included for this treatment

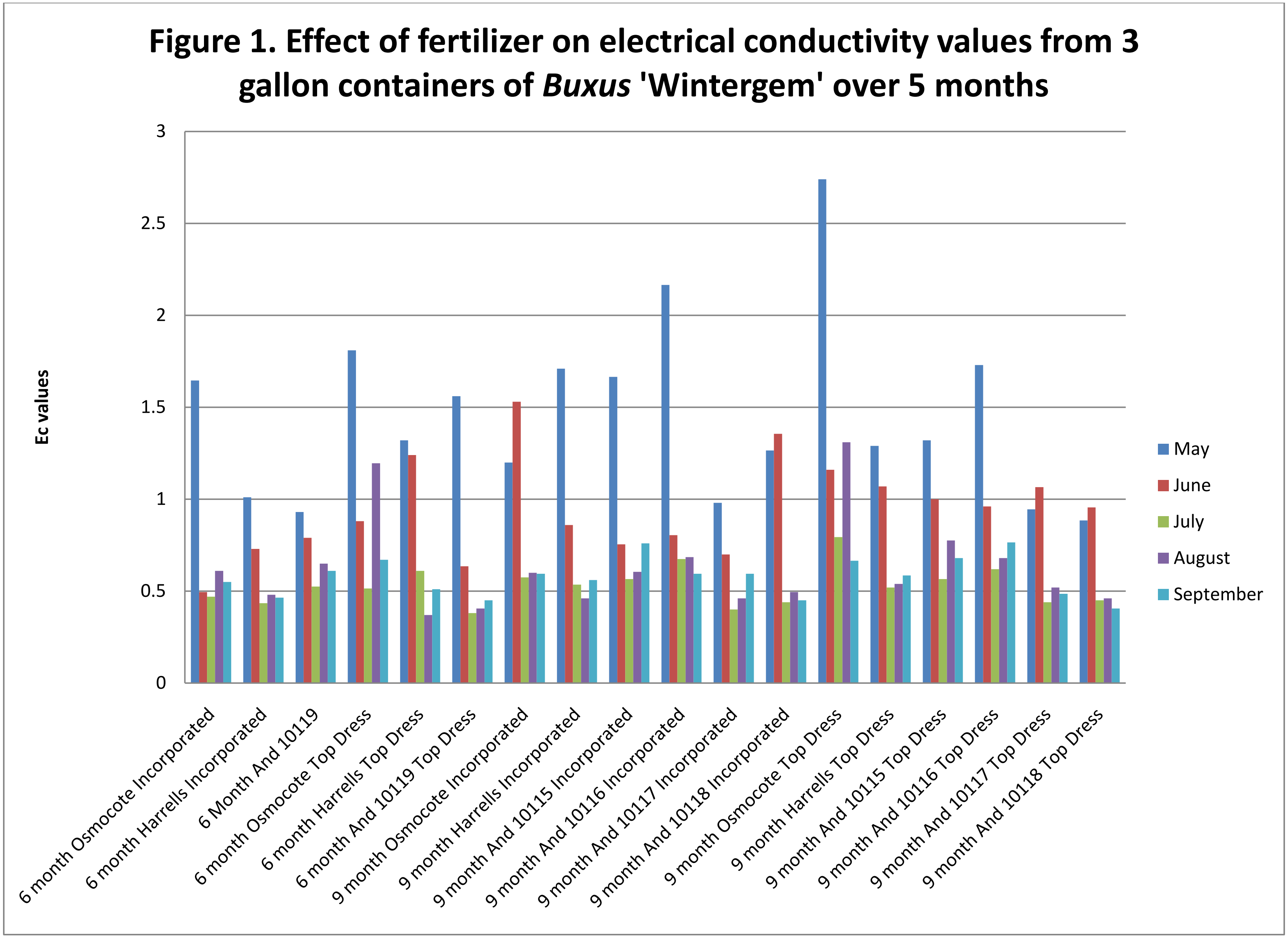


Figure 1. Effect of fertilizer on electrical conductivity values from 3 gallon containers of Buxus 'Wintergem' over 5 months
Ec values
3
2.5
2
1.5
1
0.5
0
May
June
July
August
September
6 month Osmocote Incorporated
6 month Harrells Incorporated
6 Month And 10119
6 month Osmocote Top Dress
6 month Harrells Top Dress
6 month And 10119 Top Dress
9 month Osmocote Incorporated
9 month Harrells Incorporated
9 month And 10115 Incorporated
9 month And 10116 Incorporated
9 month And 10117 Incorporated
9 month And 10118 Incorporated
9 month Osmocote Top Dress
9 month Harrells Top Dress
9 month And 10115 Top Dress
9 month And 10116 Top Dress
9 month And 10117 Top Dress
9 month And 10118 Top Dress

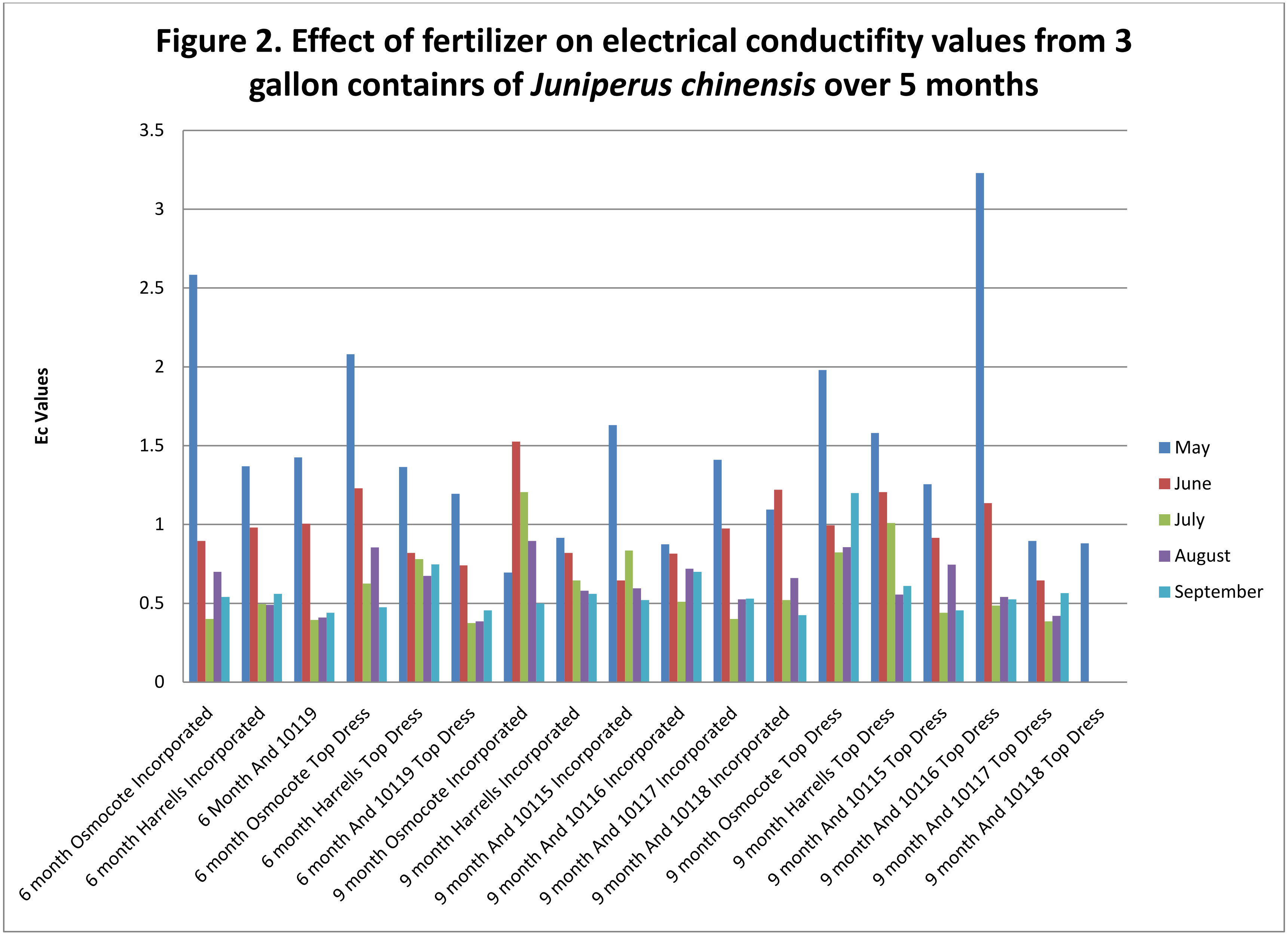


Figure 2. Effect of fertilizer on electrical conductifity values from 3 gallon containrs of *Juniperus chinensis* over 5 months
Ec Values
3.5
3
2.5
2
1.5
1
0.5
0
May
June
July
August
September
6 month Osmocote Incorporated
6 month Harrells Incorporated
6 Month And 10119
6 month Osmocote Top Dress
6 month Harrells Top Dress
6 month And 10119 Top Dress
9 month Osmocote Incorporated
9 month Harrells Incorporated
9 month And 10115 Incorporated
9 month And 10116 Incorporated
9 month And 10117 Incorporated
9 month And 10118 Incorporated
9 month Osmocote Top Dress
9 month Harrells Top Dress
9 month And 10115 Top Dress
9 month And 10116 Top Dress
9 month And 10117 Top Dress
9 month And 10118 Top Dress

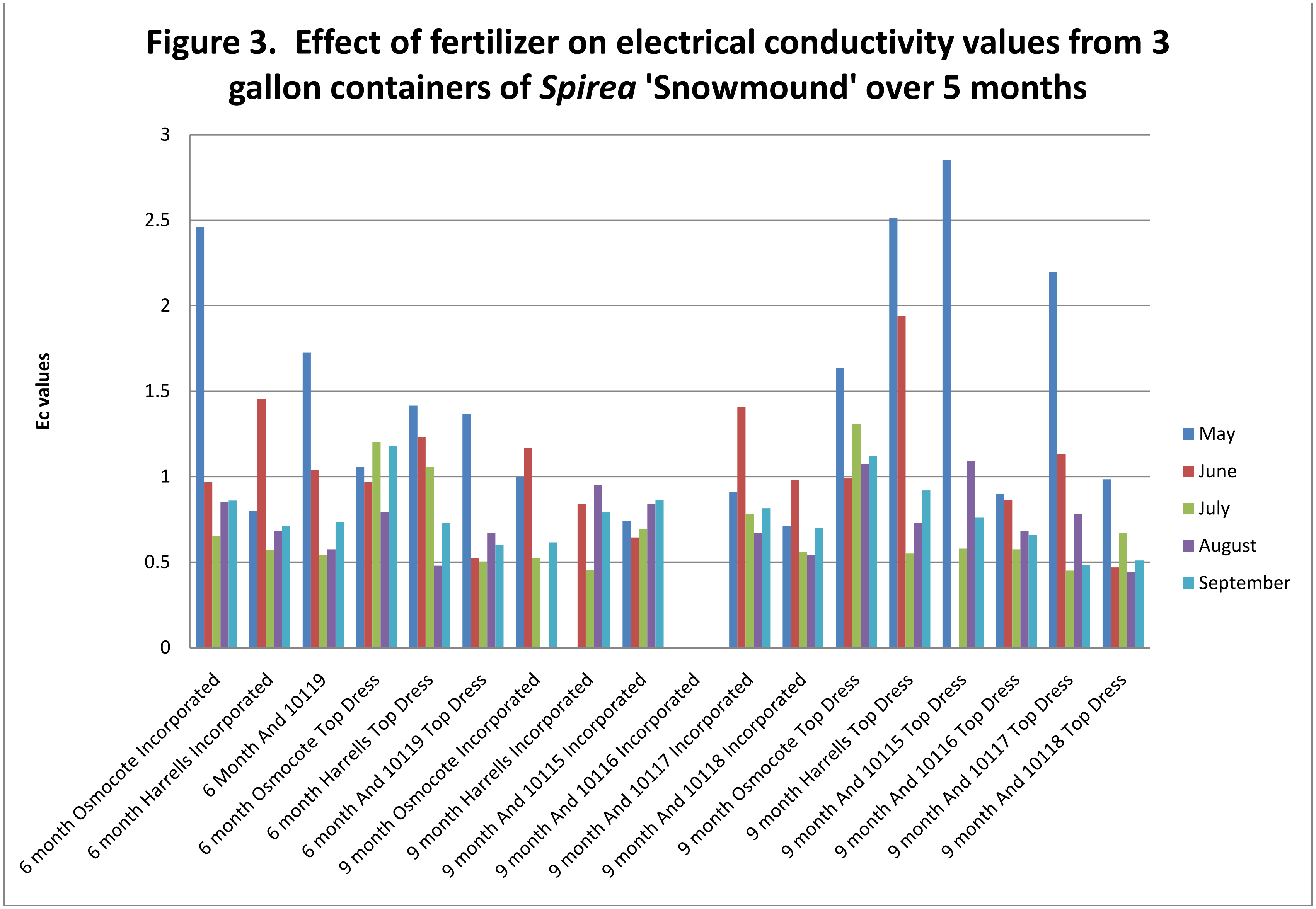


Figure 3. Effect of fertilizer on electrical conductivity values from 3 gallon containers of *Spirea* 'Snowmound' over 5 months
Ec values
3
2.5
2
1.5
1
0.5
0
May
June
July
August
September
6 month Osmocote Incorporated
6 month Harrells Incorporated
6 Month And 10119
6 month Osmocote Top Dress
6 month Harrells Top Dress
6 month And 10119 Top Dress
9 month Osmocote Incorporated
9 month Harrells Incorporated
9 month And 10115 Incorporated
9 month And 10116 Incorporated
9 month And 10117 Incorporated
9 month And 10118 Incorporated
9 month Osmocote Top Dress
9 month Harrells Top Dress
9 month And 10115 Top Dress
9 month And 10116 Top Dress
9 month And 10117 Top Dress
9 month And 10118 Top Dress

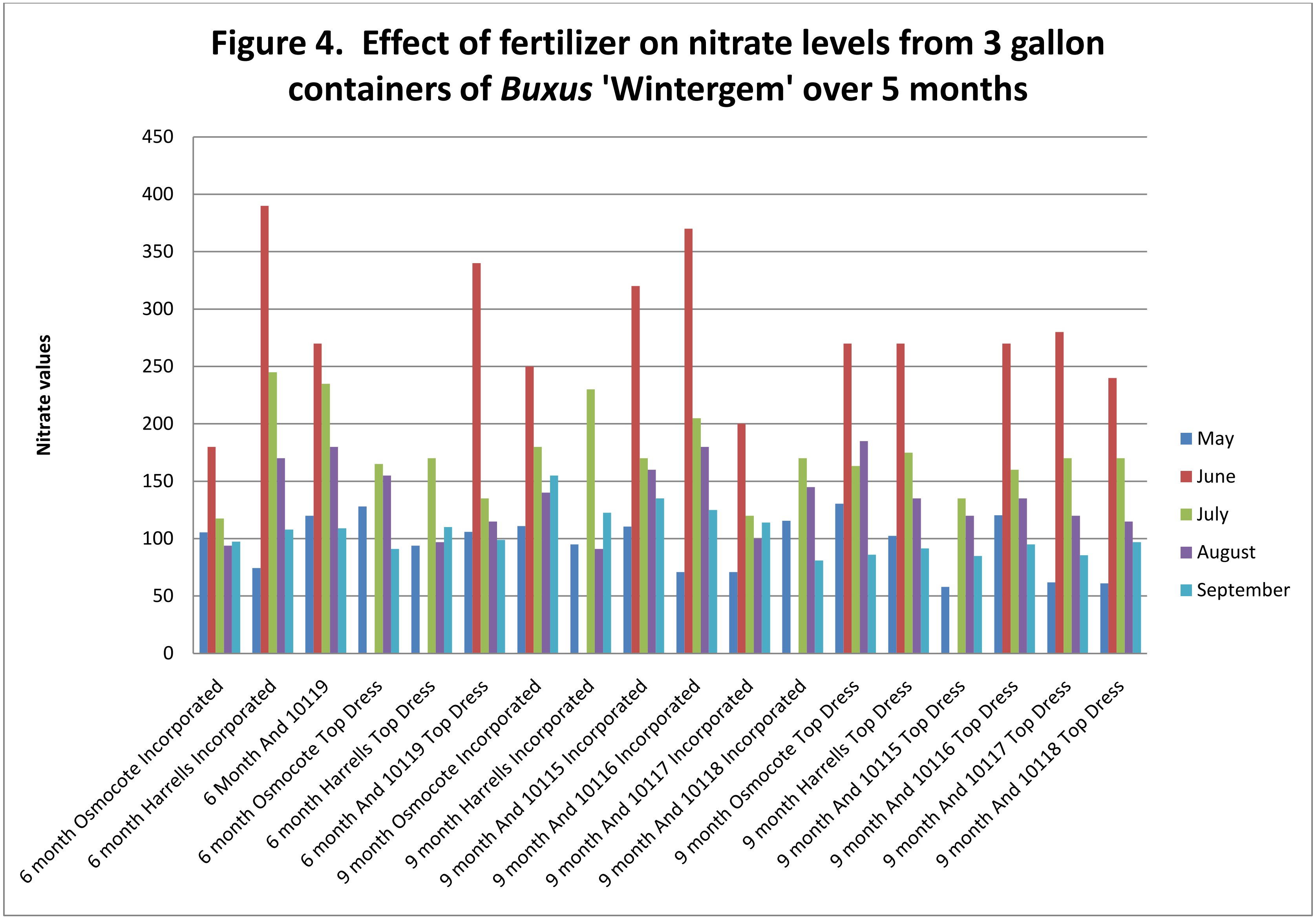


Figure 4. Effect of fertilizer on nitrate levels from 3 gallon containers of *Buxus* 'Wintergem' over 5 months
Nitrate values
450
400
350
300
250
200
150
100
50
0
May
June
July
August
September
6 month Osmocote Incorporated
6 month Harells Incorporated
6 Month And 10119
6 month Osmocote Top Dress
6 month Harrells Top Dress
6 month And 10119 Top Dress
9 month Osmocote Incorporated
9 month Harrells Incorporated
9 month And 10115 Incorporated
9 month And 10116 Incorporated
9 month And 10117 Incorporated
9 month And 10118 Incorporated
9 month Osmocote Top Dress
9 month Harrells Top Dress
9 month And 10115 Top Dress
9 month And 10116 Top Dress
9 month And 10117 Top Dress
9 month And 10118 Top Dress

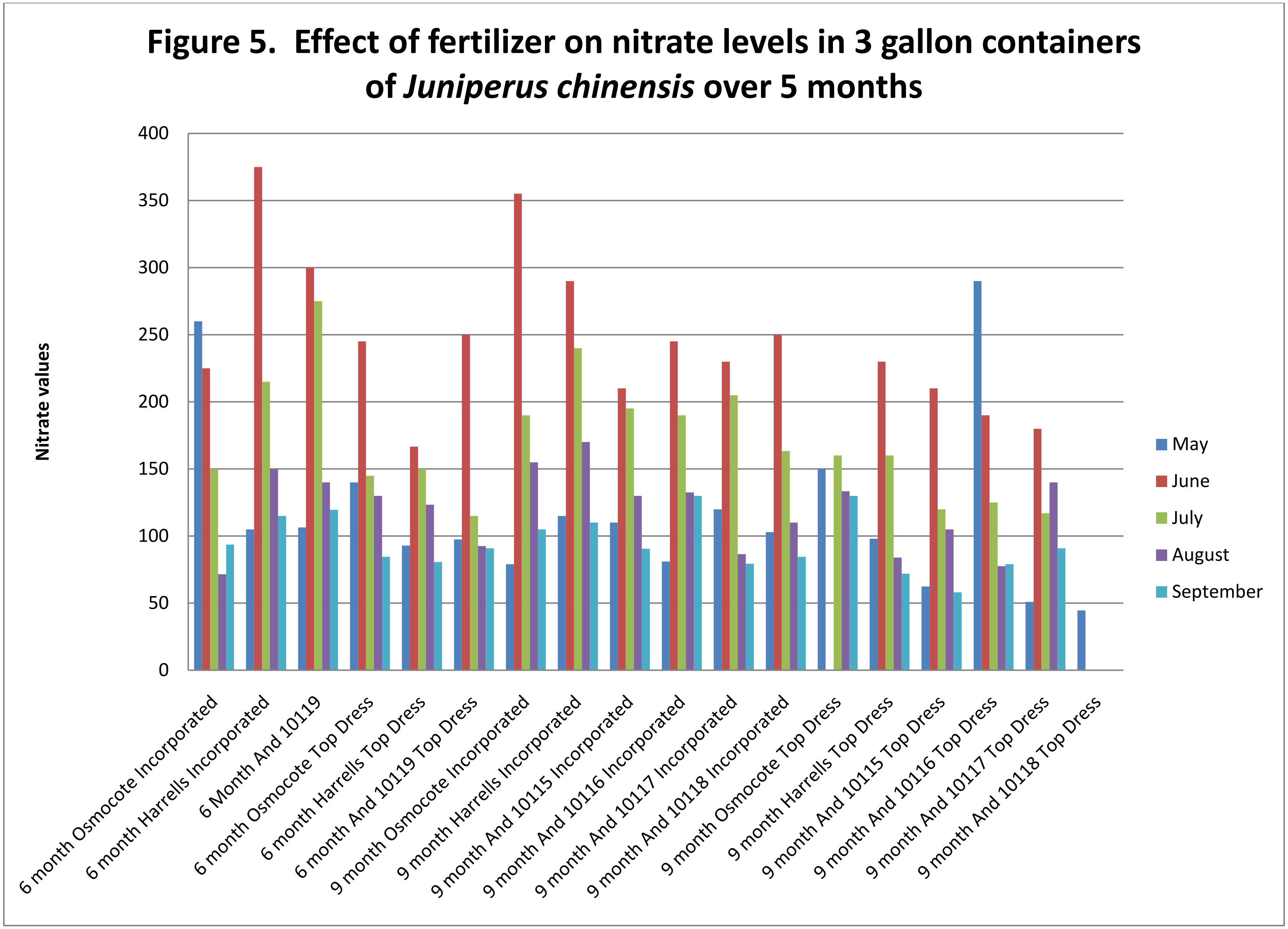


Figure 5. Effect of fertilizer on nitrate levels in 3 gallon containers of *Juniperus chinensis* over 5 months
Nitrate values
400
350
300
250
200
150
100
50
0
6 month Osmocote Incorporated
6 month Harrells Incorporated
6 Month And 10119
6 month Osmocote Top Dress
6 month Harrells Top Dress
6 month And 10119 Top Dress
9 month Osmocote Incorporated
9 month Harrells Incorporated
9 month And 10115 Incorporated
9 month And 10116 Incorporated
9 month And 10117 Incorporated
9 month And 10118 Incorporated
9 month Osmocote Top Dress
9 month Harrells Top Dress
9 month And 10115 Top Dress
9 month And 10116 Top Dress
9 month And 10117 Top Dress
9 month And 10118 Top Dress
May
June
July
August
September

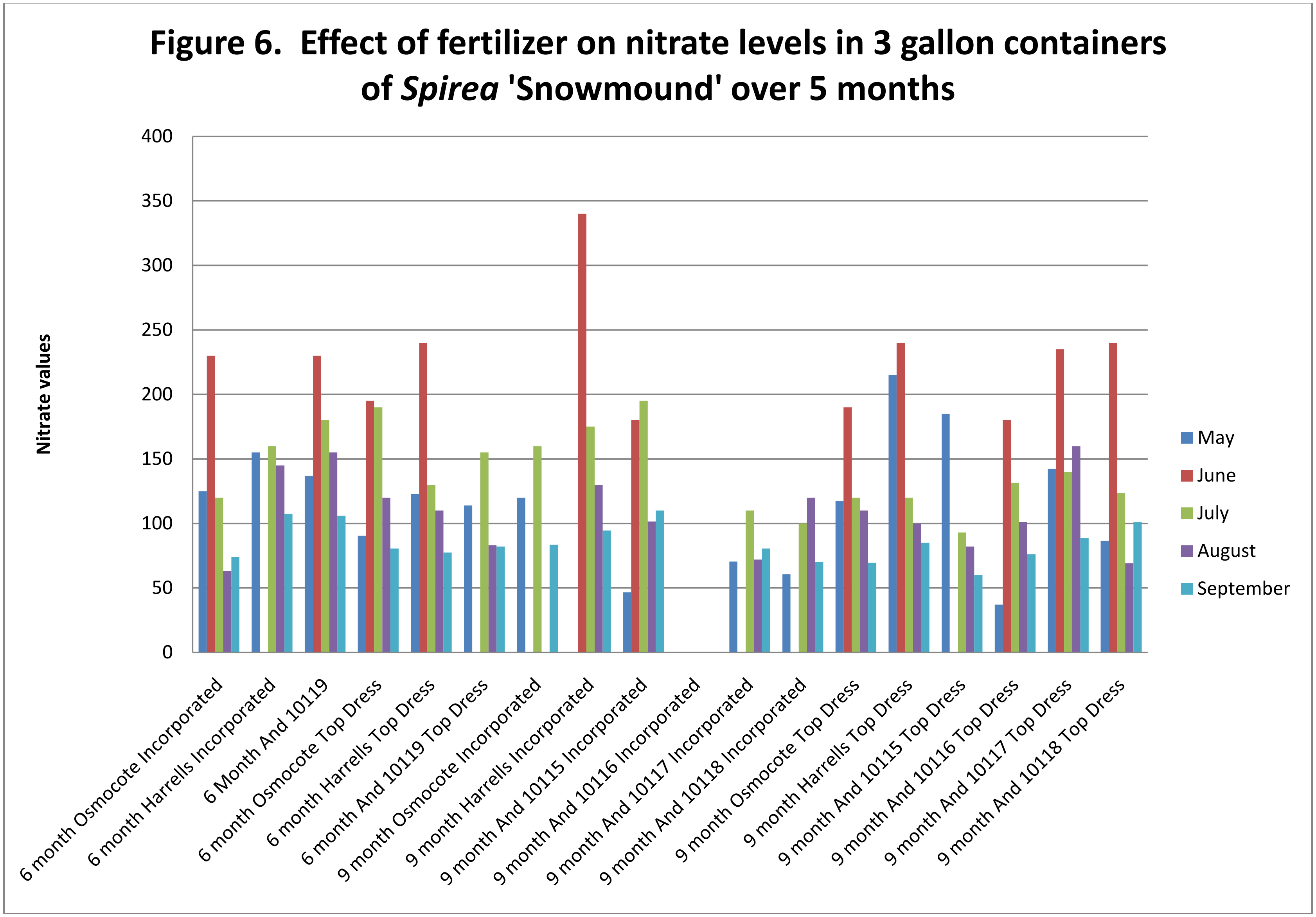


Figure 6. Effect of fertilizer on nitrate levels in 3 gallon containers of *Spirea* 'Snowmound' over 5 months
Nitrate values
400
350
300
250
200
150
100
50
0
6 month Osmocote Incorporated
6 month Harrells Incorporated
6 Month And 10119
6 month Osmocote Top Dress
6 month Harrells Top Dress
6 month And 10119 Top Dress
9 month Osmocote Incorporated
9 month Harrells Incorporated
9 month And 10115 Incorporated
9 month And 10116 Incorporated
9 month And 10117 Incorporated
9 month And 10118 Incorporated
9 month Osmocote Top Dress
9 month Harrells Top Dress
9 month And 10115 Top Dress
9 month And 10116 Top Dress
9 month And 10117 Top Dress
9 month And 10118 Top Dress
May
June
July
August
September

Field fertilization of trees using controlled release formulations

Dr. Hannah Mathers, Kyle Daniel, Luke T. Case, and Randall Zondag

Significance to the industry. Fertilization of field stock is highly variable from nursery to nursery, and it is very different from fertilization of containerized material. Some research has even suggested that fertilization is not required for field grown stock (Robbins, 2006). In Ohio, common practices of field fertilization may include no fertilization, but most nurseries apply fertilizer by liquid feed or in the form of farm grade water soluble fertilizer, with recommended rates for Ohio soils around 250 lbs/ac (Smith, 1986). However, soils are highly variable in Ohio; soils in Lake County (where there are a large number of nurseries) can vary from a very sandy soil close to Lake Erie to a soil with much more clay a few miles further south. Nutrient *holding* potential of the soil is based on the soil texture (i.e. amount of clay, silt, or sand), organic matter content, pH, and cation exchange capacity (CEC). However, nutrient availability can also be affected by soil water content, drainage, cover crops, and compaction. With all these variables, it is easy to understand why many nurserymen have trouble understanding fertilization of field grown species.

Controlled release fertilizers (CRF's) are widely used and preferred for containerized material since soilless substrates have little nutrient holding capacity. Fertilization of containerized material is much more easily and also highly managed, but is also better understood than field fertilization. Crops are much more responsive to fertilization in soilless substrate than in soils, so nutrient recommendations and applications are much easier. Using pot-in-pot (PIP) systems are relatively new to the industry compared to growing stock in the field for tree species and because PIP systems use soilless substrates, fertilization is more standardized. However, PIP systems also have disadvantages. PIP production requires much time, money, and capital that many nurseries don't want to invest in. Leaching of nutrients and pesticides is also a problem with soilless substrates. Pot size has to be large enough to sustain caliper sized plants; this is highly variable from species to species. However, possibly the best *advantage* to PIP material is that no soil is removed from the environment; since soil is continuously removed with the root ball from field nursery stock, soil nutrient levels must constantly be monitored. CRF's distribute nutrients over a specified range of time, based mostly on temperature of the substrate, which is required for soilless mixes. The field grade water soluble fertilizers are better suited for soils, but nutrient availability is highly dependent on the aforementioned variables. The question is, could CRF's be equally suited as field grade water soluble fertilizers for fertilization of field grown stock? The objective of this study is to compare water soluble fertilizers with CRF's for field grown tree production at two locations in Ohio. Included in the study are two experimental CRF's from the Anderson's Co. that use Advanced Granule Technology® (AGT).

Materials and methods. Three species, *Acer rubrum* 'Red Sunset', *Quercus rubra*, and *Pyrus callerana* 'Chanticleer', were planted in late April, 2009 and two sites; one site was at Sunleaf Nurseries in Madison, OH, and the other site was at the Waterman Farm of The Ohio State University in Columbus, OH. All species came as tree liners from J. Frank Schmidt, Boring, OR. All treatments were applied within two days of planting. Treatments in 2009 included Scotts Osmocote 33-3-6 (5-6 mo) (2.5 TB/tree), Osmocote 22-3-8 Plus Minors with Poly S (5-6 mo) (3.0 TB/tree), Anderson AGT formulations of AND 9135, 22-3-8 (3.8 TB/tree) and AND 9136, 33-0-2 (2.7 TB/tree), and the field dry-soluble (standard practice) fertilizer evaluated was

100#/ac granular 19-19-19 (4.2 TB/tree) supplied by The Anderson Co. All treatments were reapplied in May 2010, with the exception of the AND 9136, which was replaced by AND 10182. The rates of application were based on delivery of the same amount of nitrogen for all treatments of 100 # N/ac/ 9 sq ft around each tree. There was also an untreated control at each site, and at Sunleaf, there was also a liquid feed treatment in which plants were fertilized with 100 lbs liquid UAN 28% and 100 lbs potash granular dissolved together in water. Irrigation tape dispersed the liquid feed fertilizer. Twenty-five fertigation events occurred over ten weeks of the growing season to equal 4 lbs of N and K per application, every other irrigation event, M-Fri. Irrigation was applied as needed at OSU.

Experimental design was a completely randomized design at each location with three subsamples/treatment/species at Sunleaf and five subsamples/treatment/species at OSU. Calipers were taken in May and September at each location in 2009. In 2010, calipers were taken in May, July, and September at OSU, and in May and September at Sunleaf. SPAD meter readings were also taken in May, 2010 at both sites.

Results and Discussion. Results indicate that there is an effect of fertilizer on caliper growth (Tables 1 and 2), and that the mere *presence* of fertilizer is the biggest influence on caliper growth (Table 1). *Acer* showed no differences between fertilizers at OSU and Sunleaf (Tables 1 and 2). At OSU, *Pyrus* had the largest caliper and most growth from the 19-19-19 (Table 1), and at Sunleaf, the liquid feed provided the best growth and caliper size for *Pyrus* and 19-19-19 was second (Table 2). However, at OSU, the only fertilizer that was statistically different in total caliper for *Pyrus* from 19-19-19 was the Osmocote 33-3-6. It should be noted that although species are reported separately, there was not a species by treatment interaction for caliper growth when only *Acer* and *Pyrus* were included in the analyses at both locations (data not shown). One possible explanation for the increased growth of *Pyrus* with the liquid feed is that it may actually be receiving more total nitrogen and potassium than the other treatments. At 100 lbs of N and K/season/ac, and 830 trees/ac (average), this equates to about 54.7 g of N and K/tree possible. With the other fertilizers, amount was based on a square foot basis, with each tree receiving only about 9.4 g/tree of N and K ranging from 0.6 g/tree (Osmocote 33-0-2) to 9.4 g/tree (19-19-19). It can easily be seen that the biggest difference between *Quercus* and the other two species was that the Osmocote 22-3-8 provided the most growth for *Quercus* at both locations (Tables 1 and 2), and the liquid feed provided the least amount of growth for *Quercus* at Sunleaf, but the other two species benefited the most from the liquid feed (Table 2).

Nutrient uptake is quite different from genera to genera and can even be different from species to species (Birge et al., 2006). “Nutrient loading” is a term used to describe nutrient partitioning to storage organs (i.e. stem and roots) to later be used for stem growth and leaf formation, and it could be quite beneficial for future growth. However, determining “when” to nutrient load for each species is hard to determine, and higher substrate nutrient levels generally lead to higher shoot:root ratios which subsequently could lead to decreased performance when outplanted and decreased pest resistance. Data from Rose and Biernacka (1999) indicates that uptake of nutrients by *Acer xfreemanii* ‘Jeffersred’ in containers occurs from time of potting to September, although the greatest increase in nutrients occurs from July to September. The plant then supplies approximately 50% of the nitrogen required the following spring for bud break and leaf formation; however, phosphorus and potassium are not remobilized the following spring. Data from this study shows that most of the caliper growth occurs in spring for *Acer* (Figure 1). Millard (1994) indicates that approximately one third of total nitrogen required for leaves is from remobilized nitrogen in *Acer pseudoplatanus*. Although growth patterns differ (Figure 1), data from OSU and Sunleaf suggest that *Pyrus calleryana* and *Acer rubrum* may have similar patterns for nutrient uptake, but *Quercus rubra* may have a different uptake pattern (Tables 1 and 2). Struve (1995) found that liquid feeding provided more growth than slow release fertilizer to *Nyssa sylvatica*, and although not significant, slow release fertilizer provided 31% more growth to *Quercus rubra* than constant liquid feeding. Struve (1995) also reported that nutrient use efficiency was much higher for *Quercus rubra* with slow release formulations, as opposed to the *Nyssa sylvatica*, which preferred the liquid feeding. Birge et al. (2006) found that exponential feeding (feeding that increases over time) is more beneficial for *Quercus rubra* and *Quercus alba* seedlings than constant liquid feeding, and Oliet et al. (2009) found that exponential feeding was just as good as constant feeding of *Quercus ilex* seedlings. Birge et al. (2006) also found that *Quercus rubra* and *Quercus alba* seedlings have decreased growth when nutrients are applied at too high of rates. This suggests that although *Quercus* may uptake nutrients all year, a majority of the nutrients are uptaken later in the season compared to other genera, such as *Acer* or *Pyrus*. Jay Daley, general manager of Sunleaf Nursery, said that they have seen good growth flushes with *Quercus* the third and fourth years of growth (personal communication), so it will be interesting to see just how the liquid feed compares to the granule applied fertilizers. If the trend continues with *Quercus* in this trial, then it's possible that *Quercus* could be experiencing some toxicity from a nutrient rich environment, and if there is a large amount of growth the third year, then it's possible that *Quercus* could be nutrient loading.

There are differences between sites, but trends are quite evident. If the liquid feed treatment is omitted, then treatment trends are almost identical between the two sites (Tables 1 and 2). Calipers are generally smaller at OSU as compared to Sunleaf, although growth is much different from season to season (Figures 1 and 2). At OSU, there was very little growth for all three species the first year after transplanting. However, all species increased growth significantly in the second year (Figure 1). At Sunleaf, growth rates were almost the same for *Pyrus* and *Acer* in both years, but *Quercus* grew the most in the second year, similar to OSU (Figure 2). Possibly the biggest difference between sites is the type of soil. At OSU, soil is mostly a Kokomo silty clay with cation exchange capacities (CEC) of around 12-20 and a ph between 6 and 7. At Sunleaf, the soil is mostly a Tyner or Otisville loamy sand with CEC between 2-6 and pH between 4.7 to 6. Nutrients are more readily available (although are more easily leached) in sandy soils right after application of fertilizers, which could explain the higher growth rate the first year at Sunleaf with *Acer* and *Pyrus*.

In conclusion, it is very apparent that some type of fertilizer is needed for growth of shade trees in field nurseries. Although not superior at either location, AND 9135 is not significantly different in terms of caliper for any of the species at either location (Tables 1 and 2). At this point in time, it is unclear whether effects from AND 10182 are from that AGT fertilizer or the AND 9136, since AND 10182 replaced AND 9136. AND 9136 did not have minors, which AND 10182 does. At this point in time, the farm grade dry soluble 19-19-19 may be the best economical choice; however, the lack of minors is not yet evident at these two locations. The lack of minors may become evident in future growth, disease, and drought resistance. Soil and tissue analyses show that there are no clear differences between fertilizers for minors at this point in time (data not shown). Although there is some advantage to the liquid feed for *Pyrus* and *Acer* at Sunleaf, there is no *statistical* advantage to the liquid feed over some of the other granular fertilizers. The important thing to keep in mind is that nutrient uptake is species dependent, and supplying the right amount of fertilizer at the right time is a trial and error process, but this trial reinforces that many field nurseries are supplying too high of rates for acceptable growth.

Table 1. Caliper and caliper growth from various fertilizers at The Waterman Farm of The Ohio State University, Columbus, OH from April 2009 to September 2010.

	Pyrus calleryana 'Chanticleer'				*Acer rubrum* 'Red sunset'				*Quercus rubra*			
	caliper[z]		cal. growth[y]		caliper		cal. growth		caliper		cal. growth	
And10182 22-3-8	35.0	ab[x]	14.5	ab	39.2	a	10.5	a	32.2	no diff	3.0	ab
And9135 22-3-8	35.5	ab	13.6	bc	38.6	a	10.1	a	34.2	no diff	3.4	ab
Osmocote 33-3-6	33.8	bc	13.3	bc	39.6	a	9.6	a	33.7	no diff	3.8	ab
Osmocote 22-3-8	35.5	ab	13.9	b	38.7	a	9.3	a	34.1	no diff	4.7	a
19-19-19	36.0	a	15.4	a	38.8	a	10.2	a	32.9	no diff	3.6	ab
Control (no fert.)	32.8	c	11.9	c	37.0	b	7.6	b	31.9	no diff	1.1	b

z = caliper measures are in millimeters, which are based on repeated measures analysis over 5 evaluations from 2009 to 2010

y = caliper growth is determined by subtracting caliper in April 2009 from caliper in September 2010

x = Treatment means in the same column followed by the same letter are not significantly different based on lsmeans ($\alpha = 0.05$)

Table 2. Caliper and caliper growth from various fertilizers at Sunleaf Nurseries, Madison, OH from April 2009 to September 2010.

	Pyrus calleryana 'Chanticleer'				*Acer rubrum* 'Red sunset'				*Quercus rubra*			
	caliper[z]		cal. growth[y]		caliper		cal. growth		caliper		cal. growth	
And10182 22-3-8	35.2	b[x]	7.2	b	45.0	no diff	14.5	no diff	41.4	ab	11.8	abc
And9135 22-3-8	38.1	a	9.4	ab	44.8	no diff	13.9	no diff	42.3	ab	12.0	abc
Osmocote 33-3-6	35.0	b	7.2	b	46.0	no diff	15.0	no diff	40.1	b	10.0	bc
Osmocote 22-3-8	38.3	a	9.7	ab	45.4	no diff	15.1	no diff	44.1	a	14.4	a
19-19-19	39.3	a	10.9	a	46.6	no diff	15.9	no diff	42.3	ab	12.9	ab
Liquid Feed	41.1	a	12.6	a	46.9	no diff	16.0	no diff	39.4	b	9.3	c

z = caliper measures are in millimeters, which are based on repeated measures analysis over 5 evaluations from 2009 to 2010

y = caliper growth is determined by subtracting caliper in April 2009 from caliper in September 2010

x = Treatment means in the same column followed by the same letter are not significantly different based on lsmeans ($\alpha = 0.05$)

Figure 1. Change in caliper during the growing seasons of 2009 and 2010 for pear (*Calleranya* 'Chanticleer'), maple (*Acer rubrum* 'Red Sunset') and red oak (*Quercus rubra*) at OSU

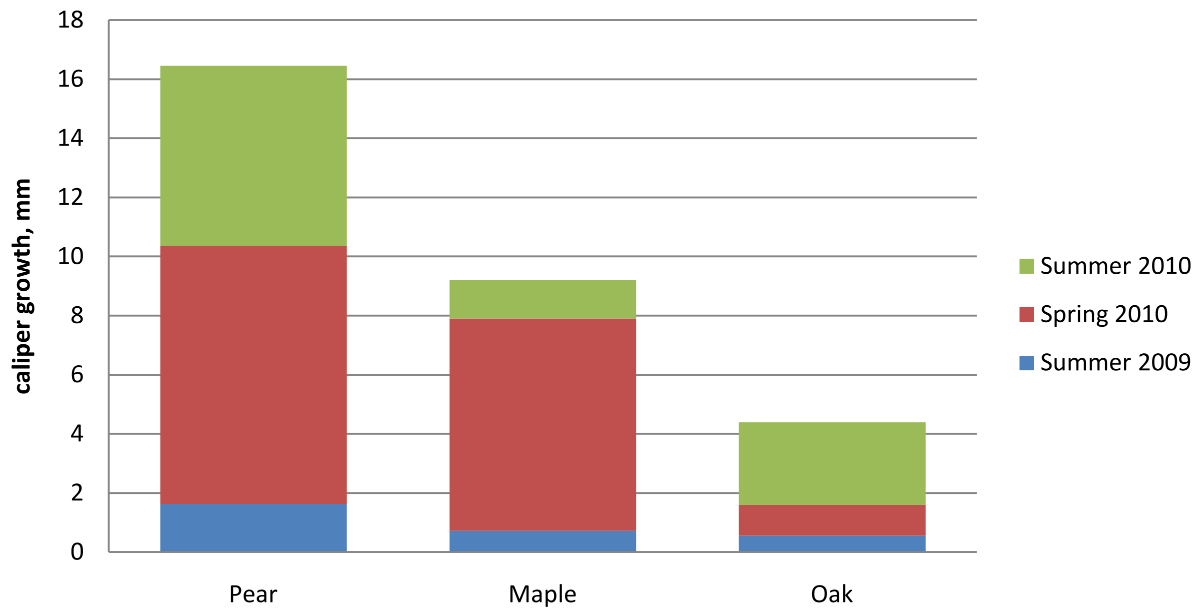
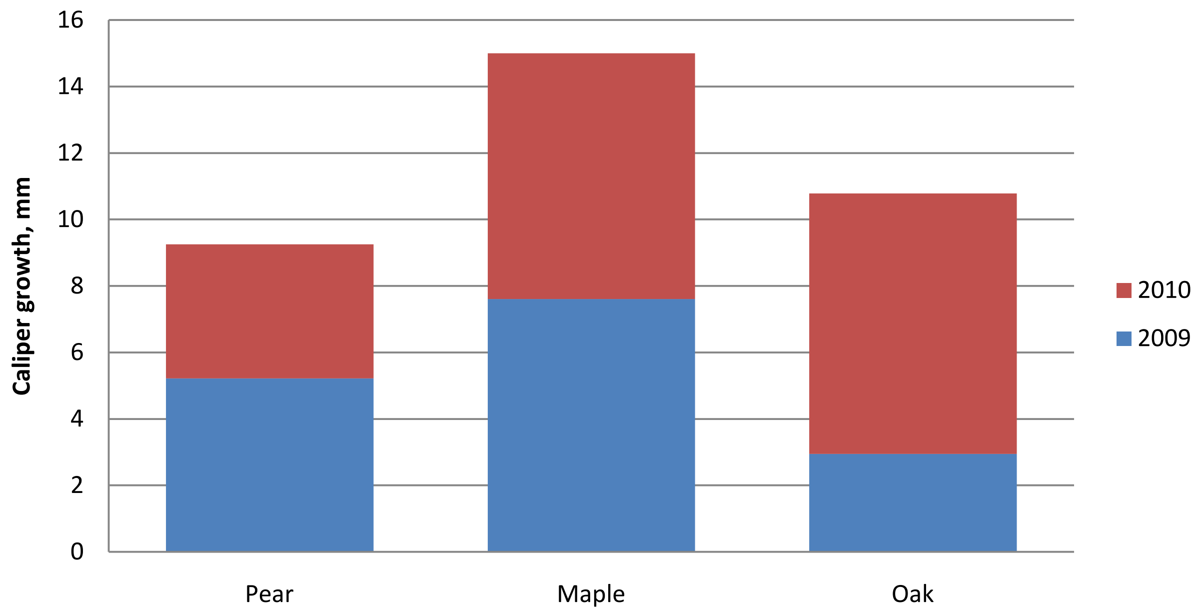


Figure 2. Change in caliper during the growing seasons of 2009 and 2010 for pear (*Calleranya* 'Chanticleer'), maple (*Acer rubrum* 'Red Sunset') and red oak (*Quercus rubra*) at Sunleaf



Bio-herbicide mulch combinations and bio-rationale approaches to ornamental weed control for containers and in the field

Principle investigators: Dr. Hannah Mathers

This study had two objectives: 1) determine the efficacy and duration of weed control of different control methods, including two bark sizes applied as a single layer on the container surfaces; and, 2) assess the phytotoxicity of the different methods in containers.

Container study.

Materials and Methods. The study was conducted at Sheridan Nursery, Elev. 269m, NE 43° 41.341', W079°56.153'; 12688 10th Line, Halton Hills, ON, in one gallon containers on a sand pad overlaid with geotextile as part of the trial work funded by this grant for the Vineland Research and Innovation Centre (Fig. 14). The trial was initiated on May 19, 2009. Air temperature was 75°F. Five single plant replications were conducted per treatment and species. Three container species were evaluated *Euonymus fortunei* 'Emerald Gaiety' (Winter Creeper Euonymus), *Sambucus canadensis* (American Elderberry) and *Pinus Mugo* (Mugo Pine). ARRPAC #1 pots (Tri-Tech Moulded Products, Inc. McMinnville, TN 37110), were used. A substrate of 60% composted softwood bark, 30% peat and 10% compost (Gro-Bark Ltd., Milton, ON) with incorporated Polyon 20-6-13 + minors (Agrium Advanced Technologies, Brantford, ON), 6 mo. Formulation was used. Two sizes of Pine bark (70% bark, a composite of White pine, Red pine and Jack Pine), >1" and <1", was obtained from Gro-Bark Ltd., Caledon, ON. Treated bark was sprayed over the top and then allowed to stand for 24 hr. to absorb the chemicals and dry before applying to the test plants. Treated bark was applied directly over-the-top of freshly potted one-gallon plants in as close to a single layer as possible. Conventional herbicides, Ronstar and BroadStar were applied at 1.0 times the label rate of pounds of active ingredient per acre. The allopathic chemicals were applied at 5% and 10% aqueous solution prepared from two plants. A spray volume of 93 L/ha was used to apply with a CO2-pressurized backpack sprayer equipped with 8002 evs flat fan nozzles spaced 41 cm apart.

No seeding of weeds was conducted. Natural blow-in of weed seeds was sufficient. Containers were arranged in a randomized complete block design with five replications, grouped by plant in the phytotoxicity trial and a CRD in the efficacy. Efficacy evaluations were conducted at 90 days after treatment (DAT) using a visual rating of weed control: 0 (no control) to 10 (complete control) and 7 (commercially acceptable). Phytotoxicity evaluations were conducted 90 DAT. A visual rating score of 1 (no injury) to 10 (complete kill) was used. A total of 25 treatments were evaluated. Six conventional treatments utilized oxadiazon (Ronstar) alone or with each bark size and flumioxazin (BroadStar) applied alone or with each bark size. Seventeen of the treatments were bio-herbicides composed of two plant extracts (which will remain anonymous for the purpose of potential patenting) applied at three concentrations to the two bark sizes and one 200 grain vinegar. The two remaining treatments were combinations of bio-herbicides and conventional herbicides applied to bark.

Results and discussion. Fourteen of the 25 treatments evaluated provided efficacy ratings at or above commercially acceptable $\geq$7 (Fig. 15). Seven of these 14 were bio-herbicide combinations with mulch and one was a bio-herbicide + Ronstar mulch combination (Fig. 16). Three of the 14 provided phytotoxicity ratings at or above commercially acceptable (Fig. 15). These three were all conventional herbicides (SureGuard applied alone, SureGuard >1" and Ronstar >1" (Fig. 15). The >1" bark was involved in 11 of the 13 highest phytotoxic treatments and there was a significant species by treatment interaction with *Euonymus fortunei* 'Emerald Gaiety' accounting for the majority of the phytotoxicity in the trial (Fig. 17). Even the untreated >1" bark provided a rating of slightly above 3 combined over species (Fig. 15). We speculate that >1" bark caused plants to be buried too deep as it contained an abundance of fine material. Eight of the bio-herbicide combinations provided phytotoxicity ratings of less than two (Fig. 15). The six most efficacious bio-herbicide treated mulch combinations all provided efficacy and phytotoxicity ratings of ≥ 7and ≤ 2, respectively, 90 DAT. The Vinegar on < 1" pine bark was very efficacious and provided the same level of weed control as the conventional herbicide Ronstar with less than half the phytotoxicity at 90 DAT. The BH1 plant extract, DU 200ml at 10% and 5% on <1" bark was statistically as efficacious as the Vinegar <1" and the Ronstar; however the phytotoxicity with BH1 was less than half that of even vinegar. Vinegar and BH1 as bio-herbicides combined with mulch evaluated in this study warrant further testing. Comparisons of horticultural vinegars to the industrial 200 grade vinegar used in this trial and the BH1 extract should also be evaluated with various mulches types.

Fig. 14. Herbicide treated mulch efficacy trial at Sheridan Nursery. Outdoor geotextile covered growing area. Conventional treatments are towards the top of the picture and bio-herbicide mulch combinations in foreground. The phytotoxicity trial with the *Euonymus fortunei* 'Emerald Gaiety' is in the background on the right. Picture taken by H. Mathers 90 days after treatment (DAT).

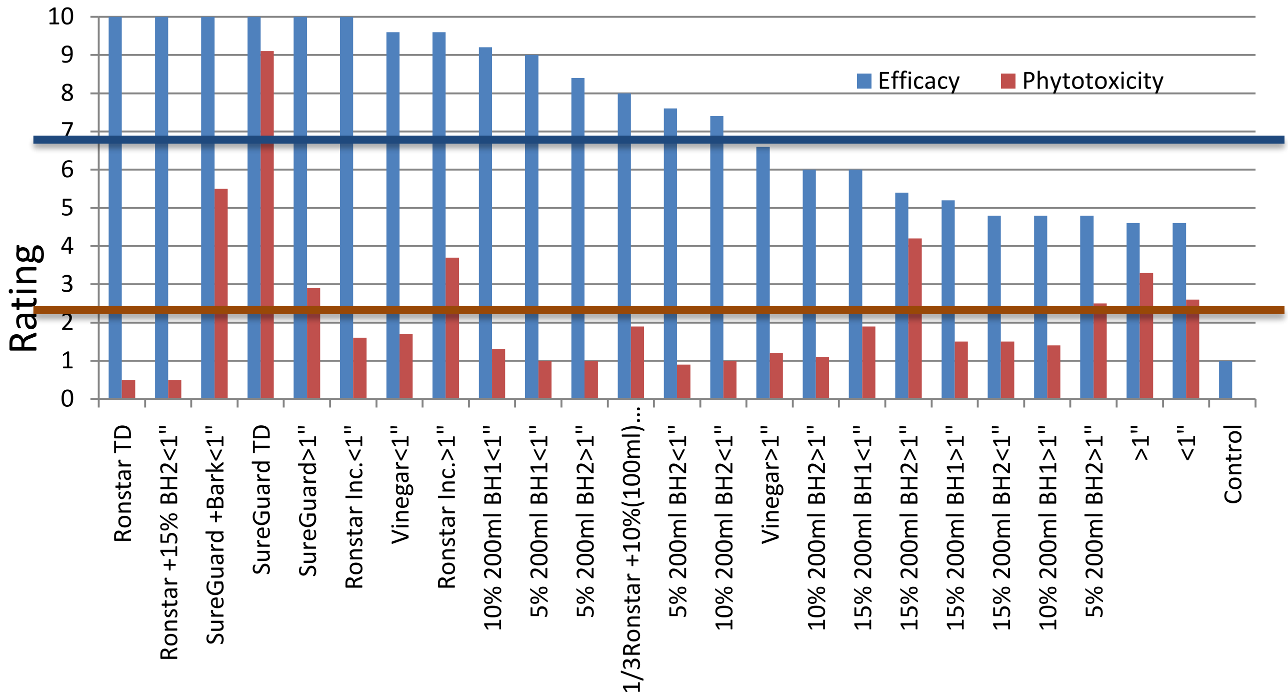


Fig. 15. Efficacy and phytotoxicity combined over three species, *Euonymus fortunei* 'Emerald Gaiety' (Winter Creeper Euonymus), *Sambucus canadensis* (American Elderberry) and *Pinus mugo* (Mugo Pine) at Sheridan Nursery. SureGuard and Ronstar were used with >1' and, 1" pine bark or alone. Two bio-herbicides [BH1 (or DU) and BH2 (or BS)] made from two plant extracts (which will remain anonymous for the purpose of potential patenting) were applied at three concentrations (5%, 10% or 15%) to the two bark sizes and one 200 grain vinegar was also applied. Efficacy ratings of weed control, 0 (no control) to 10 (complete control) and 7 (commercially acceptable) and phytotoxicity visual ratings of 0 (no injury) to 10 (complete kill) were used.

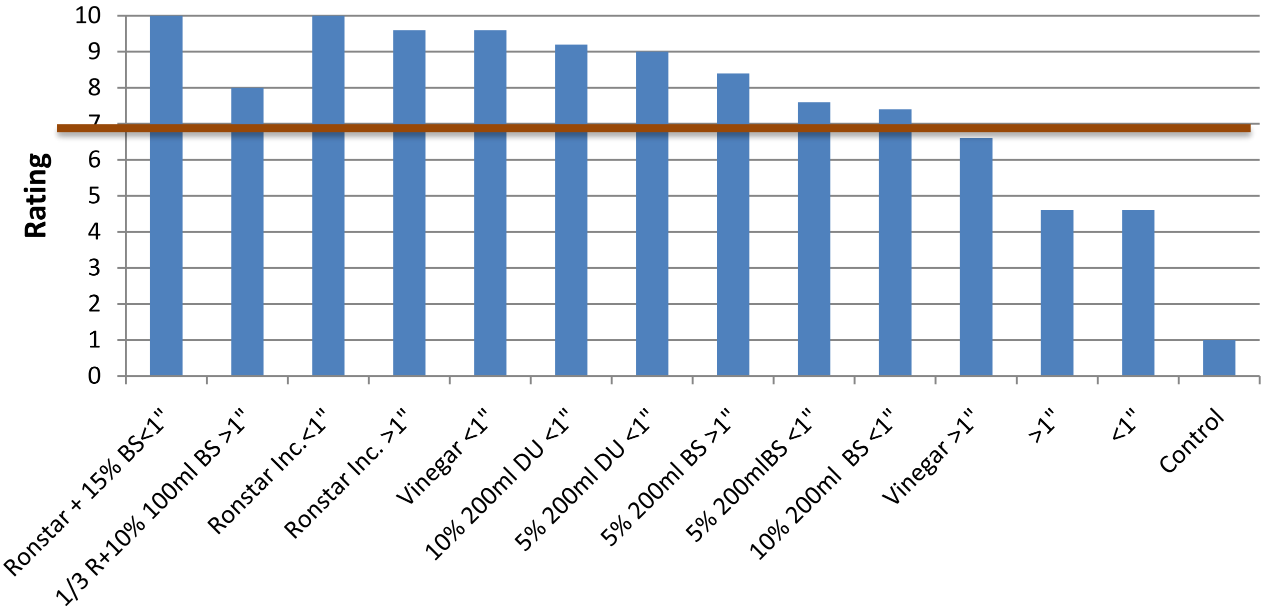


Fig. 16. Efficacy of three conventional Ronstar applications compared with bio-herbicides treatments (BH2 or BS) and (BH1 or DU) were applied to >1" and <1" pine bark from Gro-Bark Ltd., Caledon, ON, at Sheridan Nursery, Halton Hills, ON, 90 days after treatment (DAT). Two sizes of were used. The BH treatments were applied at three concentrations (5%, 10% or 15%) and one 200 grain vinegar was also applied. Efficacy ratings of weed control 0 (no control) to 10 (complete control) and 7 (commercially acceptable) were used.

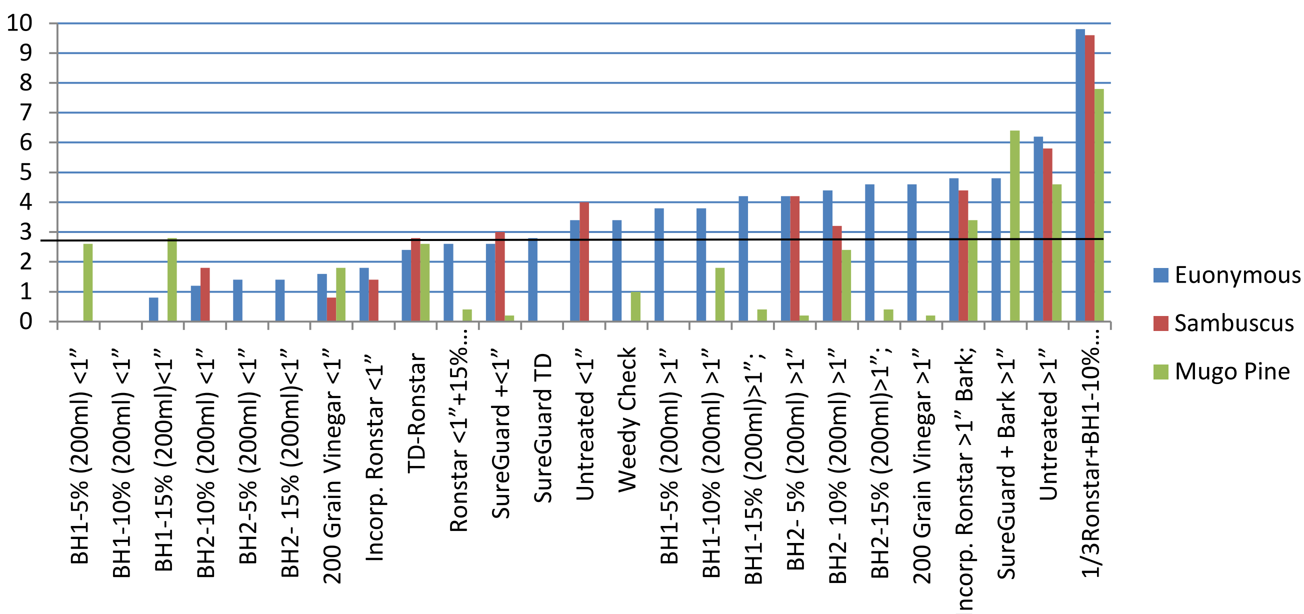


Fig. 17. Phytotoxicity by species and treatment for *Euonymus fortunei* 'Emerald Gaiety' (Winter Creeper Euonymus), *Sambucus canadensis* (American Elderberry) and *Pinus mugo* (Mugo Pine) at Sheridan Nursery, Halton Hills, ON 90 days after treatment. SureGuard and Ronstar were

used with >1” and <1” pine bark from Gro-Bark Ltd., Caledon, ON. Two bio-herbicides [BH1 (DU) and BH2 (BS)] made from two plant extracts (which will remain anonymous for the purpose of potential patenting) were applied at three concentrations (5%, 10% or 15%) and one 200 grain vinegar was also applied. Phytotoxicity visual ratings of 0 (no injury) to 10 (complete kill) were used with ≤ 3 being commercially acceptable.

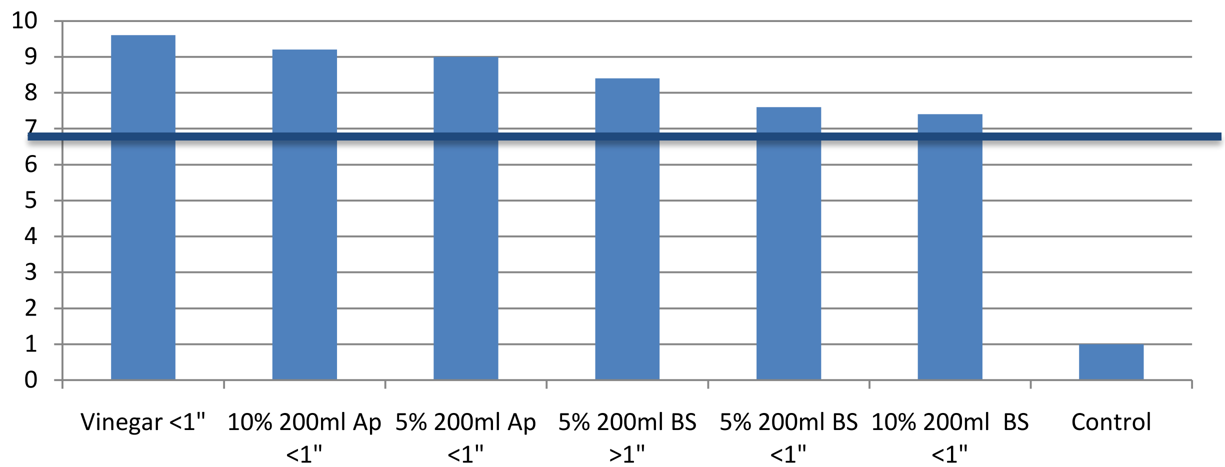


Fig. 18. The six most efficacious treatments applied at Sheridan Nursery, Halton Hills, ON 90 days after treatment compared to the control, no herbicide or bark. Two sizes of Pine bark >1” and <1”, were used. The Bio-herbicide treatments (BH2 or BS) and (BH1 or DU) were applied at three concentrations (5%, 10% or 15%) to the two bark sizes and one 200 grain vinegar was also applied. Efficacy ratings of weed control from 0 (no control) to 10 (complete control) were used with ≥7 being commercially acceptable.

Conclusions:

The Vinegar on < 1” pine bark was very efficacious and provided the same level of weed control as the conventional herbicide Ronstar with less than half the phytotoxicity at 90 DAT. The BH1 plant extract or DU 200ml at 10% and 5% on <1” pine bark was statistically as efficacious as the Vinegar <1” and the Ronstar; however, the phytotoxicity with BH1 was almost half that of even vinegar and 3.5 times less than the Ronstar. The potential of vinegar and BH1 as bio-herbicides combined with mulch shown in this study indicate that further testing is warranted. Specifically, the industrial 200 grade vinegar, horticultural vinegars and BH1 extract should be tested on various mulch types. Also the results warranted testing in a field setting to determine their suitability for use in landscape and nursery field operations.

Field Study

Objectives:

This study continued the 2009 bio-herbicide testing at Sheridan nursery and had two objectives: 1) determine the efficacy and duration of different weed control methods in field, including three barks applied at 2” depth (Vineland Research and Innovation Centre); 2) assess the phytotoxicity of the different methods in the field (Vineland Research and Innovation Centre). Only efficacy data will be presented as phytotoxicity was minimal.

Materials and Methods:

Research began on June 8, 2010 and evaluations were conducted on July 13, 2010 (35 DAT) and July 28, 2010 (50 DAT). Unfortunately, the plots were hand weeded without consultation of the primary investigator in preparation for a tour at Vineland Research and Innovation Centre in early August and no further useable data could be collected in 2010. A controlled release fertilizer (CRF) Polyon 27-07-07 top dress + minors, was used in field evaluations at Vineland. Eight cu yd. each of three bark types, 2-3" Pine bark (70% bark) (a composite of White pine, Red pine and Jack Pine), Hardwood bark (40% bark) (a composite of Oak, Poplar and Maple) and Cedar bark (bark and wood) (Eastern White Cedar) were obtained from Gro-Bark Ltd., Caledon, ON (Fig. 19 A, B, and C, respectively). The bark was laid on 3X3 ft. plots at 2" deep and sprayed over the top. The alleopathic chemical BH1 from the 2009 trial was applied at 5%, 10% and 15% aqueous solution. A spray volume of 93 L/ha utilizing a CO_2-pressurized backpack sprayer equipped with 8002 evs flat fan nozzles spaced 41 cm apart was used. Each replicated and randomized bed contained three types of ornamental plants: white spruce (*Picea glauca*) out of #2 containers, English oak (*Quercus robur)* out of #3 containers and *Coreopsis* 'Moonbeam' out of 4" pots. Plants were spaced on 1' centers. Standard nursery and landscape irrigation practices were employed for the duration of the study.

No weed seeding was conducted. Efficacy and phytotoxicity were rated as described in the 2009 experiment. There were 28 treatments evaluated. BH1 at 15, 10 and 5%, 10%, pelargonic acid (Scythe™) at 10% v/v, (Gowan Co., LLC, Yuma, AZ) and Munger Horticultural Vinegar Plus (20% acetic acid (Engage Agro, Guelph, ON) were applied to each of the three barks for a total of 15 treatments. Scythe was also applied directly to the soil around the plants. Two other vinegars 200 Grain Vinegar (similar to that used in the 2009 trial from the Ohio State University, Food Science Department) and WeedPharm™ (20% acetic acid) at 10% v/v (Pharm Solutions Inc., Port Townsend, WA) were applied to the soil and to each mulch for eight additional treatments. The final four treatments consisted of the three barks alone and a control (no mulch, no chemical).

Results and discussion. Five of 28 treatments evaluated provided efficacy ratings at or above commercially acceptable $\geq$7 (Fig. 20) at 50 DAT, 200 grain Vinegar on Hardwood bark, the Engage Agro vinegar on Hardwood, Scythe applied to any of the three barks with cedar or hardwood slightly better performing than pine. The BH1 at 10% on hardwood from the 2009 experiment had a rating of 6.8 which was not significantly different than the treatments with ratings of seven. At 35 DAT (data not shown) the BH1 at 10% on hardwood had an efficacy rating of 7.0. The WeedPharm, the 200 grain vinegar and the Scythe applied directly provided less than 50% of their efficacy when combined with bark. At the initiation of the trial, we assumed that the three horticultural vinegars would perform the same as each was 20% acetic acid; however, at 35 and 50 DAT there were significant differences in performance. The best horticultural vinegar is the Munger, especially with hardwood bark. The least efficacious vinegar with bark was the WeedPharm. The performance of the Scythe as a bio-herbicide combined with any bark type was a surprise. We had no previous evidence to indicate Scythe would combine well with bark to provide residual weed control. Although the BH1 did not perform as well as in 2009, it was still in the top six treatments for 2010. The field conditions of 2010 were a more stringent test for the bio-herbicides than the containers of 2009. Weed pressure was extremely high as indicated by the control phytotoxicity rating at 50 DAT (3.4

rating). The BH1 10% on hardwood merits further testing in field conditions due to its performance in 2009 and the 2010 evaluations.

Of the six most efficacious treatments, only one, Scythe on pine, provided a phytotoxicity rating above commercially acceptable ≤ 3. Five additional treatments were phytotoxic (≥ 3): WeedPharm direct, 200 grain vinegar direct, DU 10% on pine, 200 grain vinegar on cedar and the control (data not shown).

Fig. 19. Three bark types, (A) Hardwood bark (40% bark) (a composite of Oak, Poplar and Maple); (B) Cedar bark (bark and wood) (Eastern White Cedar); and, (C) Pine bark (70% bark) (a composite of White pine, Red pine and Jack Pine) obtained from Gro-Bark Ltd., Caledon, ON laid out approximately one inch thick before application of bio-herbicides.

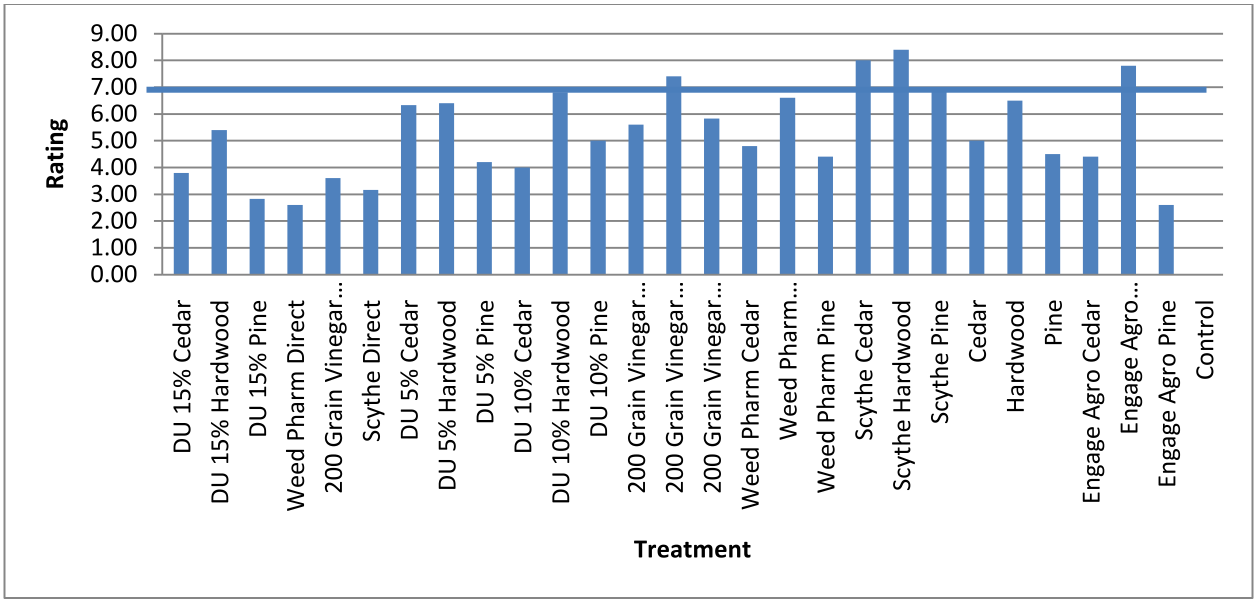


Fig. 20. Efficacy evaluations of the three bark types (Pine, Hardwood and Cedar bark) from Gro-Bark Ltd., Caledon, ON at 50 days after treatment (DAT) and bio-herbicide treatment (BH1 or DU) applied at three concentrations (5%, 10% or 15%) to the three barks. Efficacy ratings of weed control ranged from 0 (no control) to 10 (complete control) with ≥ 7 being commercially acceptable.

Conclusions:

Munger Horticultural Vinegar Plus and Scythe should be evaluated further on various barks especially hardwood, as these were the best treatments in the 2010 evaluation (Fig. 21). The BH1 plant extract or DU 200ml at 10% due to its high efficacy and low phytotoxicity warrants further examination with different carriers and perhaps surfactants. More testing with other alleopathic plant extracts could also be performed.

Fig. 21. Efficacy of Scythe applied to Hardwood bark obtained from Gro-Bark Ltd., Caledon, ON at 50 days after treatment (DAT). Note no weeds growing in the plot but many weeds growing out over the plot from the sides.

Characterizing the propagule-seed bank at Michigan nurseries

Principle investigators: Dr. Hannah Mathers and Luke Case

There is a need to develop more data regarding plant groups (e.g. deciduous trees, value, acreage and pests) to help quantify the impacts of Invasive Alien Species, trade (etc.) on U.S. nursery stock. In this project, we will discover whether nursery sites are increasing the frequency of weedy and/or invasive plants *into* natural areas and if certain practices are also responsible for increasing spread. We hypothesize that utilizing standard weed control programs [glyphosate, DNA's, and triazines (in nurseries only)] will give rise to higher frequencies of viable propagules than sites practicing newer IPM approaches: alternating MOA's, utilizing combinations of control (i.e. mulches, physical controls, chemical controls, etc.) and weed scouting.

Propagule banks will be characterized at 4 sites: two representative (defined by plant palette) field nursery sites in MI, Lincoln Nurseries (Grand Rapids, MI) and Zelenka Nursery (Grand Haven, MI), and two natural areas (within a half-mile radius of these nursery). The number and species composition of seeds and other propagules of potentially invasive and noxious weed species in the soil propagule-bank will be sampled during early fall (after most seedlings have emerged) using methods described by Cardina and Sparrow (1996) at each site. Randomly chosen ten 1-meter^2 plots at each site including five plots "on-site" in active nursery fields and five plots in "wild areas" bordering the nurseries were taken in Sept. 2010 (Fig. 22A). In each of the plots, actively growing plant species were identified, their presence recorded and multiple soil cores were taken to a depth of 25 cm to obtain approximately 1.5-L of soil per plot. Soil samples were taken to a greenhouse at OSU to grow the propagules (Fig. 22B).

Fig. 22 A. One-meter^2 plot at Lincoln Nursery in an active nursery field taken Sept. 2010. **B.** Growth of the propagules from one-meter^2 being identified and counted at Ohio State University, HCS Greenhouses, Columbus, OH.

Plants were identified, counted, and removed. Correlations of actively growing species between the nursery fields and wild areas were performed. Correlations of species obtained from soil samples growing in greenhouses at OSU have not yet been evaluated as emergence of all species will not be complete until spring. The evaluation of the propagule bank at Michigan nurseries compared to Ohio and Ontario nurseries will continue in 2011. Several years of data need to be collected to conduct a meaningful analysis.

Results and Discussion. At this point in the study, there is no evidence of a correlation between the wild areas and the cultivated areas at either nursery evaluated (Fig. 24). This indicates that nursery field weed infestations are not occurring from the surrounding area or are nursery species grown invading into surrounding areas. Weed diversity is much higher at Lincoln Nursery than at Zelenka in their cultivated areas (Fig. 24). This could be a possible indication of more herbicide usage at Zelenka Nursery. Elsen (1990) found a link between increased herbicide use and reduction in weed diversity on farm land. In addition to the loss of weed diversity at Zelenka, the main species that now predominate are very resistant to ornamental weed control programs, such as mugwort (*Artemisia vulgaris* L), creeping yellow field cress (*Rorippa sylvestris)* and Red Stem Filaree (*Erodium cicutarium)* which were only found at Zelenka. Six species were found in greatest frequency: at both sites: mugwort, found at 100% of Zelenka nursery cultivated sites; Erodium, found at three Zelenka cultivated sites and one wild site; marestail *Conyza canadensis*, found at 2 Lincoln cultivated, one Lincoln wild, and three Zelenka cultivated sites; dandelion, found at 2 Lincoln cultivated and four Zelenka cultivated sites; chickweed, found at 3 Lincoln cultivated, two Lincoln wild, and two Zelenka cultivated sites; and purslane found at 5 Lincoln cultivated and one Zelenka cultivated sites (Fig. 24). Four species of greatest concern are highlighted below.

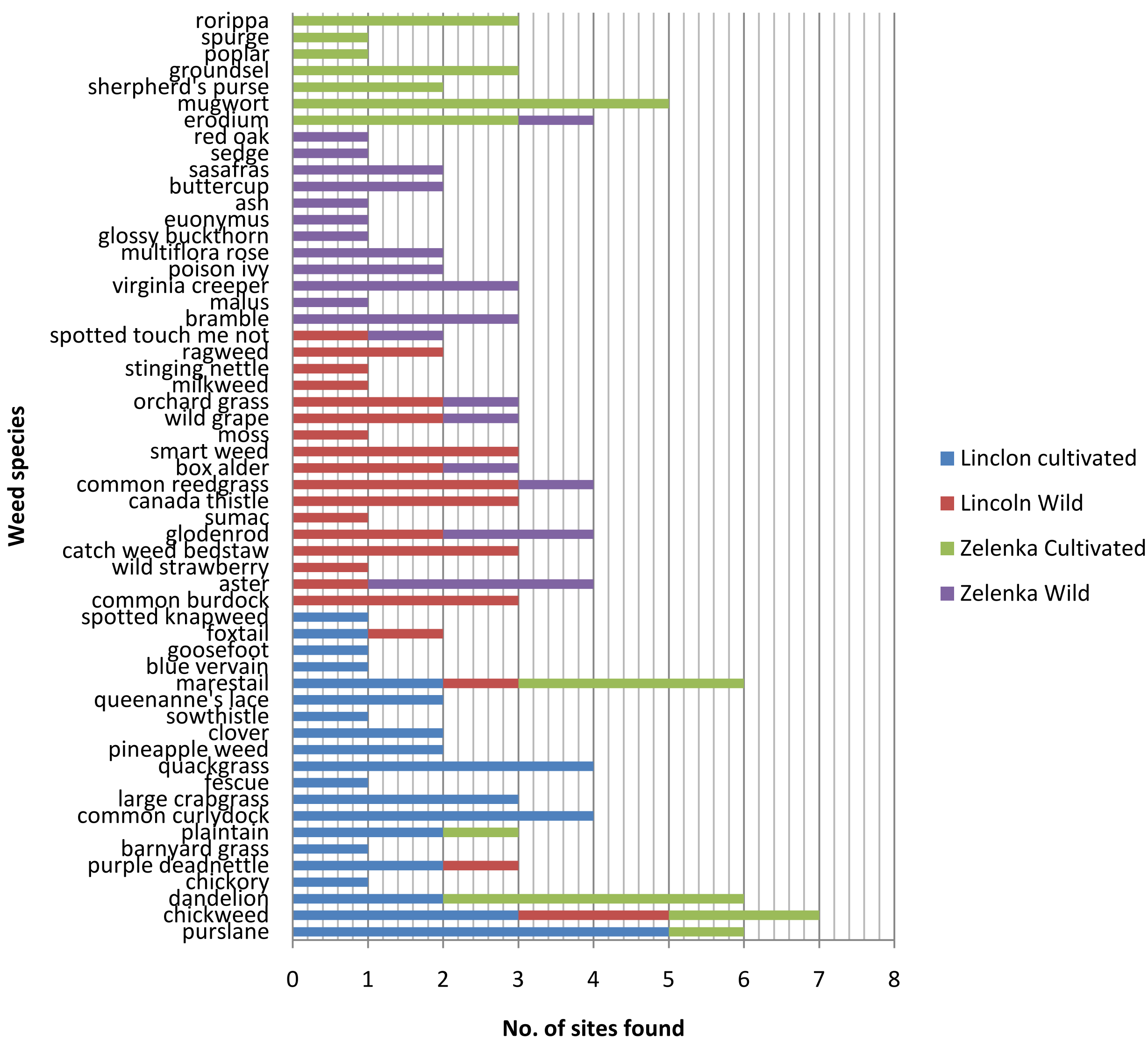


Fig. 24. Weed species identified at field nursery sites in MI, Lincoln Nurseries (Grand Rapids, MI), Zelenka Nursery (Grand Haven, MI), and natural adjacent areas. The species composition of invasive and noxious weed species on the site were sampled during early fall (after most seedlings have emerged) using methods described by Cardina and Sparrow (1996) at each site.

Creeping Yellow Field Cress or Kik (*Rorippa sylvestris)*

Creeping yellow field cress or Kik (*Rorippa sylvestris)* (Fig. 25A), a perennial that spreads by rhizomes (Fig. 25B) is unlike marsh yellowcress (*Rorippa islandica*), an annual, creeping yeIlow field cress which is more familiar to MI growers. A three-centimeter piece of

Kik can make 2000 plants in one year (C. Elmore, personal communication). Unfortunately, *R. sylvestris* can also cross with the annual *R. islandica* increasing its ability to spread and reproduce. The leaves of Kik are more finely cut than those of marsh yellowcress (Uva et al. 1997). It overwinters as a rosette of finely lobed leaves (Fig. 25A). The leaves are alternate and pinnatifid with 3-7 irregularly toothed lateral lobes and a larger terminal lobe (Uva et al. 1997). It tolerates a wide range of soil types and conditions, but is often found on heavy, wet or poorly drained fields. Suggested control is a 2, 4-D product + Gallery (isoxaben). Casoron (dicholbenil) at 2 to 4 lb ai /ac is another suggestion; however, both of these controls need to be used with extreme caution around nursery stock due to potential phytotoxicity issues. Check the label carefully for stock tolerance and restrictions. For example, do not apply Casoron when soil temps are above 16°C or on sandy soils or soils with less than 2-3% organic matter. 2, 4-D products are broadleaf postemergence weed killers and generally only used in non-crop nursery areas, never as over-the-top applications and with extreme caution even as directed sprays.


Fig. 25A

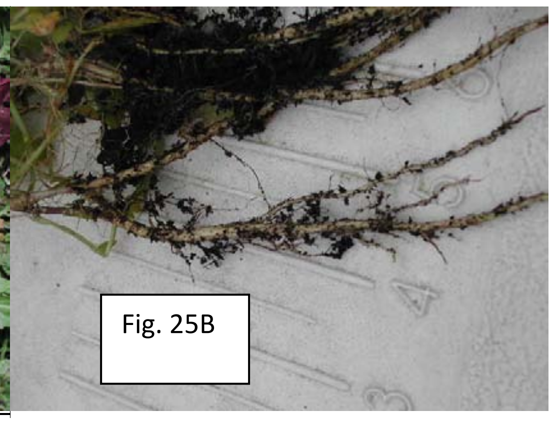


Fig. 25B

Mugwort or false chrysanthemum (*Artemisia vulgaris* L.)

Mugwort (*Artemisia vulgaris* L.) is a non-native perennial aster that has naturalized in parts of Canada and much of the eastern U.S. Mugwort foliage appears similar to common ragweed (*Ambrosia artemisiifolia* L.) and ornamental chrysanthemums (*Chrysanthemum* spp.). Unlike cultivated chrysanthemums and common ragweed, the lower surfaces of mugwort leaves are covered with a dense, silver-white pubescence (Fig. 26). Mature *A. vulgaris* stems, which can grow 2 m (6 ft.) tall, yield rankly aromatic flower heads in panicles of composite flowers, each consisting of 15 to 30 greenish-yellow disk-shaped florets, in late summer. Seed set is variable, an attribute of climatic factors. At optimum, individual plants may generate 200,000 seeds in a season. In the eastern U.S., few seeds are viable. Weed dispersal in nurseries and landscape plantings occurs primarily by rhizomes transported on contaminated cultivation equipment and ornamental nursery crop plants. Once established, mugwort rhizomes gradually expand outward from the source, excluding other plants and forming a dense, monotypic stand (Fig. 26). Mugwort is extremely adaptable to soil and climatic variation, extending across 56 countries. It has been named one of the 10 most problematic weeds in nurseries of the eastern U.S.

Fig. 26. Mugwort infested boxwood field at Zelenka Nursery, summer 2010. The two rows to the left have been sprayed with SedgeHammer causing a stunting effect discussed above in Objective 2, p.16.

Red Stem Filaree (Erodium cicutarium)

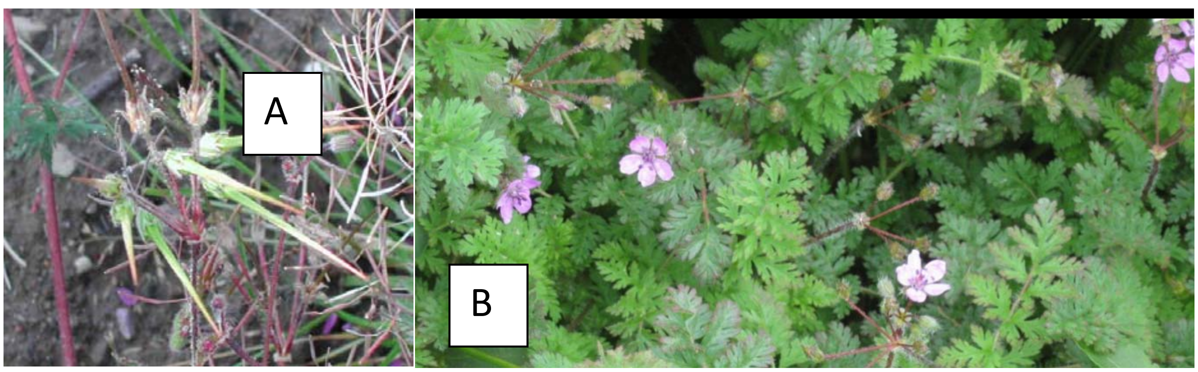


Fig. 27. Erodium infested field at Zelenka Nursery, summer 2010.

Red stem filaree is also known as filaree or common storksbill (Uva et al. 1997). It is a winter annual or biennial that overwinters as a prostrate basal rosette. Stems elongate the following spring and can reach 10-50 cm in height. Leaves and stems are often reddish (Fig. 27). The flowers are pink to purple and 5-8 mm long (Uva et al. 1997) (Fig. 27B). Each flower produces a beak-like fruit that separates into 5 sections (mericaps) when mature (Fig. 27A). Each section consists of a seed and spirally twisted hairy tail that coils under dry conditions and uncoils when moist (Uva et al. 1997). This tail creates a corkscrew action with the seed digging itself into the ground. It is usually found on dry, sandy soil and is a problem in many perennial crops including nursery, orchards, and Christmas trees. Nursery growers in other states have found success using a combination of Goal and DNA herbicides, such as OH II (oxyfluorfen + pendimethalin) (C. Elmore, personal communication). In a search of C&P Press, Surflan (oryzalin) and Snapshot (isoxaben + trifluralin) were the only two DNA and DNA containing herbicides (respectively) that were registered for use. OH II did not appear as a registered product. Another suggested control is Goal 2XL (oxyfluorfen) applied in the fall. Since filaree is primarily a winter annual this approach has worked (C. Elmore, personal communication).

Again, check the label carefully for stock tolerance and restrictions as Goal can be quite injurious to many nursery crops and is quite volatile. Gallery 75DF (isoxaben) applied in the fall is another suggestion.

Horseweed/ Marestail (*Conyza canadensis*)

Horseweed (*Conyza canadensis)* is becoming an increasing problem in many crops across the Midwest. Horseweed is developing resistance to a number of herbicides, including glyphosate. Horseweed is an annual/biennial that reproduces by seed that has a pappus allowing it to be windblown for up to a mile. Dimension, Gallery, Snapshot, OHII, Regal O-O are all options to control horseweed. Marestail can follow a winter annual (emerging late August) or a summer annual (emerging March) life cycle; therefore, it can emerge in either fall or spring. Fall emerging Marestail will have a more extensive root system than those that emerge in the spring (Johnson and Nice, 2003). The more established root system of the fall emerging plants make them more difficult to control because they can resprout from meristems in the lower part of the stem and roots. Therefore, systemic postemergence herbicides are required in "high enough quantities" to inhibit this resprouting (Johnson and Nice, 2003). SureGuard (flumioxazin) is also effective on Marestail as a preemergence. SureGuard also offers an alternative mode of action and is best used for this weed as your fall preemergence in nursery fields. Unfortunately, SureGuard is not registered for use in the landscape. It is registered for use in deciduous trees in nursery fields and containers.

Conclusions. The four weed species reported above are becoming serious weed problems in MI nurseries that are using standard herbicide-based weed control programs (glyphosate, triazines, and DNA's). The standard programs are actually increasing the weed populations of these species by releasing them from competition from other weeds. Research is needed to evaluate a variety of preemergence herbicides alone, or in combination, that might control these three species.

Greening the Highways: Increasing survival of out-planted trees in stressful environments

Principle investigators: Dr. Hannah Mathers, Lynne Sage, Michele Bigger and Luke Case

Significance to the industry. The first long-term out-plant survival tests in North America evaluating various nursery production and highway planting methods began in May 2010 at six sites, three at the 401/Allan Expressway and three at 427/401 in Ontario. In most states and provinces including the Ministry of Transportation in Ontario (MTO) 2 Mn^+ trees/ annum are budgeted to be planted along highways but less than 10% are estimated to survive. This project is the first to investigate how out-plant survival in these stressful roadside environments may be increased. As a result of this project greater attention has been placed on the environmental benefits that greening highways can accomplish. The MTO hired a new landscape architect in 2010, instructed to place a high priority on this research project and future research sites. Increased attention and increasing survival of roadside plantings will mean a new market for millions of Ontario grown tree liners. As the project progresses a PhD student (Michele Bigger) from Ohio State University, hired in 2010 will be documenting the environmental, economic, and health, benefits derived from planting highways. There have been several programs, presentations and articles completed regarding this research. On September 16, 2010 a Vineland, LOHTA Research Day was held at the Vineland Research and Innovation Centre (VRIC), 4890 Victoria Ave. N. Vineland Station, Ontario, Canada with hands-on tree liner production training, CD's and project summaries distributed to over 65 participants. On September 14, 2010 the VRIC retractable roof greenhouse (RRG) and liner production project was a tour stop for the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) bus tour with over 130 people attending. In August, the project was video-taped as a featured project in the OMAFRA Growing Forward – Farm Innovation Program. In July the project was also featured by AdFarm as a story for the OMAFRA, Growing Forward Fall issue newletter, p. 12. The project was also highlighted in an Ohio Florist Association (OFA) tour on July 10 in Columbus, OH. The project was also featured on Sept 21, 2010 at a Celebrating Vineland self-guided tour and research showcase event with over 100 invited guests. A presentation was given to 60 attendees of the 4th Annual Shade Tree Short Course in Ames Iowa, USA in Feb. 2010. A poster was also presented regarding the project at the American Society of Horticultural Science in Palm Desert, CA in August, 2010 and the 2010 IPPS Eastern and Western Region.

2. Introduction and Literature Review. In 2010 we have conducted three studies for this report. First, comparisons of out-plant survival of four landscape trees (*Acer freemanii, Celtis occidentalis, Betula papyrifera* and *Gleditsia triacanthos* grown in a RRG (VRIC), gutter vented greenhouse (Willowbrook, Fenwick, ON) with four levels of GeoHumus media amendments during production, and two species grown in containers from (Earthgen) planted at the six sites listed above. Mortalities for all species planted at the six sites were also performed, soil samples collected and analyzed and individual tree mapped performed for long-term referencing. Measures and mortality data will continue to be collected until April 2015. Second, GeoHumus media amendments during production and at time of planting were also completed for *Cercis candensis* at VRIC. Third, a comparison of two standard container substrates, Gro-Bark and ASB Greenworld on three species of tree liners, in three production environments, a peaked -RRG, a flat-roof-RRG and outside on a gravel pad was also conducted April to November of 2010. By 2030 only 10% of the world's forests will remain at our current rate of cutting. Today 80% of Canadians and Americans live in the urban environment and are increasingly concerned about the health of the "urban forest." The urban forest is the only forest most people will ever see and in future generations it will be the only forest. Besides being very efficient oxygen generators, one mature tree in one day produces enough oxygen for four people/day; trees are also our air purifiers in the environment. One tree removes 7,000 dust particles per liter of air per day. Along the roadside a 10% cover of trees will decrease ozone levels by 4 ppm (parts per million). One sugar maple (12" DBH) along a roadway removes in one growing season 60mg cadmium, 140 mg chromium, 820 mg nickel, and 5200 mg lead from the environment (Coder, 1996). One urban park or 212 hectares of tree cover can remove 9 lb. of nitrogen dioxide, 6 lb. of sulfur dioxide, and 2 lb. of carbon monoxide daily or a $136/day value based upon pollution control technology, plus 100 lb. of carbon (Coder, 1996). Trees close to the highway are 9% more efficient at absorbing pollutants than at a distance. All of these great benefits listed above of trees are only achieved if the tree makes it to maturity or $\geq$20 years. A mature tree absorbs 70 times more air pollution and carbon dioxide than a newly planted tree. Obviously -- the best time to plant a tree was – 20 years ago. The second best time is now! Our rate of tree planting, however, as considerably out of balance with our need for trees is not the bigger issue. Tree survival is the issue. The average life-span of a downtown urban tree is less than 10 years (USDA Forestry Service, 1998). McPherson and Simpson (1999) found that less than 60% of trees planted in low care (non-stressful sites) urban environments will survive the first five years. Information on increasing out-plant survival is greatly needed. This project will result in advancement of the nursery/ landscape industry economically and environmentally.

3. Presentation of Results and Discussion

A. Comparisons of out-plant survival of four landscape trees at 401/427 and 401/Allen Expressway. Of the 5072 deciduous trees planted at the six sites in May 2010, 525 were from the Vineland, and Willowbrook Nurseries. Two other sole source suppliers were identified for the project, Earthgen Tree Nursery (Wainfleet, Ontario) and **Braun Nursery Limited (**Mount Hope, Ontario). The remaining plant material was supplied from a variety of sources. All plants were densely planted on 6 ft. centers. Trees supplied by VRIC compared to Willowbrook or Earthgen trees are showing superior height growth (Fig. 1) and superior caliper growth to Willowbrook (data not shown). Vineland RRG grown liners are also showing reduced mortality compared to all plant sources (data not shown). The O% GeoHumus is the best treatment pooled of the two nurseries of origin, the six sites and the four species evaluated (Fig. 2). There is a significant difference with the six sites for caliper growth (Fig. 3) and height (data not shown) with two of the sites at the 401/427 (#3, 2) and one of the sites at the 401/Allen (#5) providing superior growth.

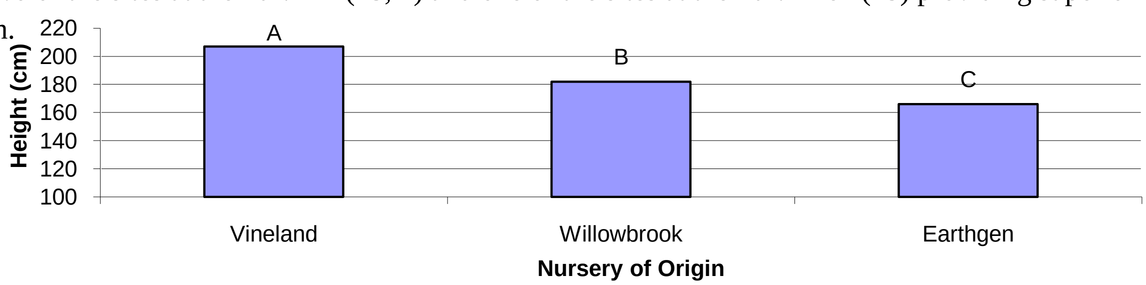


Fig. 1. Height growth over six planting sites at 401/427 and 401/Allen and six species.

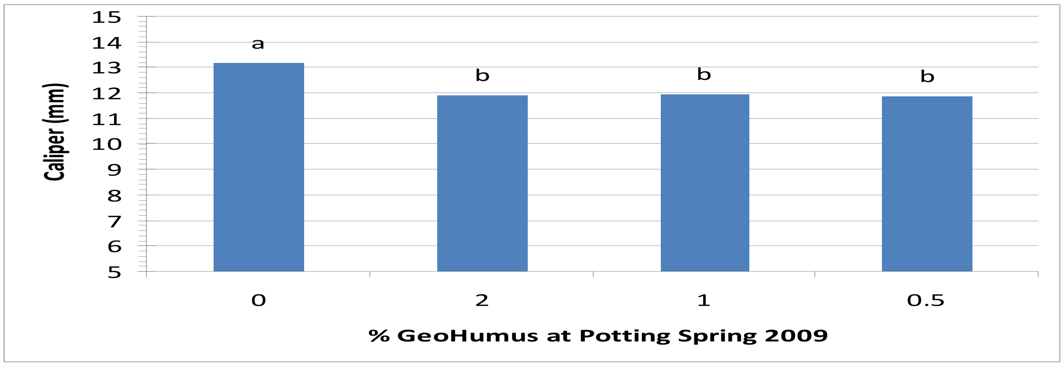


Fig. 2. GeoHumus treatments during production effecting trees in out-plant pooled over six sites at 401/427 and 401/Allen, six species and three nurseries, Vineland, Willowbrook and Earthgen.

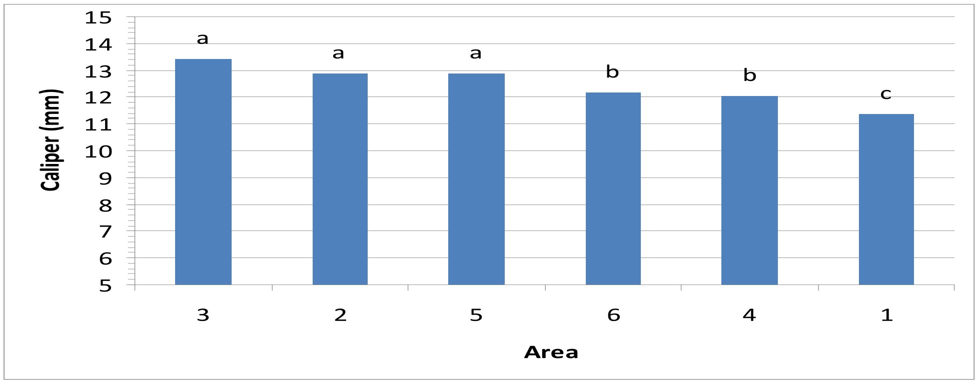


Fig. 3. Caliper measured over six species and three nurseries for the six sites at the 401/427 (Site area #1, 2 and 3) and 401/Allen (Site area # 4, 5 and 6).

B. GEOHumus media amendments during production and at time of planting at VRIC. GeoHumus that was added to plants at 0, 0.5, 1 and 2% in production was still having an impact on height (Fig. 4) and caliper (Fig. 5) after 12 month in containers and seven months in the field. The addition of GeoHumus made in June, 2010 at time of field planting at the Vineland Research and Innovation Centre (VRIC), Victoria Rd. Farm was non-significant.

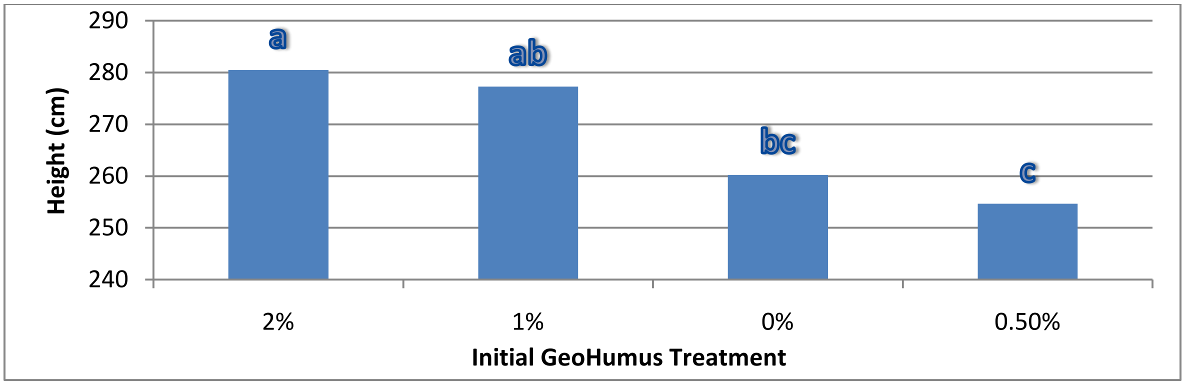


Fig. 4. Impact of GeoHumus added to Redbuds at 0, 0.5, 1 and 2%, 12 month earlier in containers and after seven months in the Vineland Research and Innovation Centre fields on height.

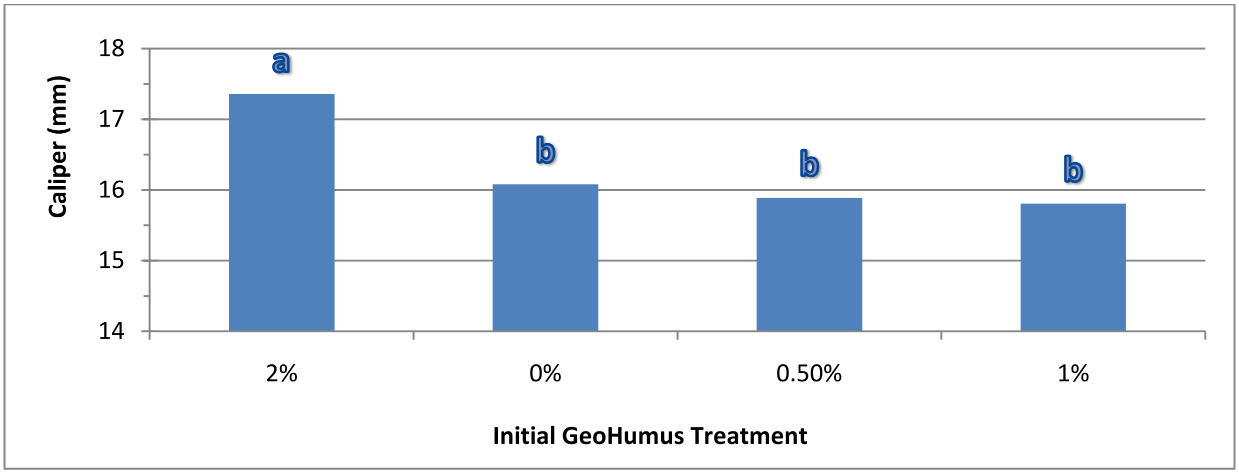


Fig. 5. Impact of GeoHumus added to Redbuds at 0, 0.5, 1 and 2%, 12 month earlier in containers and after seven months in the Vineland Research and Innovation Centre fields on caliper.

C. Comparison of two standard container substrates, four levels of GeoHumus and three production environments. The best GeoHumus substrate amendment level for height growth was 1% for *Syringa amurensis* and 2% for *Betula jacquemontii*. For *Acer rubrum* 0, 0.5 or 1% provided the same height growth and were better than 2% (Fig.6). GeoHumus was non-significant for caliper growth. Species height and caliper was significantly impacted by production environment. *Acer rubrum* height and caliper were largest in the peaked-RRG (Fig. 7 and 8, respectively). *Betula* caliper was best in the peaked-RRG (Fig. 8); however, *Betula* height in either RRG environment was superior to outside (Fig. 7). *Syringa* caliper was unaffected by environment (Fig. 8); however, height in either RRG environment was superior to outside (Fig.7). Over all species and environments the ASB Greenworld was the superior substrate compared to the Gro-Bark substrate (data not shown). Even though the two mixes were identical at 60% bark, 30% sphagnum peat, and 10% compost, porometer data indicated they had similar air and water holding capacity, but the Gro-Bark had significantly greater density (data not shown). Indicating the Gro-Bark mix has some portion of mineral soil (either clay or sand) in with it having a possible impact on increasing water holding capacity. The influence of the substrate type was greatest on *Betula* (Fig. 9).

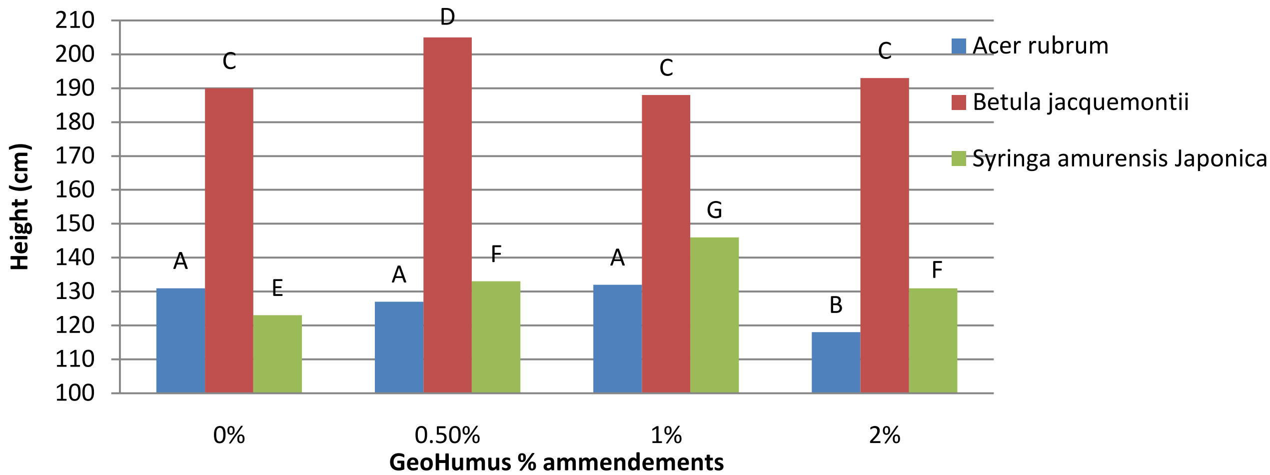


Fig. 6. GeoHumus by species interaction on height of *Acer rubrum Betula jacquemontii* and *Syringa amurensis meas*ured in November, 2010 at the Vineland Research and Innovation Centre combined over three environments, peaked-retractable roof greenhouse (RRG), flat-RRG and outside in #3 containers and combined over two substrates.

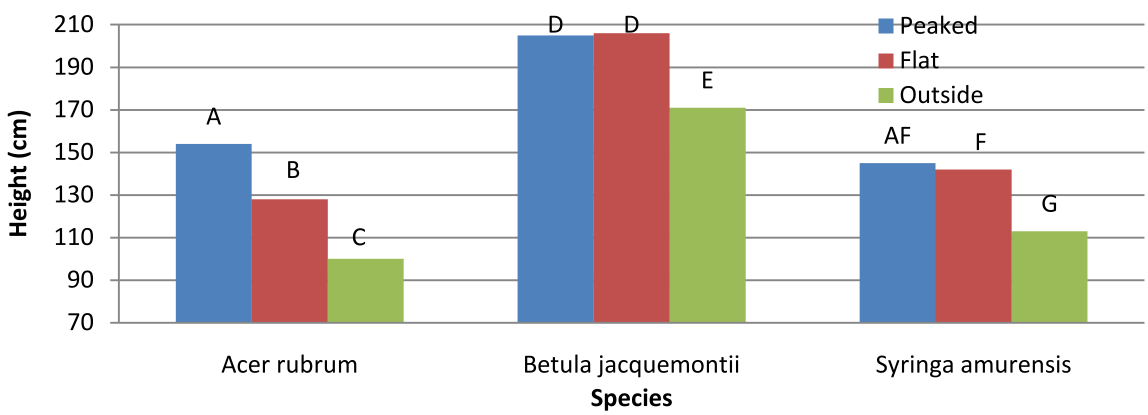


Fig. 7. Environment by species interaction on height of *Acer rubrum*, *Betula jacquemontii and Syringa amurensis* measured in November, 2010 at the Vineland Research and Innovation Centre combined over four GeoHumus levels and two substrates growing in a peaked-retractable roof greenhouse (RRG), flat-RRG or outside in #3 containers.

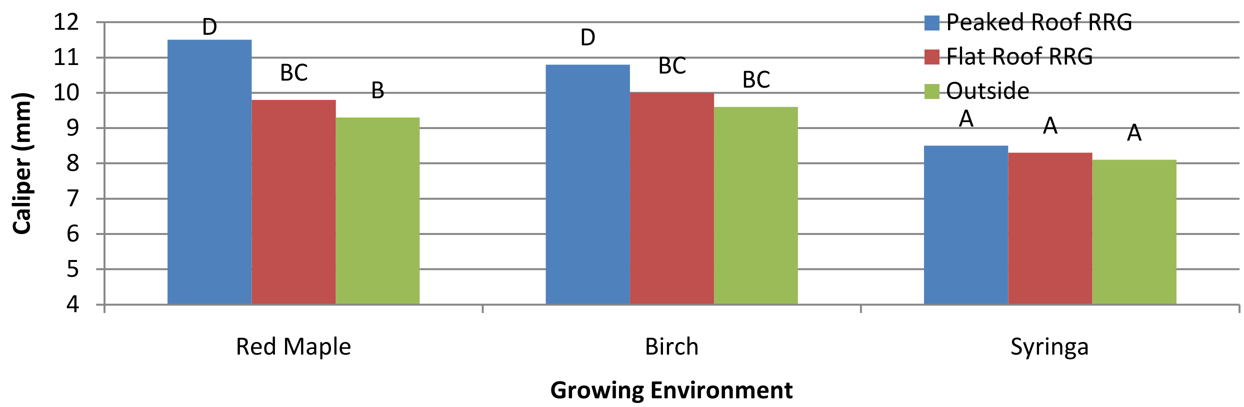


Fig. 8. Environment by species interaction on caliper of *Acer rubrum Betula jacquemontii and Syringa amurensis* measured in November, 2010 at the Vineland Research and Innovation Centre combined over four GeoHumus levels and two substrates growing in a peaked-retractable roof greenhouse (RRG), flat-RRG or outside in #3 containers.

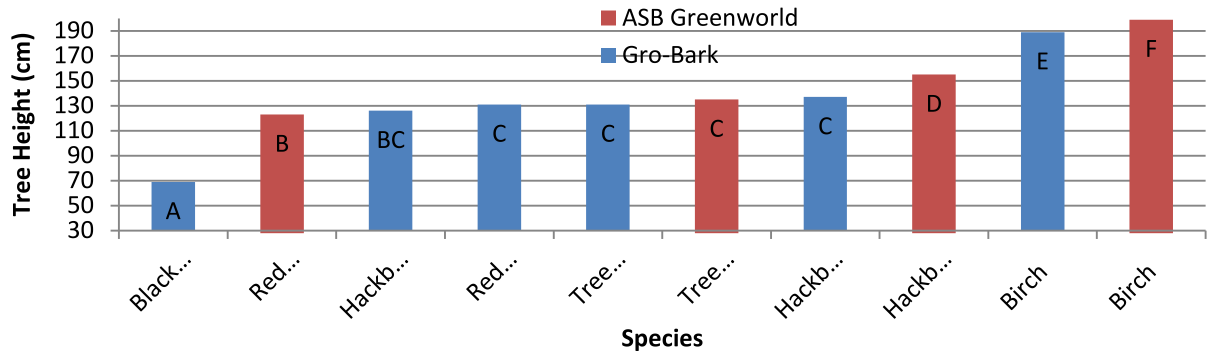


Fig. 9. Substrate by species interaction on caliper of *Acer rubrum, Betula jacquemontii, Celtis occidentalis, Syringa amurensis and Quercus* measured in November, 2010 at the Vineland Research and Innovation Centre combined over four GeoHumus levels and three environments growing in #3 containers.

Conclusions. GeoHumus as in the 2009 study has an influence on plant growth in production dependent on species. If the GeoHumus by species interaction is significant in production, this affect will continue to be significant in the field regardless whether GeoHumus is added at field planting or not. The peaked-roof RRG continued as in the 2009 experiment, to produce trees with greatest heights and calipers. The influence of the peaked-RRG production environment is also continuing to increase survival and growth at the 401/427 and 401/Allen sites seven months after out-planting. Preliminary results testing one nursery substrate compared to the conventional Gro-Bark media used in Ontario, indicates further studies to identify substrates suited to the Ontario industry and for improved out-plant survival are warranted. This research will be continuing in 2011 with planting of the 2010 crop along highways with the continued support of the LO Growers Committee and FIP.

References

- American Forests Magazine, 2000, "Trees Tackle Clean Water Regulations", Summer 2000.
- American Forestry Association. 1992. Tree Facts: Growing Greener Cities.

- Coder, Dr. Kim D., “Identified Benefits of Community Trees and Forests", University of Georgia, October, 1996.
- USDA Forestry Service. 1998. *www.na.fs.fed.us/spfo/pubs/uf/briefs98/ufassess.htm*

Effects of Various Planting Depths and Root Disturbances on Four Commonly Grown Nursery Trees

Principle investigators: Kyle Daniel, Dr. Hannah Mathers, and Luke Case

Significance to the industry. Basic knowledge of plant physiology indicates that a healthy root system is very important to a plant's health and survival. Some would argue that the root system is the most important anatomical structure to the plant's health and survival. There has been much debates over the root systems in production and outplant settings. Two of the debated practices include planting depth and differing methods of treating pot-bound roots.

Planting depth of nursery and landscape trees has been a debated topic over the last several years. Researchers and educators have told growers and landscapers not to plant the tree too deep or mulch deep around the trunk of the tree. Planting deep can cause numerous problems, such as various types of fungal diseases. What has begun to happen is that trees are being planted too high. According to Pellett (1971) (Chandler, 1954; Pellett and White, 1969; Weiser, 1970), within the same plant, the root system is considerably less cold hardy than that of stem tissue under field conditions. Given this, if a plant's roots are exposed, due to planting too high, the plant will have a greater chance of not overwintering properly and could lead to death.

An important factor considering planting depth is knowing where the root shank is located. The root shank is the area in which stem tissue and root tissue converge. Stem tissue and root tissue have very different anatomical features, with the greatest being; stem tissue having the vascular system towards the outside and the cortex inside, and the root tissue having the vascular bundle in the center with the cortex on the outside. With plants that are grown from seed, a root shank may be easier to observe than that with an adventitious root shank that came from asexual propagation techniques.

Pot bound roots are defined as having roots so densely matted as to allow little or no space for further growth (Merriam-Webster Dictionary, last accessed November 16, 2010). During times of active growth, if a plant is not out-planted or up-shifted, the roots will have filled the pot, and the growth of the plant will be severely stunted. Several methods have been utilized in the past, which include, cutting the roots, splitting the root ball, no disturbance, etc. with varying successes. This study looks at the various options for pot-bound trees.

The purposes of this study include: 1) What effect will depth of planting have on the overall growth of the plant. 2) What effect will depth of planting have on the overall hardiness of the plant. 3) What effect will four treatments have on pot-bound roots in upshifting.

Materials and Methods

Planting Depth

In the Spring of 2009 two species of oaks *Quercus acutissima* and *Quercus rubra* were planted into three gallon pots. There were two planting depths that the plants originated, planted at soil surface and planted deep. From these two, four treatments were imposed: seeds at soil surface/planted correctly, seeds at soil surface/planted high, seeds deep/planted deep, and seed deep/planted high. Plants were grown throughout the summer and overwintered in a flat roof cravo in the 3 gallon pots.

Plants were taken from the pots and were planted in the field on April 21, 2010 at The Ohio State University's Waterman Farm (Columbus, OH). The following four days included 4.47 cm of rain, so no irrigation was immediately applied. Irrigation was applied throughout the summer on an as needed basis based on rainfall observations. The plants were planted in a completely randomized designed with 1.54 meters between plants and 3.048 meters between rows. Plants were planted in the field at the depth that was in the pot, soil line to soil line. Grass was seeded via broadcast method at a rate of 60 lbs./acre between rows on April 22, 2010 with a blend of : creeping red fescue 48.73%, perennial rye grass 14.74%, chewings fescue 19.8%, and Kentucky bluegrass 14.55%. Fertilizer was applied at a rate of 200 lbs./acre around the trees in a .9144 meter x .9144 meter area with a Scotts Field Fertilizer ER of 33-3-6 on April 22, 2010. Trees were staked in the field to promote growth. A soil analysis was performed on April 28, 2010 with an analysis of pH of 7.2, LTI of 70, P 66 ug/g, K 352 ug/g, Ca 3227 ug/g, Mg 606 ug/g, and a CEC of 22.1. Weed control included two applications of glyphosate on May 5 and June 7 at a 5% solution. Tillage was performed on July 6, August 6, and September 30 with a 5 HP front-tine tiller. Mowing was performed on an as needed basis throughout the growing season.

Root Disturbance

Syringa reticulata and *Tilia cordata,* which were in one gallon pots in with roots that were pot-bound, were up-shifted on June 18, 2008 into 7 or 15 gallon pots. Plant height and caliper were obtained on June 18 and June 20, 2008, respectively. The media tat was used was a blend of pine bark, aggregate, and com-til. There were four treatments imposed on the two genera, which included; undisturbed, four cuts through the root ball at N,S,E,W, removal of one inch of the root ball around the pot, and washing off the media from the roots.

Plants were fertilized with a Scotts, controlled release 19-5-8 formulation. Irrigation was supplied via overhead sprinkler in the flat roof Cravo system. Plants were staked with 8 ft. bamboo stakes. Plants were evaluated at initiationPlants were arranged in a completely randomized design. Plants were harvested after final caliper and height measures were taken on November 7, 2008. Roots were taken from the trunk and dried in drying oven until dry. Weights were obtained at this time.

Data Analysis:

All 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 III Sum of Squares analyses was performed.

Results and Discussion

Through one season of growth and overwintering in the flat roof cravo, significant death occurred throughout both species of oak. *Q. rubra* was significantly more cold hardy than that of *Q. acutissima* pooled over all treatments (Figure 1). The Northern red oak's (*Q.* rubra) native range is from the eastern half of the United States and from Arkansas up into central Ontario Canada. The sawtooth oak (*Q. acutissima*) is native to Eastern Asia and has escaped into states from Louisiana and East and North to Pennsylvania. Although the sawtooth oak is usually more adaptable to adverse conditions than that of the Northern red oak, this study indicates that the Northern red oak is more cold hardy, in general, than the sawtooth oak.

Depth treatment also played a major factor in that seeds deep that were upshifted and planted deep sustained significantly less mortality than the other three treatments pooled over species (Figure 2). This would mean that the root shank would be below ground along with bark/stem tissue. The roots would have greater insulation provided by the media in which they were growing if the roots and stem were below media surface. This is after one season of growth. While plants are in the field, this could become problematic from the standpoint of disease.

In terms of height, the sawtooth oak started at the soil surface/planted deep and started deep/planted high were the two tallest interactions (Fig. 3). The sawtooth and red oak started deep/planted deep were the two shortest significantly with the treatment by species interaction. This could be due the deep/deep treatments not emerging as early and young tissue being photosynthetically active, thus making more photosynthate. This would, in turn, allow the plant to grow at a faster rate than the deep/deep treatments. Being there was an interaction regarding height, main effects are not presented.

Caliper of the trees pooled over species indicated that plants started deep/upshifted high being was significantly lower than the planted at soil surface/upshifted deep treatment (Fig. 4).

The root disturbance of *Syringa reticulata* and *Tilia cordata*, indicated that, at the $p<0.055$ level, *Tilia* with four cuts N,S,E,W had significantly greater caliper than that of *Tilia* that had the one inch removed from sides and bottom (Fig. 5). This would indicate that the species by treatment of *Tilia* increases caliper when no roots are taken away, as apposed to taking off the roots. There was no difference in height and dry weight. *Syringa* showed no significant differences.

Fig. 1: Death of *Q. rubra* and *Q. accutisima* pooled over treatments (seeds at soil surface/planted high, seed deep/planted deep, seeds at soil surface/planted deep, seed deep/planted high), overwintered in a Cravo at The Ohio State University, Columbus, OH

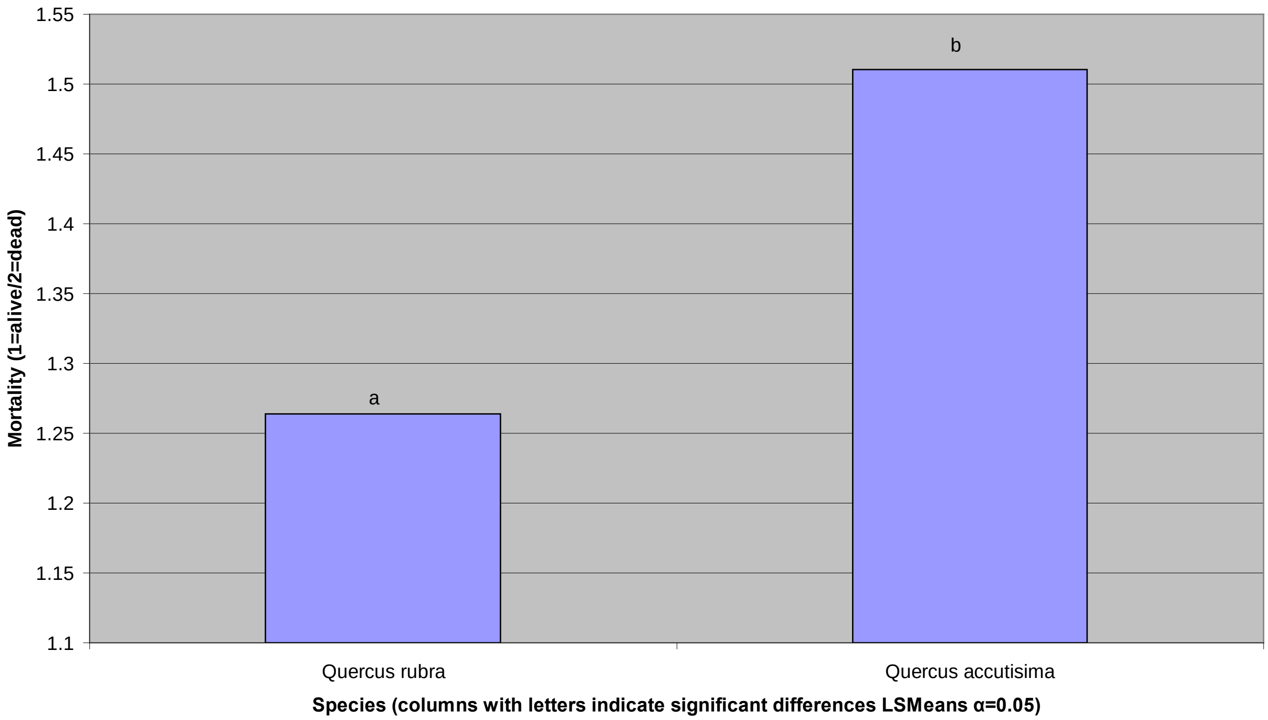


Fig. 2: Mortality pooled over *Q. rubra* and *Q. accutisima* after treatments imposed (seeds at soil surface/planted high, seed deep/planted deep, seeds at soil surface/planted deep, seed deep/planted high) at Ohio State University, Columbus, OH, 43210.

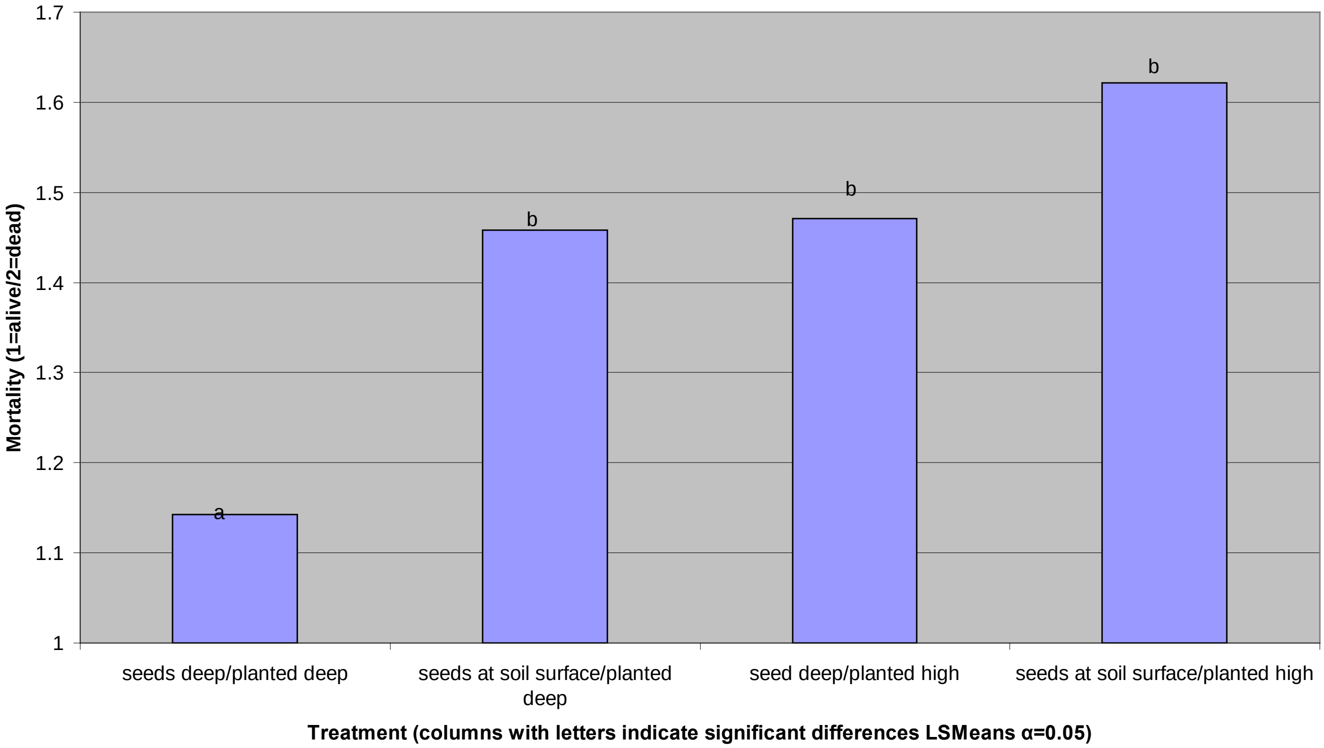
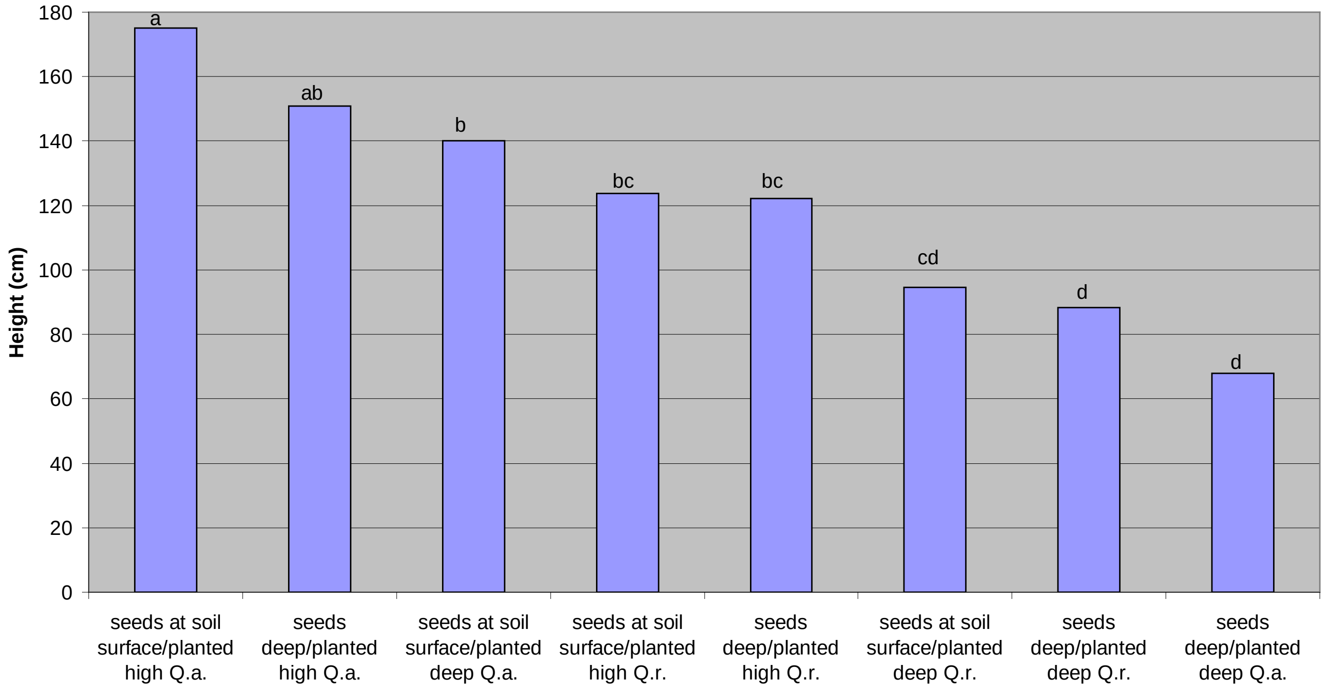


Fig. 3: Height of four planting depths on *Quercus rubra* and *Quercus accutisima* (seeds at soil surface/up-shifted high, seeds deep/planted high, seeds at soil surface/planted deep, seeds deep/planted deep) at Ohio State University, Columbus, OH.



Planting Regime/Oak Species (height x species interaction) (columns with letters indicate significant differences at the p>0.05 level)

Fig. 4: Caliper of four planting depths on *Q. rubra* and *Q. accutisima* (seeds at soil surface/upshifted high, seeds deep/planted high, seeds at soil surface/planted deep, seeds deep/planted deep) pooled over genera at Ohio State University, Columbus, OH.

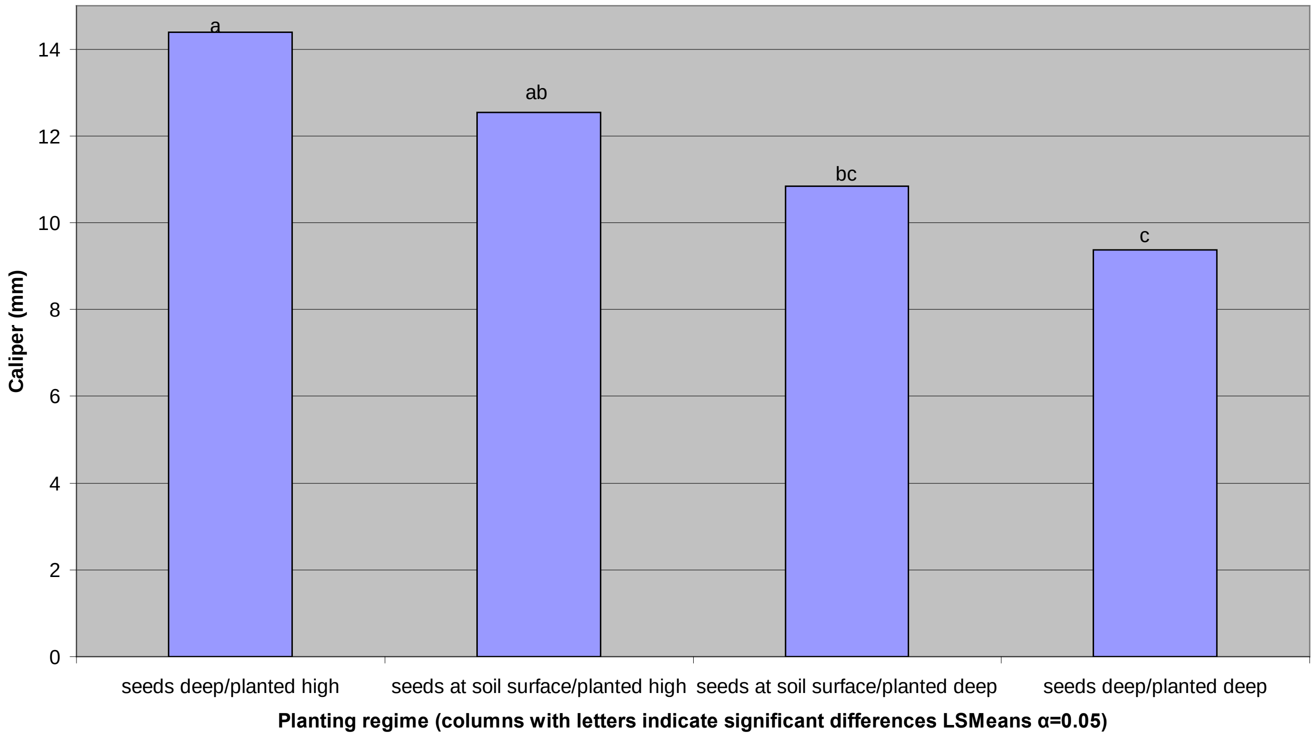
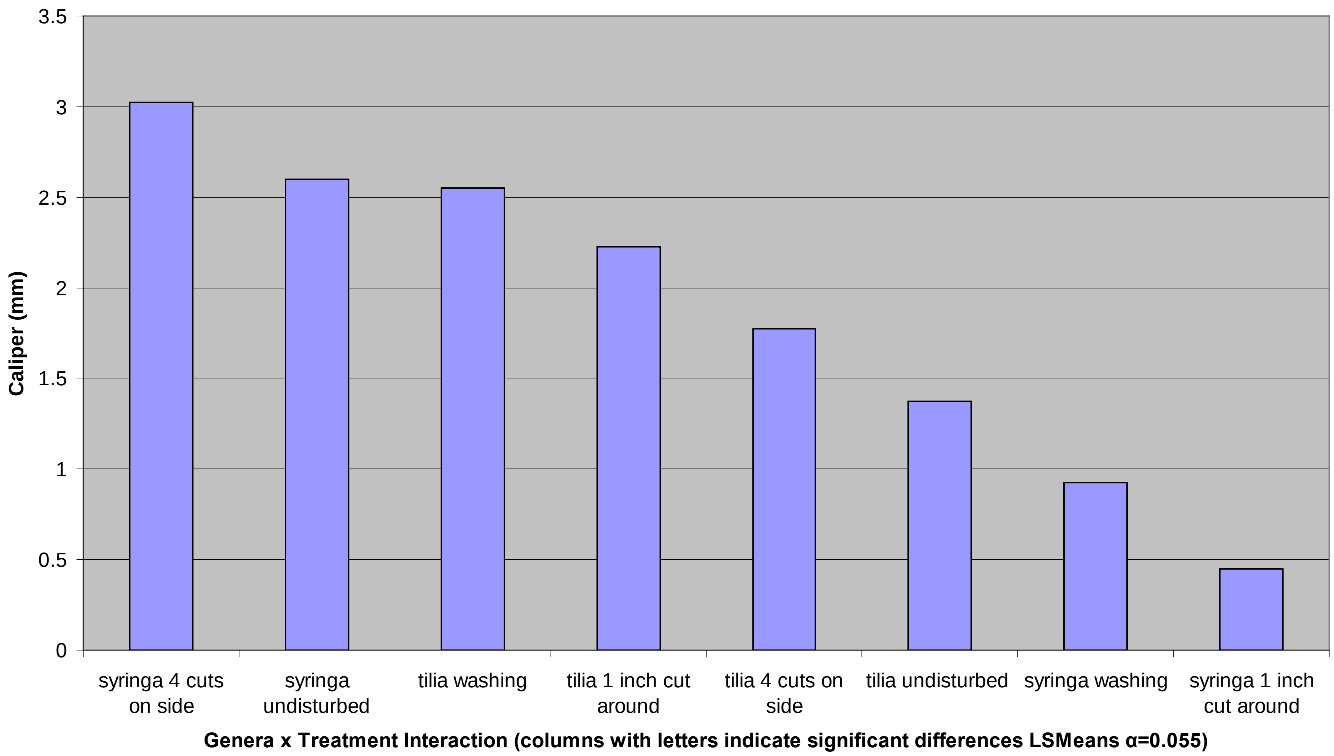


Fig. 5: Difference of initial caliper and final caliper of two Genera (*T. cordata* and *S. reticulata*) after root disturbance treatments(four cuts on side, undisturbed, washing, one inch cut around) at Ohio State University, Columbus, OH.



Double crop system for tree liners using Retractable Roof Greenhouses

Principle investigators: Dania Rivera and Dr. Hannah Mathers

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

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

Materials and Methods. Plants were grown inside the peaked-roof RRG (Cravo Equipment, Ltd., Brantford, Ontario, Canada) at The Ohio State University (OSU), Columbus, Ohio. The RRG was covered with a clear woven-polyethylene covering (RC02; Cravo Equipment Ltd., Brantford, ON, Canada). A MicroGrow controller (MicroGrow Systems, Temecula, California) operated the RRG roof and sidewalls according to external ambient temperature settings, closing roof and sidewalls when temperatures fell below 70° F during the day and 50° F at night between April to December (“summer” settings). From December to March (“winter” settings), the roof and sides of the RRG remained closed and a propane heater was activated at 28°F to protect the plants from freezing. The sides opened from December to March at 38 °F to prevent premature budbreak. From March to April, at two week intervals, temperatures were ramped from “winter” settings to “summer” settings. Plants were grown in 3-gallon, black round containers (Nursery Supply Co.) in a soilless mix (Kurtz Brothers Inc.) of 60% pine bark, 20% rice hulls, 10% sand, 5% composted sewage sludge (Com-Til, Lockbourne, Ohio) and 5% stone aggregate.

In order to double crop, trees were started in October 2007 and 2008 (fall plantings) and in June 2008 and 2009 (summer plantings). Plants were grown either October to June (fall plantings), June to October (summer plantings) or for one year, October to October (fall plantings) or June to June (summer plantings), before planting into a pot in pot (PIP) system or harvesting for data collection. October plantings either received bottom heat from December to March or remained at ambient temperature (AT) as the control. June plantings were grown only at AT. For each crop, three landscapes species grown from tissue culture (North American Plants, LLC, Lafayette, Oregon) were planted in the RRG. All plants were trained to a 5’ or 6’ bamboo stakes (A.M. Leonard, Inc.) with 0.5 inch diameter and attached to the stakes with grafting tape (A.M. Leonard, Inc.).

Fall 2007 planting. Red maple (*Acer rubrum* L. 'October Glory®'), littleleaf linden (*Tilia cordata* Mill. 'Greenspire®') and Avondale redbud (*Cercis chinensis* L.) were planted in the RRG in October 2007 (Table 1). All the trees species had a starting height of 3 inches. October plantings either receive bottom heat (BH) or remained at ambient temperature. Beginning in April 2008, plants either received a top dressing of controlled release (CR) fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scotts Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks. The same total nitrogen was delivered in the CR and the CR + LF treatments. Plants were arranged in a split plot design (main plot- temperature, subplot – fertilizer) with 4 replications. Thirty four plants per species per treatment were assigned per four treatments AT CR, AT CR+LF, BH CR, and BH CR+LF.

"Fall" irrigation (October to December) consisted of using sprinkler head irrigation 3 times per day (7:00am, 11:00am and 3:00pm) for 5 minutes applying approximately 1.7mm of total water per pot. During winter plants were watered as needed. From April to August ("Summer" irrigation) plants received 500 ml of water (per pot) in 3 events, 7:00 am, 10:00 am and 2:00 pm per day, using 1/8 inch spaghetti tubing (Roberts Irrigation Products, Inc., San Marcos, California) with Orange Mini Flow emitters with a 160° Spray pattern (SS-AG160LGN-100, Roberts Irrigation Products, Inc., San Marcos, California).

A random sample of plants was evaluated in December and April and measures of root volume were taken to measure effects of BH or AT treatments. Many Avondale redbud trees died during overwintering so the effects of BH or AT treatments could not be evaluated.

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

The measures were analyzed using PROC GLM with SAS software (SAS Institute, Inc., Cary, NC). Treatments were compared using least significant differences (LSD) with $\alpha = 0.05$. Unfortunately, due to plant loss during the experiment, there were not enough plants for a whole set of replications per treatment to be left in the RRG to grow on for a full year as originally planned.

Summer 2008 planting. Summer 2008 planting occurred on June 18, 2008, using the same species and fertilizer treatments as in the Fall 2007 planting (Table 1). Fertilizer was applied at potting. Plants were arranged in a split plot design (main plot fertilizer) with 4 replications. The destructive sampling was scheduled for October 2008. Only height and caliper were taken at this time. The plants were not yet of commercial size so the experiment was extended to June 17, 2009. Four plants per treatment of each specie were destructively evaluated for the same growth plant characteristics as measured and analyzed for the Fall 2007 planting.

Fall 2008 planting. The same cultivars as the Fall 2007 and Summer 2008 plantings were used but received in different sizes (North American Plants, LLC, Lafayette, Oregon): red maples (7.62cm tall), Avondale redbuds (15.24cm tall) and littleleaf lindens (25.4cm tall). A total of 34

plants per species per treatment were planted in the same soilless media with either 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G) on October 1, 2008 (Table 1). Plants were arranged in four randomized blocks. All plants were top dressed at potting with CR fertilizer, 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scotts). From December 2008 to March 2009 plants were separated into two groups: one with bottom heat (BH) using low watt propagation mats (Olson products Inc., Medina, Ohio) and a control group at ambient temperature (AT). Bottom heat started at 40ºF and was increased to 70ºF in January 2009. Treatments consisted of 0G AT (as a control), 0G BH, 1G AT and 1G BH. Harvest occurred in June 2009 and October 2009.
Summer 2009 planting. The landscape tree species, red maple, littleleaf linden were the same species as Fall 2007, Summer 2008 and Fall 2008 plantings. Signature ^{TM} Japanese tree lilac (*Syringa reticulata* 'Sigzam') (North American Plants, LLC, Lafayette, Oregon) was use to substitute Avondale redbud, which had proved non-hardy in Ohio winters. All trees were planted on June 18, 2009 (Table 1). Red maple (15.24 cm tall) and little leaf lindens (7.62 cm tall) were grown from tissue culture, Japanese tree lilac (7.62 cm tall) were obtained from cuttings. Plants were potted into soilless media with or without 1% of Geohumus by volume and fertilized with CR fertilizer, 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scotts). Measurements and destructive samples occurred during October 2009 and June 2010.

Results
Fall 2007 planting. As previously stated, harvest of the fall 2007 planting was delayed until August, 2008 due to insufficient growth. Red maple trees showed no significant differences from the main effect of BH vs. AT for any of the measures (Table 2). The main effect of fertilizer treatment was significant for caliper with the combination treatment of CR+LF providing increased caliper measures for red maple (Table 2). Littleleaf linden trees had a significantly larger root and shoot dry weights with AT compared with trees receiving BH when evaluated 10 months after planting, although height, caliper and leaf area were not significantly different (Table 2). Fertilizer treatment was also non-significant for any parameter evaluated for littleleaf linden (Table 2). Avondale redbud trees, which were planted on June 16, 2008, were significantly taller with CR+LF fertilizer treatment in comparison to CR only (Table 2). Caliper, leaf area, root and shoot dry weights were not affected by fertilizer treatment (Table 2).

For commercial purposes, the height and caliper of plants (after 10 months) started in Fall 2007 were smaller than the desired size of 120 cm and 12.7mm, respectively, even when delayed until August. Red maple plants were on average around 90 cm with a caliper approximately 7.8mm and littleleaf linden had an average of 108cm in height and approximately 7.1 mm in caliper. Avondale redbud trees averaged 57cm in height and 5.0 mm in caliper, smaller than commercially desired in part due to their later planting and thus shorter growing season than the other trees.
Summer 2008 planting. For the Summer 2008 plants, only height and caliper were evaluated in October 2008 due to reduced growth, and were allowed to grow one year (June 2008 to June 2009) to measure all growth parameters instead of the original schedule of June 2008 to October 2008.

In October 2008, red maples and Avondale redbud benefitted when fertilized with CR compared to CR+LF (Table 3). Both red maple and Avondale redbud had increased height, and Avondale redbud also had increased caliper. Littleleaf linden trees were not significantly different for height or caliper (Table 3). In contrast to Fall 2007, there was an increase in growth with CR+LF for the caliper of red maple and the height of Avondale redbud. However, for the summer 2008 crop, red maple and Avondale redbud had improved heights and calipers with the CR only treatment.

When evaluated in June 2009 (a year after planting), red maple still exhibited improved height with CR (Table 4), although caliper, leaf area, root and shoot dry weight were not significantly different (Table 4). Type of fertilizer had no effect on Littleleaf linden or Avondale redbud for any of the measures (Table 4). The grower practice of adding LF to CR applications is not supported by this research. From a grower perspective, applying CR one time reduces fertilizer use, expense, equipment, labor, and leaching potential of fertilizers.

Fall 2008 planting. Samples of plants were evaluated in April 2009 to primarily compare effects of the BH treatment. At this point, we also found differences in Avondale redbud growth attributable to Geohumus amendment (Table 5). There were only enough red maples to evaluate for the final evaluation, so they were not included in the April 2009 evaluation. Littleleaf linden had a significant shoot dry weight increase with the addition of BH (Table 5). Root dry weights were similar between Geohumus treatments and temperature treatments for littleleaf linden and Avondale redbuds (Table 5). There was also a significant interaction of the Geohumus and the BH on the shoot dry weight of Avondale redbud ($P \leq 0.0538$) (Table 5). The higher shoot dry weight was with the Geohumus and bottom heat (1G+BH) treatment. The increased temperature of 70ºF promoted growth, which came from early bud break from exposure to warmer root zone temperatures.

When plants were evaluated in June 2009, red maple did not exhibit differences for any measures with the Geohumus treatment (Table 6). Red maple was however, significantly larger in caliper with BH treatment (Table 6), although leaf area and root and shoot dry weight were not affected by the BH treatment (Table 6). Red maple height was influenced by a significant interaction (Table 6) between Geohumus and BH. The combination of no Geohumus (0G) and bottom heat (BH) produced taller red maples. This suggests that *Acer rubrum* may not have true root dormancy.

Littleleaf linden developed larger height and caliper in AT rather than with BH (Table 6). Leaf area and root and shoot dry weights were not significantly different between temperature treatments. Larger caliper was produced when Geohumus (1G) was present in the media when averaged over AT and BH treatments.

Avondale redbud developed larger height, caliper and leaf area (Table 6) with the BH treatment (Table 6) but root and shoot dry weights were not affected by temperature treatment (Table 6). The addition of 1% Geohumus significantly increased shoot dry weight, but height, caliper, leaf area and root dry weight were unaffected by Geohumus (Table 6).

Geohumus maintains water available in the media and had an interaction with BH. The increase in plant growth found in this study was not differed by plant organ and species. Red maple trees increased in height, Avondale redbud trees increased in shoot dry weight and littleleaf linden trees increased in caliper. These differences could be due to susceptible timing with heat applications for example littleleaf linden caliper increase with BH in Fall, Avondale red bud shoot dry weight increase promoting early bud break in spring.

Summer 2009 planting. Red maple, littleleaf lindens and Japanese tree lilac showed no difference for any growth parameter measured with Geohumus (Table 7). During the experiment many red maple trees died and a complete sample to compare treatments properly was not available. Japanese tree lilac, which were received in June 2009 went into a stalled growth pattern and were dormant during the beginning of the season. Some of the Japanese tree lilac started to grow later in the Fall, thus the results with this species are inconclusive. Mathers, in a study in 2009, found that Birch and maple planted as cuttings in June were half the size of their counterparts planted in April or May (Mathers, 2009, unpublish).

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

Red maple trees had similar heights of 90, 112 and 97cm when grown in Fall 2007, Fall 2008 and Summer 2009 (Figure 1) respectively. Average height during Summer 2008 was shorter (40.9 cm), which could be attributed to the start size of the plants, 7.62cm for Summer 2008 plants and 15.24cm for Summer 2009 plants. None of the red maple trees reached the desired height from tissue cultured plugs. We established at the onset of the experiment of 120cm for height. However, fall planted trees grew much better. Perhaps, plants that are grown through the winter are more adapted to the seasons and have the benefit of growing in early spring. Previous studies in RRG that protected plants from freezing, used bottom heat at 70°F (21°C) and placed the plants in the RRG on March 28, obtained red maples as high as 222cm in CR and 209cm in CR+LF (Stoven et al., 2006). Crops from summer plantings do not react to the warm weather as fast as crops from fall plantings. The use of larger plants for the Summer crops may improve growth as observed in this study. Caliper was different between each planting and did not near reach our goal of 12.7mm (Figure 2). Red maple calipers of 7.8, 8.1, 6.6, 8.7 were obtained in Fall 2007, Summer 2008, Fall 2008 and Summer 2009. More research needs to be done with this species to accelerate the growth to be able to double crop red maples.

Avondale redbuds heights (Figure 1) and calipers (Figure 2) also did not reach optimum size. However, the heights of these trees were benefited by the CR+LF treatment in Fall 2007 (57cm). In Fall 2008, bottom heat promoted the growth of this plant as early as April 2009 when combined with Geohumus. The increase in growth influenced by BH was observed also in height, caliper and leaf area in June 2009 evaluation. Geohumus promoted the shoot dry weight in June 2009 evaluation. Avondale redbuds are not hardy for zone 5. Plants that were grown during winter experience shoot tip die back and re-grew from lower parts of the plants. Even under protection of the RRG this plant experienced difficulty for production in Columbus, Ohio. For this reason, Avondale redbuds were not planted in Summer 2009. Eastern redbuds (*Cercis canadensis*) were the plants originally planned for this experiment. However due to a supplier error we received Avondale redbud instead.

Even though littleleaf lindens used in the Fall 2007 and Fall 2008 plantings had different initial heights, 25.4cm and 7.62cm respectively, height was similar at the time of evaluation; 113 and 108cm respectively (Figure 1), which was close to the desired size for liner sized material. Average heights for Summer 2008 and 2009 were 71 and 51 cm, respectively, and did not grow as tall as plants from Fall plantings (Figure 1). Calipers of littleleaf lindens were 7.1, 6.2, 7.9 and 4.6 for Fall 2007, Summer 2008, Fall 2008 and Summer 2009, respectively (Figure 2). Littleleaf linden was easy to grow in the RRG and grew larger than red maples which were considered “easy to grow” trees (Nursery grower, personal communication). Littleleaf lindens may need to be started with larger plants in Summer to reach the desired size. This species has the potential to be double cropped in the RRG.

Conclusion. The original Ohio Production System (OPS) for tree liners was developed by Dr. Dan Struve, The Ohio State University, and utilized a greenhouse for seedling growth before transferring outside. Work by Stoven et al. (2006) proved that quality liners of “bread and butter" species can be produced in one growing season by placing seedlings directly into the RRG during the winter months with minimum heat (a "modified" OPS system). Further research has shown that quality liners of other hard-to-grow, hard-to-find species can also be produced from the RRG using the modified OPS system (Mathers et al., 2010). Double cropping using the modified OPS system would alleviate some of the expense of the RRG; however, previously, no data existed for double cropping in Ohio using a RRG.

Data from this trial shows that the methods used for double cropping need to be improved for production of quality liners, but this trial points out many of the improvements needed. All the plants were obtained from tissue culture or cuttings that were relatively small, which made it very hard to get the growth needed from only half a year of production time, so increasing the growth of seedlings from tissue culture, cuttings, or seeds could alleviate some of the growth needed for a double crop. Perhaps, one of the biggest problems for the "double crop" was that the summer plantings did not correspond well to production and shipping times of propagated seedlings. It is virtually impossible to find seedlings that are coming out of dormancy in June; seedlings in this study that were planted in June were obtained before June and had to remain in the propagation flats or boxes and put in the cooler. For "double cropping", further research needs to be implemented for seedling production in relation to the summer planting.

Geohumus is a product designed initially to aid in water retention in arid soils. However, because much water is used in nursery production, the idea was that Geohumus could be added as a treatment to further increase the efficiency of the OPS system in containers with soilless substrates. Another interest in the addition of Geohumus is that it could help with outplant survival, either in field nurseries or in the landscape. Overall, in this study, Geohumus did little for growth of the crop; however, keep in mind it is not supposed to increase productivity, but to decrease water use while *maintaining* good growth. Since treatments involving *amount* of water were not in this study, it is not surprising that results were similar between the two treatments. The significance of using Geohumus with BH with Avondale redbud suggests that further research is warranted with Geohumus, and research that involves water usage/applied in relation to Geohumus is also warranted. Current research in Dr. Mather's program is being conducted to see the effects of Geohumus on outplant survival.

Different species exhibit different levels of root dormancy. Promotion of root growth during shoot dormancy could lead to increased shoot growth during the growing season. Daniel et al. (2008) found that *Magnolia virginiana* roots were able to grow in increased root zone temperatures during shoot dormancy while roots of *Cornus kousa* were not. This study also shows that root dormancy is very species specific, and in some instances, the addition of BH could increase root growth during shoot dormancy. Research is needed to find the effects of increased root zone temperatures on root growth of different species.

Table 1. Double crop timeline. Four crops, Fall 2007, Summer 2008, Fall 2008 and Summer 2009, were double cropped The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada).

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

Planting (P) occurred either in October or June for Fall and Summer crops respectively. Measurements (M) evaluation of height and caliper of all plants were taken. Destructive samples (D) to evaluate leaf area, shoot and root dry weights were made for all crops before moving to a PIP system.

Table 2. Main effects and interactions of bottom heat and fertilizer on growth measures evaluated in August 2008 for the trees from Fall 2007 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada).

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

z = Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were treated with bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F or left at ambient temperature (AT) from December 2007 to March 2008.

y = Plants were fertilized in April 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks.

x = Different letters in the same column signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Table 3. Main effect of fertilizer on growth measures evaluated in October 2008 for the trees from Summer 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada).

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

z = Red Maple (*Acer rubrum* L. 'October Glory'®) and littleleaf linden (*Tilia cordata* Mill. 'Greenspire'®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott's Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott's Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks.
y = Different letters in the same column signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Table 4. Main effect of fertilizer on growth measures evaluated in June 2009 for the trees from Summer 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada).

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

z = Red Maple (*Acer rubrum* L. ‘October Glory’®) and littleleaf linden (*Tilia cordata* Mill. ‘Greenspire’®) were fertilized in June 2008 with either a top dressing of controlled release fertilizer 40g of 19N-2.2P-6.6K (19-5-8, Osmocote Pro with minors, 8-9 months, Scott’s Co.), or a top dressing of 20g of CR supplemented with liquid fertilizer (LF), 400 ppm of 21N-3.1P-5.9K (21-7-7, Scott’s Company, Marysville, Ohio), via a fertilizer injector (Dosatron®, Clearwater, Florida) once every two weeks.

y = Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Table 5. Main effects and interactions of Geohumus and bottom heat on shoot and root dry weight (gr) evaluated in April 2009 from the trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada).

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

z = Littleleaf lindens (*Tilia cordata* Mill. ‘Greenspire’®) and Avondale redbuds (*Cercis chinensis* L. ‘Avondale’) were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G).
y = Trees were also subjected to bottom heat (BH) using heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009.
x = Different letters in the same column signify least significant differences (LSD) P=0.05, NS non-significant.
w = Interaction with Geohumus P = 0.0538.

Table 6. Main effects and interactions of Geohumus and bottom heat on growth parameters evaluated in June 2009 to the trees from Fall 2008 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada).

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

z = Red Maple (*Acer rubrum* L. 'October Glory'®), littleleaf lindens (*Tilia cordata* Mill. 'Greenspire'®) and Avondale redbuds (*Cercis chinensis* L. 'Avondale') were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G)

y = Bottom heat (BH) using bottom heat mats (Olson Products Inc., Medina, Ohio) at 40°F with an increase to 70ºF or left at ambient temperature (AT) from December 2008 to March 2009.

x = Different letters signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.

Table 7. Growth parameters evaluated in June 2010 to the trees from Summer 2009 planting grown at The Ohio State University, Columbus, OH, in the retractable roof greenhouse (RRG) (Cravo Equipment, Ltd., Brantford, ON, Canada).

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

z = Red Maple (*Acer rubrum* L. ‘October Glory’®), littleleaf lindens (*Tilia cordata* Mill. ‘Greenspire’®) and Japanese tree lilacs (*Syringa reticulate* ‘Sigzam’) were grown in 1% by volume of Geohumus (1G) (Geohumus International Gmbh, Frankfurt am Main, Germany), or without amendment (0G).
y = Different letters in the same column signify least significant differences (LSD), * ,**, *** significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. NS non-significant.
x = not enough data to compare.

Figure 1. Height (cm) of tree species grown in the RRG. Fall 2007 plants were grown for 11 months. Fall 2008 plants were grown for 8 months. Summer 2008 and 2009 were grown for 4 months. Fall season were schedule to be grown from October to June and Summer season last from June to October. Means with different letters between each species are significantly different based on Fisher's protected least significant difference ($\alpha = 0.05$).

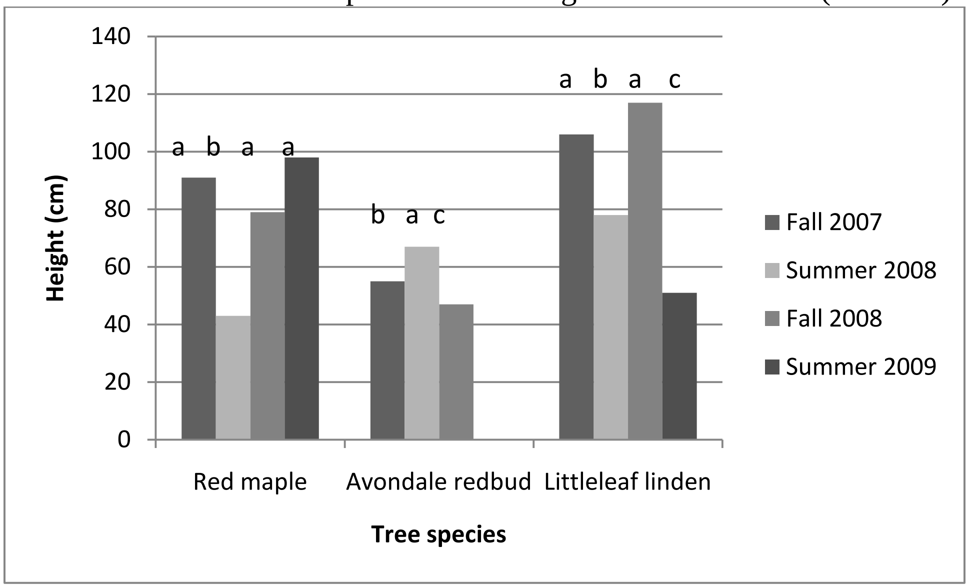


Figure 2. Caliper (mm) of tree species grown in the RRG. Fall 2007 plants were grown for 11 months. Fall 2008 plants were grown for 8 months. Summer 2008 and 2009 were grown for 4 months. Fall season were schedule to be grown from October to June and Summer season last from June to October. Means with different letters between each species are significantly different based on Fisher's protected least significant difference ($\alpha = 0.05$).