Yearly Research Summary Report
2012 Ornamental Research

Dr. Hannah Mathers
Luke Case
Michele Bigger
Phoebe Gordon
Laura Giese

THE OHIO STATE UNIVERSITY
EXTENSION

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State-wide Weed Control Initiative for Ohio Nurseries

Principle investigators: Dr. Hannah Mathers and Luke Case

Project summary. Over 225 herbicide trials were set up in fields or containers at seven nurseries: Studebaker Nurseries, New Carlisle, OH; Willoway Nurseries, Inc., Avon, OH and Willoway Nurseries, Inc., Huron, OH; North Branch Nursery, Pemberville, OH; Klyn Nurseries, Perry, OH; Sunleaf Nursery, LLP, Madison, OH; and Herman Losely & Son, Inc., Perry, OH. Nursery visits were conducted between October 28, 2011 and November 15, 2011 to determine current weed problems and crops, herbicide management practices and problems. These meetings determined which herbicides and crops would be evaluated in the 2012 season. Products were chosen to address their current issues and concerns. The total financial impact of these 225 trials is estimated at $10 Mn due to savings in four key areas, reduction in crop losses, proper herbicide use, marketing the crop sooner and reduction in cultivation, weeding and postemergence herbicide use.

Of the seven nurseries interviewed, none were satisfied with their current herbicide programs. Two sites were experiencing major issues in their container production thought to be related to over use of inhibitors of microtubule assembly (Weed Science Society of America (WSSA) Group 3 herbicides). The Group 3 herbicides (ex. the dinitroaniline (DNA) herbicide family) (or mitosis inhibitors) represent the majority of the herbicides labeled for nursery and landscape use. Group 3 herbicides are classified as shoot inhibitors and root inhibitors; both have the same mode of action (MoA). These two sites had incurred over $1 million (Mn) in crop losses in 2011 due to lack of rooting, poor growth and severely stressed plants. As a result of over 81 trials at these two sites alone in 2012, we provided evidence that the $1Mn in plant losses incurred in 2011 were advanced in part by Group 3 herbicides (Fig. 1). We also helped to end a cultural practice that may have been contributing to the poor rooting and promoted the buildup of the Group 3 herbicides in the media. We also suggested a weed control program for the 2013 season that minimizes use of Group 3 herbicides while still addressing their major weed issues which they have struggled with for years. The impact of our Specialty Crop Block Grant (SCBG) work at these two sites in 2012 is estimated at $1.5 Mn per site from reduction of crop losses (Table 2).

Many nurseries we met with in fall 2011 were unaware that shoot and root inhibitors were in the same MoA. Five of the sites thought rotations between root and shoot inhibitors were rotations in MoAs. These sites were thus experiencing weed species they could not control (Fig. 2). As a result of our trials at these sites, we have provided herbicide recommendations outside their current program to control five major problem species (Table 1). Our SCGB work at these nurseries has saved $640.00 per

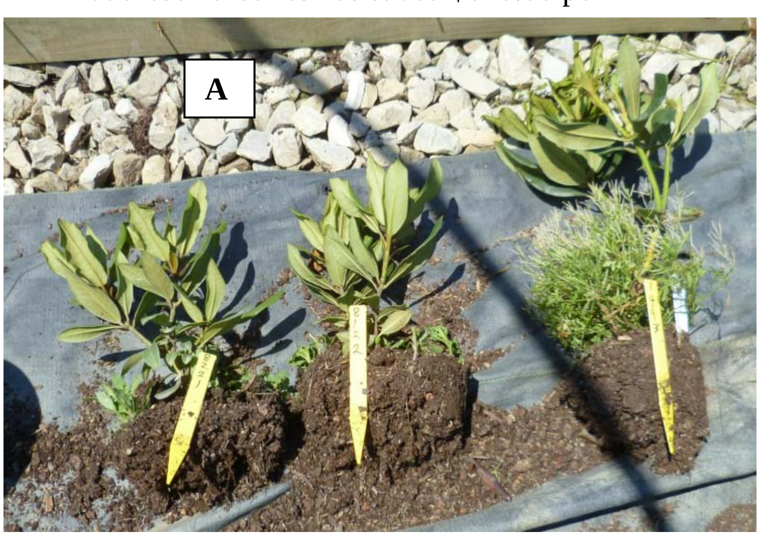


Fig. 1. A. Gallery + Barricade applied on *Rhododendron* 'Nova Zembla' (second row from bottom evaluated 05/03/12, 4WAT showing severe stunting.

B. Gallery + Barricade (left to right – 2X, 1X and control) applied on *Rhododendron* ‘Nova Zembla’ evaluated 07/11/12, 3 months after treatment, showing progressive root injury and top stunting as rate of application increased. (Photos by: Dr. H. Mathers)

hand weeding event per acre for a total of $ 0.5 Mn per site in hand-weeding costs due to past improper herbicide choices (Table 2).

Table 1. Five common Ohio container weeds at five nurseries evaluated and controls determined for each.

Common name	**Scientific name**	**Life cycle**	**Controls**
Pennsylvania bittercress	*Cardamine pennsylvanica*	Winter annual	Snapshot
Prostrate spurge	*Chamaescyce maculata* or *Euphorbia maculata*	Summer annual	Rout, Snapshot, BroadStar
Groundsel	*Senecio vulgaris*	Winter and summer annual	BroadStar, Rout
Pearlwort	*Sagina procumbens*	Perennial	Snapshot, Rout
Northern willowherb	*Epilobium ciliatum*	Summer annual	Rout, BroadStar

One field nursery had severe weed infestations due to abandoning their controls which had relied almost exclusively on expensive hand weeding operations. Inability to employee large weeding crews due to the economic downturn and without proper herbicides, their fields became infested with weeds (Fig. 2). As a general rule, for every pound of weed growth produced, about one less pound of crop growth is produced. Many of the crops at this nursery are sold by inch of top growth achieved. As a result of our SCBG trials, we were able to recommend two new herbicide products, Tower + pendulum and Indaziflam, that were providing exceptional control 7 WAT even in this field (Fig. 2) infested with perennials with potential long-term economic impact to the crop. We estimate that our studies at this site were worth $2 Mn as a result of marketing the crop one or two years sooner due to releasing the crop from current weed pressures. The work at this site was also applied at one other nursery for a total of $4 Mn (Table 2).

Fig. 2. The two rows in the center of Taxus 'Runyon' were hoed and various herbicides were applied. Rows to the right of the photo show the lack of inherent weed control at the site. To the left of the two trial rows is a grass roadway and adjacent infested weedy beds. (Photo by: H. Mathers)

Another field nursery required more effective longer residual preemergence herbicides. They had reduced their postemergence herbicide usage over the past three years due to previous OSU research relating glyphosate to bark cracking. This nursery had been using SureGuard, a PPO inhibitor, for the past several years and needed an alternative MoA to rotate out of the PPO MoA. At this site, we were able to recommended three new herbicide alternatives that provided statistically similar or superior control to SureGuard at 10 WAT: Tower + pendulum, V-10336 at 15 or 30 oz. /ac and Barricade + Goal. We estimate that the ability to rotate chemistries at this site will be worth $0.25 Mn in reduction of supplemental cultivation and postemergence use to control break through weeds. This information was also applied at one other site for a total of $0.5 Mn (Table 2).

Table 2. Summary of the Specialty Crop Block Grant (SCBG) financial impact of 225 herbicide trials at seven nurseries in 2011-12.

Type of savings	**Amount**	**No. of sites**	**Total**
Reduction of crop losses	1.5 Mn	2	3.0 Mn
Proper herbicide selection	0.5 Mn	5	2.5 Mn
Market crop sooner	2 Mn	2	4.0 Mn
Reduction in cultivation, weeding and postemergence herbicides	0.25 Mn	2	0.5 Mn
Grand Total			**10 Mn**

Project approach. The trade and common names and manufacturers of the herbicides used are as follows: BroadStar (flumioxazin, Valent U.S.A), Indaziflam (Bayer Corp.), Tower (dimethenamid-p, BASF Corp.), Tower + Pendulum (pendimethalin, BASF Corp.), Gallery (isoxaben, Dow Agro Sciences), FreeHand (dimethenamid-p + pendimethalin, BASF Corp.), Snapshot 2.5G (isoxaben + trifluralin, Dow Agro Sciences), Biathlon (oxyfluorfen + prodiamine, OHP, Inc.), Ronstar (oxadiazon, Bayer Corp.), F6875SC (sulfentrazone +prodiamine, FMC), Gallery + Surflan (oryzalin, Dow Agro Sciences) and Gallery + Barricade (prodiamine, Syngenta). Phytotoxicity evaluations were performed at 1 WA1T (week after first treatment), 2 WA1T, 4 WA1T, 1 WA2T (weeks after second treatment), 2 WA2T, and 4WA2T. Visual ratings were performed on a scale of 0-10 with 0 being no phytotoxicity, 10 being dead, and ≤ 3 commercially acceptable. All liquid treatments were applied with a CO_2 backpack sprayer with a spray volume of 20 gal/ac using nozzles delivering 0.15 gal/ min/ nozzle and the nozzle spacing at 12 inches. Field plot sizes included 3 plant subsamples for tree rows or 3X 3 ft. areas for liner beds in each replication, with 4 replications/ rate for each variety. Container plots sizes included 4 replications/ treatment with 3 subsamples in each replication.

Trials were initiated at five of the seven nurseries involved in the project. On March 22, 2012 at North Branch Nursery Inc., Pemberville, OH one gallon (gal) containers of *Buxus* 'Green velvet' were applied with Tower EC, Indaziflam and Gallery + Surflan. Three gal containers of *Rosa* 'Knockout' were applied with Biathlon, Gallery + Surflan and Indaziflam. Three gal containers of *Berberis thunbergii* 'Crimson pygmy' were applied with Tower + pendulum Aqua Cap, Indaziflam and Gallery + Surflan. North Branch Nursery field rows of *Malus* ‘Indian Magic’ and *Ulmus* X 'Frontier' received applications of Biathlon, Tower + pendimethalin and F6875SC. Rates applied are indicated in Table 1. Field rows of *Amelanchier* X *grandiflora* ‘Robin Hill', *Buxus* ‘Green velvet’ and *Acer rubrum* ‘Red Sunset’ received SureGuard 51 WDG, V-10336 61.5 WDG and Tower. Rate applied are indicated in Table 2 and 3. Treatments were reapplied on May 3, 2012.

At Willoway Nurseries Inc., Huron Farm, Huron, OH on April 4, 2012 in a polyhouse with two or three cut vents at 80 °F containers of *Rhododendron* ‘Nova Zembla’ (1 gal) received Tower, FreeHand, Ronstar, Snapshot, Gallery +Barricade and Tower + pendulum; *Azalea* 'Karen' (2 gal) received FreeHand, Biathlon, Ronstar, Snapshot, Gallery + Barricade and Tower + pendulum; *Ilex Xmeserveae* 'Blue Maid' (1 gal) received Indaziflam and Biathlon; *Ilex crenata* ‘Sky pencil’ (1 gal) received FreeHand, Indaziflam, Snapshot ,Gallery +Barricade, Biathlon and Tower + pendulum; *Spirea* 'Neon Flash' (1 gal.) received Gallery; *Weigela* 'Rainbow Sensation' (3 gal) received Tower, Gallery, Ronstar and Tower + pendulum; *Pieris* 'Red Mill’ (1 gal) received FreeHand, Gallery, Biathlon, Snapshot, Gallery + Barricade, and Tower +Pendulum; and, *Kalmia latifolia* 'Olympic Fire' (1 gal) received Gallery. Rates applied are indicated in Table 4. Treatments were reapplied on May 16, 2012.

At Willoway Nurseries Inc., Avon Farm, Avon, OH on April 4, 2012 in an open roof Erie greenhouse at 70°F containers of *Itea* ‘Little Henry’ (3 gal) received Gallery; *Hydrangea macrophylla* ‘Endless Summer’ received Indaziflam, Biathlon, Ronstar and Tower + pendulum; *Hydrangea arborescens* ‘Invincible spirit’ (3 gal.) and *Hydrangea paniculata* ‘Limelight’ (3 gal) received Indaziflam and Biathlon. Rates applied are indicated in Table 5. Cuttings of ‘Endless summer’ were taken June 2011, shifted to 1 gal on Aug-Sept. 2011, shifted to 3 gal on Saturday, March 31, 2012. They had received no herbicides prior to our applications on April 4. *H.* ‘Limelight’, and ‘Invincibelle spirit’ and the *Itea* were in 3 gal containers from 2011. The empty pots (3 gal) for all Indaziflam treatments used the same media as with the 'Endless Summer' and were potted on March 31, 2012. Treatments were reapplied on May 16, 2012.

At Klyn Nurseries, Inc., Perry, OH on April 12, 2012 containers of *Hemerocallis* 'Stella d oro' (1 gal) received Biathlon; *Azalea viscosum* (1 qt.) received Biathlon; *Hydrangea paniculata* 'Unique' (2 gal) received FreeHand, Tower, and Tower + pendulum; *Viburnum plicatum f. tomentosum* 'St. Keverne' (1 gal) received Indaziflam; *Buxus* 'Winter Gem' (1 qt.) and *Rosa* 'Mini rainbow'(3 gal.) received F6875SC; and *Thuja nigra* (3 gal) received Indaziflam. Klyn Nursery field *Buxus* 'Winter Gem' received Tower + pendimethalin, Indaziflam, Tower and FreeHand. Rates applied are indicated in Table 6. All applications were conducted in a polyhouse with the plastic removed at 50°F. Treatments were reapplied on May 24, 2012.

At Herman Losely & Son, Inc., Perry, OH on April 12, 2012 *Taxus* X*media* 'Tauntonii' liner beds received Biathlon, Tower + pendulum, and Indaziflam. Sensitive field materials such as *Stewartia pseudocamellia, Franklinia alatamaha* and *Fothergilla gardenia* received application of Tower, Tower + 1" of pine mulch, and Tower + pendimethalin + 1" of pine mulch. Rates applied are indicated in Table 7. Treatments were reapplied on May 24, 2012.

At Sunleaf Nursery, LLP, Madison, OH, on April 12, 2012 field rows of *Liquidambar styraciflua* 'Slender Silhoutte', *Gleditsia* 'Skycote', *Acer platanoides* 'Crimson King' and *Tilia* 'Greenspire' received applications of Biathlon, Barricade + Goal 2XL, Tower + Pendulum, SureGuard 51 WDG, V-10336 61.5 WDG and Tower 6EC. Rates applied are indicated in Table 8. All trees were planted in 2008 and were just barely budding out at time of application at 50°F. All rows were hoed previous to application. Tower + Pendulum, Biathlon, and Barricade + Goal were reapplied on May 24, 2012; the other treatments were not reapplied.

At Studebaker Nursery, New Carlisle, OH, on May 1, 2012, field rows of *Buxus* 'Green velvet', *Buxus* 'Northern Charm', and *Taxus* 'Runyon' received applications of Tower, Tower + Pendulum, Indaziflam, Gallery, F6875, and Biathlon. Liner beds of *Buxus* 'Green velvet' and *Taxus* 'Runyon' received applications of FreeHand, Tower + Pendulum, Indaziflam, and Tower. Also, on May 1, 2012, containers of *Euonymus alatus* 'Compacta' and *Viburnum* 'Jeddi' (3 gal) received indaziflam and F6875; Hydrangea paniculata 'Little lamb' (3 gal) received F6875; *Hemerocallis* 'Stella d'Oro' (1 gal) received Biathlon; and *Rosa* 'Knockout' (1 gal) received BroadStar. Treatments were reapplied on June 11, 2012.

Goals and outcomes achieved.

The overall goal of this SCBG was to reduce weed control costs in Ohio nurseries by targeting individual weed species as opposed to the typical shotgun approach. We also wanted to reduce the labor associated with weed control by using new targeted herbicides. We emphasized four key crops Viburnum sp., Hydrangea sp., Buxus sp. and herbaceous perennials which have seen dramatic increases in the past five years but have limited herbicide options. By emphasizing these crops we hoped to see further market expansion in these crops resulting in more and advanced jobs. Of the 225+ phytotoxicity trials conducted 75% provided ratings of commercially acceptable or 169 new herbicide options at these seven sites. Specific results are indicated below by site.

North Branch Nursery

The container trials at North Branch Nursery Inc., Pemberville, OH revealed a new herbicide being released by Bayer and OHP, Indaziflam G caused no phytotoxicity on *Buxus* 'Green velvet', *Rosa* 'Knockout' and *Berberis thunbergii* 'Crimson pygmy,' regardless of the rate applied (Table 3). Indaziflam has a similar MoA to Gallery i.e. cellulose biosynthesis (CBI). However, unlike Gallery it is long-lasting up to 150 days, meaning fewer applications are required and has a very low application rate of 0.11 lb. ai /ac and is a broad spectrum herbicide controlling grasses and broadleaf weeds. Another new herbicide Biathlon (oxyfluorfen + prodiamine) by OHP which is a low dust, uniform sized granule produced with a new - Verge technology also provided no phytotoxicity with Rose (Table 3). Biathlon controls grass and broadleaf weeds in field and container ornamentals, ground maintenance and other non-crop areas. The only significant phytotoxicity caused at North Branch was caused by a combination of Gallery + Surflan on Rose (Table 3). Gallery + Surflan is the most common preemergence herbicide combination used in the industry; however, Gallery (isoxaben) is a Group 21 herbicide that includes the herbicide family benzamide. Benzamides inhibit cell wall synthesis causing mottling and random leaf chlorosis on susceptible contacted plants (Fig. 3). The Gallery + Surflan were added in the North Branch trial as an industry standard or control. It is significant that both Indaziflam and Biathlon caused less phytotoxicity than the industry standard showing their utility as alternative herbicides.

The field trails at North Branch Nursery Inc. the industry standard SureGuard was tested against a new herbicide by Valent U.S.A. V-10336 at three rates. The V-10336 provided some burn-down on pineapple weed (the primary weed in the North Branch plots) and a little bit on dandelions. In both the *Acer rubrum* and *Amelanchier* plots the V-10336 provided excellent efficacy (Tables 4 and 6) with minimal phytotoxicity (Tables 5 and 7) 10 weeks after treatment (WAT). The weed control was statistically similar to the SureGuard indicating V-10336 could be used as alternative to the industry standard.

Table 3. Phytotoxicity of several herbicides on containerized ornamentals at North Branch Nursery

Buxus 'Green velvet'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Indaziflam	200 lbs.	0.2	0.0	0.7	0.3	1.0	0.4
Indaziflam	400 lbs.	0.0	0.2	1.0	0.9	1.1	0.7
Indaziflam	800 lbs.	0.3	0.2	0.6	0.4	1.1	0.8
Tower	21 oz.	0.2	0.2	0.8	2.7 **	2.5 **	1.9 **
Gallery + Surflan	1.3 lb. + 2 qt.	0.7	0.4	1.6	1.2	1.5	1.2
Untreated	--	0.2	0.0	0.7	0.3	0.7	0.3

Berberis 'Crimson Pygmy'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Indaziflam	200 lbs.	0.0	0.0	0.0	0.0	0.0	0.0
Indaziflam	400 lbs.	0.0	0.0	0.0	0.0	0.1	0.0
Indaziflam	800 lbs.	0.2	0.0	0.0	0.0	0.3	0.1
Tower + Pendulum	21 oz. + 2 qt.	0.2	0.2	4.0 **	3.8 **	4.0 **	3.6 **
Gallery + Surflan	1.3 lb. + 2 qt.	0.0	0.0	3.7 **	2.8 **	3.9 **	2.1 **
Untreated	--	0.0	0.0	0.0	0.0	0.0	0.3

Rosa 'Knockout'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Indaziflam	200 lbs.	0.0	0.1	0.0	0.4	0.3	0.0
Indaziflam	400 lbs.	0.2	0.5	0.0	0.1	0.1	0.0
Indaziflam	800 lbs.	0.4	1.2 **	1.6 *	1.3 **	1.4	1.0
Biathlon	100 lbs.	1.0 **	1.1 **	0.3	0.1	0.6	0.3

Gallery + Surflan	1.3 lb. + 2 qt.	3.4 **	4.3 **	5.2 **	3.9 **	4.1 **	3.8 **
Untreated	--	0.0	0.3	0.0	0.0	0.6	0.0

Fig. 3. Leaf crinkling, mottling and random leaf chlorosis caused by the cellulose inhibitor Gallery on three gal containers *Rosa* 'Knockout.'(Photo by: H. Mathers)

Table 4. Weed control of several ornamental herbicides in the *Acer rubrum* 'Red Sunset' / *Buxus* 'Green Velvet' plots at North Branch Nursery in 2012.

Treatment	Rate/ac	1 WAT^{z}	2 WAT	4 WAT	7 WAT	8 WAT	10 WAT
SureGuard	12 oz.	8.8^{yx} bc	8.8 ab	8.7 a	9.2 a	9.1 a	9.2 a
V-10336	7.5 oz.	9.4 ab	7.5 c	9.1 a	9.5 a	9.3 a	9.1 a
V-10336	15 oz.	9.7 a	9.3 ab	9.3 a	9.5 a	9.6 a	9.6 a
V-10336	30 oz.	--	--	--	--	--	--
Tower	21 oz.	7.4 c	8.3 b	7.2 b	6.3 b	6.4 b	6.5 b
Untreated	--	8.9 b	9.2 a	9.3 a	0.0 c	3.9 c	2.4 c

z = weeks after treatment

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

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

Table 5. Phytotoxicity of several ornamental herbicides on *Buxus* 'Green Velvet' when intercropped with *Acer rubrum* 'Red Sunset' at North Branch Nursery in 2012.

Treatment	Rate/ac	1 WAT[z]	2 WAT	4 WAT	7 WAT	8 WAT	10 WAT
SureGuard	12 oz.	0.5[yx]	1.1	0.5	0.4	0.5	0.9
V-10336	7.5 oz.	0.6	0.9	1.0	0.5	0.6	0.9
V-10336	15 oz.	1.0	1.3	1.7	1.5 **	1.7	2.1 *
V-10336	30 oz.	--	--	--	--	--	--
Tower	21 oz.	0.2	1.1	1.0	0.5	0.2	0.6
Untreated	--	1.1	2.0	2.5	0.0	0.9	0.9

z = weeks after treatment

y = Ratings are based on a 0-10 scale with 0 being no phytotoxicity, 10 death and ≤3 commercially acceptable.

x = Ratings followed by * and ** are significantly different from the control at specified date based on Dunnett's t-test (α = 0.10 and 0.05, respectively).

Table 6. Weed control of several ornamental herbicides in the *Amelanchier* X *grandiflora* 'Robin Hill'/ *Buxus* plots at North Branch Nursery in 2012.

Treatment	Rate	1 WAT	2 WAT	4 WAT	7 WAT	8 WAT	10 WAT
SureGuard	12 oz.	9.1 a	8.5 a	8.6 a	8.1 b	8.7 b	9.0 a
V-10336	7.5 oz.	9.4 a	8.9 a	8.4 a	8.4 ab	8.8 ab	9.0 a
V-10336	15 oz.	9.3 a	8.9 a	8.9 a	9.0 a	9.1 ab	9.3 a
V-10336	30 oz.	9.4 a	8.8 a	8.9 a	8.7 ab	9.5 a	9.4 a
Tower	21 oz.	7.5 b	6.9 b		6.1 c	5.9 c	7.3 b
Untreated	--	7.6 b	6.8 b	6.9 b	6.1 c	6.3 c	7.4 b

z = weeks after treatment

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

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

Table 7. Phytotoxicity of several ornamental herbicides on *Buxus* 'Green Velvet' when intercropped with *Amelanchier* X *grandiflora* 'Robin Hill' at North Branch Nursery in 2012.

Treatment	Rate	1 WAT	2 WAT	4 WAT	7 WAT	8 WAT	10 WAT
SureGuard	12 oz.	0.5	0.3	0.3	0.3	0.3	0.0
V-10336	7.5 oz.	1.6 **	1.8	1.0	0.5	1.8 **	1.4 **
V-10336	15 oz.	0.9	0.9	0.6	0.5	0.5	0.4
V-10336	30 oz.	1.9 **	1.6	2.0	1.5 *	2.0 **	1.5 **
Tower	21 oz.	0.3	1.3		0.3	0.3	0.4
Untreated	--	0.0	0.3	1.7	0.0	0.0	0.1

z = weeks after treatment

y = Ratings are based on a 0-10 scale with 0 being no phytotoxicity, 10 death and ≤3 commercially acceptable.

x = Ratings followed by * and ** are significantly different from the control at specified date based on Dunnett's t-test (α = 0.10 and 0.05, respectively).

Willoway - Huron

The container trials at Willoway Nursery, Huron, OH, yielded a wealth of efficacy and phytotoxicity data. Tests with Ronstar showed no phytotoxicity on *Rhododendron* 'Nova Zembla,' *Azalea* 'Karen' and *Weigela* 'Rainbow Sensation' (Table 8). Gallery also caused no injury on *Spirea* 'Neon Flash' and, *Kalmia latifolia* 'Olympic Fire' (Table 8) while providing control of creeping oxalis. Most of the mitosis inhibitor MoA used at this site seemed to compound existing crop phytotoxicity problems from the previous growing season. The exception was FreeHand on *Rhododendron* 'Nova Zembla' and *Azalea* 'Karen.' *Weigela* 'Rainbow Sensation' experienced some transitory injury with increasing rates of Gallery 2WAT (Fig. 4) which disappeared by the end of the trial.

Fig. 4. Gallery (isoxaben) applied to *Weigela* 'Rainbow Sensation' at Willoway Nursery, Inc., Huron, OH showing from increasing injury with increasing rates 2WAT, left to right 4X (5.2 lb. /ac), 2X (2.6 lb. /ac) and 1X (1.3 lb. /ac). (Photo by: H. Mathers)

Table 8. Phytotoxicity of several ornamental cultivars from various herbicides at Willoway Nurseries, Huron

Azalea 'Karen'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
FreeHand	150 lb.	Willoway Huron	0.0	0.0	0.3	0.4	0.4
FreeHand	300 lb.	Willoway Huron	0.0	0.0	0.1	0.0	0.0
FreeHand	600 lb.	Willoway Huron	0.0	0.0	0.3	0.7	0.3
Biathlon	100 lbs.	Willoway Huron	0.0	0.0	0.1	4.1 **	0.0
Biathlon	200 lbs.	Willoway Huron	0.0	0.0	0.4	0.0	0.0
Biathlon	400 lbs.	Willoway Huron	0.0	0.0	0.5	0.0	0.5
Ronstar	100 lbs.	Willoway Huron	0.0	1.6 **	0.2	0.0	0.0
Ronstar	200 lbs.	Willoway Huron	0.0	2.0 **	1.0 **	2.3 **	0.8

Snapshot	150 lbs.	Willoway Huron	0.0	0.7	0.8 **	4.5 **	0.6
Snapshot	300 lbs	Willoway Huron	0.0	2.1 **	0.2	0.9	0.8
Gallery + Barricade	1.3 lb. + 21 oz.	Willoway Huron	0.0	0.0	1.6 **	1.9	1.2
Gallery + Barricade	2.6 lb. + 42 oz.	Willoway Huron	0.0	0.0	2.5 **	1.8	1.5
Tower + Pendulum	21 oz. + 2 qt.	Willoway Huron	0.0	0.0	3.3 **	5.8 **	7.0 **
Untreated	--	Willoway Huron	0.0	0.0	0.0	0.0	0.6

Rhododendron 'Nova Zembla'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Tower	21 oz.	Willoway Huron	0.6 *	0.0	0.5	3.0 **	2.8 **
Tower	42 oz.	Willoway Huron	0.2	0.0	0.3	2.3 **	3.6 **
Tower	84 oz.	Willoway Huron	0.3	0.0	0.3	2.8 **	2.6 **
FreeHand	150 lb.	Willoway Huron	0.0	0.0	0.3	1.3 **	0.5
FreeHand	300 lb.	Willoway Huron	0.0	0.0	0.3	1.2 **	0.8
FreeHand	600 lb.	Willoway Huron	0.0	0.0	1.0	0.0	0.5
Ronstar	100 lbs.	Willoway Huron	0.0	0.0	0.3	0.0	0.0
Ronstar	200 lbs.	Willoway Huron	0.0	0.0	0.3	0.0	0.2
Snapshot	150 lbs.	Willoway Huron	0.0	0.0	0.3	0.1	0.2
Snapshot	300 lbs.	Willoway Huron	0.0	0.0	0.3	0.4	0.9
Gallery + Barricade	1.3 lb. + 21 oz.	Willoway Huron	0.3	3.2 **	3.6 **	0.8	2.0
Gallery + Barricade	2.6 lb. + 42 oz.	Willoway Huron	0.0	3.1 **	2.6 **	0.5	1.5
Tower + Pendulum	21 oz. + 2 qt.	Willoway Huron	0.0	2.8 **	1.1 *	2.2 **	2.8
Untreated	--	Willoway Huron	0.0	0.0	0.5	0.0	0.0

Weigela 'Rainbow Sensation'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Tower	21 oz.	Willoway Huron	1.5	2.0	0.8	0.0	1.1
Tower	42 oz.	Willoway Huron	1.7	2.0	0.8	2.1 **	2.3
Tower	84 oz.	Willoway Huron	1.9	1.8	0.5	3.3 **	2.4
Gallery	1.3 lb.	Willoway Huron	0.2	2.9 **	0.4	0.5	0.0

Gallery	2.6 lb.	Willoway	1.8	2.7	0.7	1.5	1.8
		Huron		**			
Gallery	5.2 lb.	Willoway	4.0	3.8	1.3	1.9	1.6
		Huron	**	**		**	
Ronstar	100 lbs.	Willoway	1.6	3.3	1.0	1.5	0.4
		Huron		**			
Ronstar	200 lbs.	Willoway	1.3	3.8	1.4	1.3	1.1
		Huron		**	**		
Tower + Pendulum	21 oz. + 2 qt.	Willoway	0.0	2.8	0.9	2.9	2.2
		Huron		**		**	
Untreated	--	Willoway	1.7	1.2	0.3	0.0	1.3
		Huron					

Spirea ‘Neon Flash'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Gallery	1.3 lb.	Willoway	1.1	0.0	1.9	1.2	1.6
		Huron			*		
Gallery	2.6 lb.	Willoway	2.0	0.8	0.9	2.7	1.8
		Huron	**			**	
Gallery	5.2 lb.	Willoway	0.4	0.0	1.3	3.3	1.3
		Huron				**	
Untreated	--	Willoway	0.3	0.0	0.5	0.0	0.3
		Huron					

Kalmia latifolia 'Olympic Fire'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Gallery	1.3 lb.	Willoway	2.3		0.1		
		Huron		0.0		0.0	0.0
Gallery	2.6 lb.	Willoway	4.0		1.2		
		Huron	**	0.0	**	0.0	0.0
Gallery	5.2 lb.	Willoway	3.2		0.4		
		Huron		0.0		0.0	0.0
Untreated	--	Willoway	2.4		0.1		
		Huron		0.0		0.0	0.0

Pieris 'Red Mill'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
FreeHand	150 lb.	Willoway			0.3	0.0	
		Huron	0.0	0.0			0.0
FreeHand	300 lb.	Willoway			0.0	0.0	
		Huron	0.0	0.0			0.0
FreeHand	600 lb.	Willoway			0.2	0.0	
		Huron	0.0	0.0			0.0
Gallery	1.3 lb.	Willoway			0.8	0.0	
		Huron	0.0	0.0	**		0.0
Gallery	2.6 lb.	Willoway			0.1	0.0	
		Huron	0.0	0.0			0.0
Gallery	5.2 lb.	Willoway			0.3	0.0	
		Huron	0.0	0.0			0.0
Biathlon	100 lbs.	Willoway			0.0	0.0	
		Huron	0.0	0.0			0.0
Biathlon	200 lbs.	Willoway			0.2	0.0	
		Huron	0.0	0.0			0.0
Biathlon	400 lbs.	Willoway			0.1	0.0	
		Huron	0.0	0.0			0.0

Snapshot	150	Willoway Huron	0.0	0.0	0.1	0.0	0.0
Snapshot	300	Willoway Huron	0.0	0.0	0.2	0.0	0.0
Gallery + Barricade	1.3 lb. + 21 oz.	Willoway Huron	0.0	0.0	0.5 *	0.0	0.0
Gallery + Barricade	2.6 lb. + 42 oz.	Willoway Huron	0.0	0.0	0.2	0.0	0.0
Tower + Pendulum	21 oz. + 2 qt.	Willoway Huron	0.0	0.0	2.6 **	2.0 **	0.0
Untreated	--	Willoway Huron	0.0	0.0	0.0	0.0	0.0

*** no phyto on Ilex merservea from indaziflam or biathlon

The addition of Barricade to Gallery caused severe shoot inhibition on *Rhododendron* ‘Nova Zembla’ up to 4WAT (Fig. 1A) (Table 8). Although the shoot inhibition had disappeared by the end of the trial (Table 8) an examination of the roots showed severe stunting still persisted into July (Fig. 1B).

Fig. 5. Photo taken 07/11/12 at Willoway Nursery, Huron, OH showing increasing root inhibition on *Weigela* 'Rainbow Sensation' with increasing rates caused by Tower applied at 1X (right) (21 oz. /ac) and 2X (middle) (42 oz. /ac). The control is shown in the top left corner. (Photo by: H. Mathers)

Tower applied to *Weigela* 'Rainbow Sensation' also caused some shoot inhibition after the second application that seemed to be fading by the end of the trial (Table 8); however, again an examination of the roots in July showed root inhibition was persisting and was greater at the 2X rate versus the 1X rate (Fig. 5). Tower + pendulum also caused shoot inhibition to *Rhododendron* ‘Nova Zembla’ which after the second application was increasing in severity (Table 8 and Fig. 6). The *Pieris* ‘Red Mill’ and *Ilex* ‘Sky pencil’ never grew out of the phytotoxicity problems that had impacted them the season before. An examination of the roots showed acute stunting on all plants. As a result, the SCBG herbicide treatment effects were impossible to determine.

Fig. 6. *Rhododendron* ‘Nova Zembla’ at Willoway Nursery, Huron, OH the plant on the right was sprayed Tower + pendulum at 21oz + 2 qt, /ac and is exhibiting shoot inhibition.

Although FreeHand caused minimal injury in this trial it had little efficacy on three of this nurseries worst weeds including bittercress, marestail and groundsel. Tower was also ineffective on groundsel and pearlwort.

Willoway – Avon

The container trials at Willoway Nursery, Avon, OH showed no phytotoxicity with Ronstar (Fig. 8A) and Biathlon (Fig. 8B) (with one application) on *Hydrangea macrophylla* 'Endless Summer' (Fig. 8A), Gallery on *Itea* 'Little Henry,' Indaziflam (at 200 lbs. /ac) on *Hydrangea paniculata* 'Limelight' and Biathlon on with *Hydrangea arborescens* 'Invincibelle spirit.' However, Indaziflam was phytotoxic to *Hydrangea macrophylla* 'Endless Summer' (Fig. 8A and B) and *Hydrangea arborescens* 'Invincibelle spirit' (Table 9). The injury from the Indaziflam was worse than from the Biathlon causing after the second application almost total kill at the highest rate of 800 lbs. /ac (Table 9, Fig. 7).

Fig. 7. (right) *Hydrangea macrophylla* 'Endless Summer' 1WA2T, 05/17/12, applied with Indaziflam 800 lbs. /ac. (Photo by: H. Mathers).

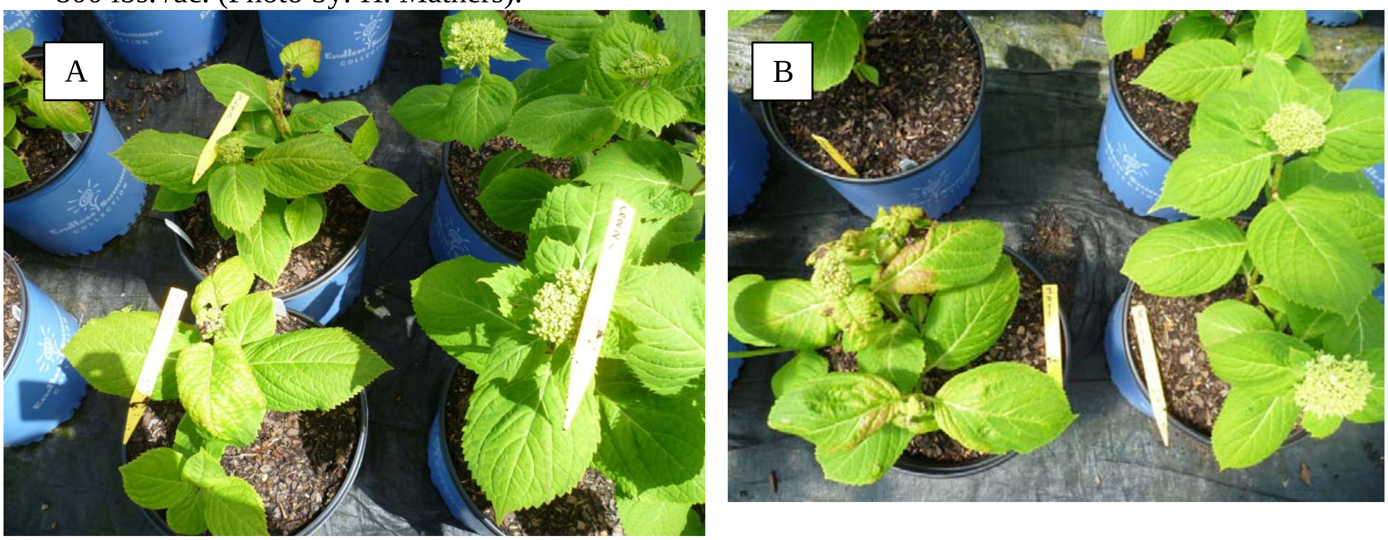


Fig. 8 A. Indaziflam (left) and Ronstar (right) on *Hydrangea macrophylla* 'Endless Summer' 2WAT showing stunting and leaf malformation caused by the 1X rate (200 lbs. /ac) vs. no injury from Ronstar at 2X (200 lbs. /ac). **B.** Indaziflam (left) and Biathlon (right) on *Hydrangea macrophylla* 'Endless Summer' 2WAT showing stunting, chlorosis, leaf puckering and malformation caused by the 4X rate (800 lbs. /ac) vs. no injury from Biathlon at 1X (100 lbs. /ac). (Photos by: H. Mathers).

Biathlon did cause injury after the second application at all rates (Fig. 9 A and B). The growing points experienced significant injury where the granules were retained in the top foliage (Fig. 9 A and B).

Fig. 9 A. and B. Biathlon on *Hydrangea macrophylla* ‘Endless Summer’ 2 weeks after the second application (2WA2T) showing stunting, chlorosis and injury to the growing point **(B)** caused by the 2X rate (200 lbs. /ac). (Photos by: H. Mathers).

Tower + pendulum (21 oz. + 2 qt., respectively) also caused damage to *Hydrangea macrophylla* ‘Endless Summer’ which increased after the second application (Table 9, Fig. 10).

Fig. 10. Tower + pendulum (21 oz. + 2 qt., respectively) were causing leaf and growing point deformation on *Hydrangea macrophylla* ‘Endless Summer’ at Willoway Nursery, Avon, OH 2WAT. (Photo by: H. Mathers),

As indicated above Indaziflam was also injurious on *Hydrangea arborescens* ‘Invincibelle spirit’ at all rates and *Hydrangea paniculata* ‘Limelight’ at high rates (2X and 4X) (Table 9). Although damaged occurred at all rates for ‘Invincibelle spirit,’ it was most severe at the 4X rate (800 lbs. /ac) (Fig. 11). Damage to ‘Limelight’ was also most severe at the 4X rate (800 lbs. /ac) (Fig. 12).

Fig. 11. (left) *Hydrangea arborescens* 'Invincibelle spirit' 2WA2T of 1X rate (200 lbs. /ac) (left) and 800 lbs. /ac) (right) applied with Indaziflam showing severe stunting, chlorosis and leaf malformation. (Photo by: H. Mathers).

Fig. 12. (right) *Hydrangea paniculata* 'Limelight' 2WAT application of 4X rate (800 lbs. /ac) of Indaziflam showing chlorosis, necrosis, leaf puckering and malformation. (Photo by: H. Mathers).

Table 9. Phytotoxicity of several ornamental cultivars from various herbicides at Willoway Nurseries, Avon, OH.

Itea 'Little Henry'

Treatment	Rate/ac	Location	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	
Gallery	1.3 lb	Willoway Avon	1.8		2.6		0.4		0.9		2.4	*
Gallery	2.6 lb	Willoway Avon	1.4		1.3		0.5		0.9		2.0	
Gallery	5.2 lb	Willoway Avon	2.1		2.5		0.6		0.9		2.8	**
Untreated	--	Willoway Avon	1.7		2.2		0.0		0.2		0.9	

Hydrangea 'Endless Summer'

Treatment	Rate/ac	Location	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	
Tower	21 oz	Willoway Avon	0.0		0.0		0.4		0.7		3.8	**
Tower	42 oz	Willoway Avon	0.0		0.0		0.8		1.0		4.8	**
Tower	84 oz	Willoway Avon	0.0		0.2		1.4		0.8		5.7	**
Indaziflam	200 lbs	Willoway Avon	0.9		2.6	**	3.8	**	3.5	**	5.5	**

Indaziflam	400 lbs	Willoway Avon	2.1	**	3.2	**	4.3	**	4.8	**	7.8	**
Indaziflam	800 lbs	Willoway Avon	3.3		5.1	**	5.2	**	6.3	**	9.1	**
Biathalon	100 lbs	Willoway Avon	0.4		0.2		0.3		0.7		3.5	
Biathalon	200 lbs	Willoway Avon	1.1	*	1.2	**	1.4		1.0		3.6	*
Biathalon	400 lbs	Willoway Avon	0.5		0.2		0.7		1.2		3.5	
Ronstar	100 lbs	Willoway Avon	1.1	*	0.9	*	1.3		0.9		5.4	**
Ronstar	200 lbs	Willoway Avon	1.7	**	1.7	**	2.5	**	1.1		4.6	**
Tower + Pendulum	21 oz + 2 qt	Willoway Avon	2.5	**	3.1	**	3.8	**	2.7	**	5.9	**
Untreated	--	Willoway Avon	0.3		0.1		0.7		0.6		2.2	

Hydrangea 'Invincibelle'

Treatment	Rate/ac	Location	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	
Indaziflam	200 lbs	Willoway Avon	0.0		1.5	**	1.7	**	1.8	**	3.5	**
Indaziflam	400 lbs	Willoway Avon	0.0		4.4	**	3.2	**	3.1	**	5.6	**
Indaziflam	800 lbs	Willoway Avon	0.0		5.5	**	4.0	**	4.0	**	6.2	**
Biathalon	100 lbs	Willoway Avon	0.0		0.0		0.1		1.3		2.5	**
Untreated	--	Willoway Avon	0.0		0.0		0.1		0.5		1.1	

Hydrangea 'Limelight'

Treatment	Rate/ac	Location	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	
Indaziflam	200 lbs	Willoway Avon	1.8		2.3	**	0.8	**	0.8	**	0.0	
Indaziflam	400 lbs	Willoway Avon	3.8		4.3	**	3.0	**	1.7	**	1.5	**
Indaziflam	800 lbs	Willoway Avon	5.3		5.3	**	3.7	**	2.3	**	2.8	**
Biathalon	100 lbs	Willoway Avon	0.0		0.0		0.0		0.3		0.0	
Untreated	--	Willoway Avon	0.0		0.0		0.0		0.0		0.0	

Klyn Nursery

The container trials at Klyn's indicated many of the products tested provided minimal damage to the selected crops and may be used as alternative herbicides. Biathlon provided no significant phytotoxicity with *Azalea viscosum* or *Hemerocallis* 'Stella d oro' (Table 10). Applications of FreeHand and Tower provided no significant phytotoxicity with *Hydrangea paniculata* 'Unique' (Table 10). Indaziflam was acceptable on *Viburnum plicatum f. tomentosum* 'St. Keverne' and F6875SC was acceptable on *Buxus* 'Winter Gem' and *Thuja nigra* (Table 10). Damage did occur on *Rosa* 'Mini Rainbow' following applications of F6875SC which included significant burning of foliage with increasing rates (Fig. 13 and Table 10) and continued as stunting for the remainder of the trial.

Fig. 13. F6875SC applied on *Rosa* 'Mini Rainbow' at Klyn Nursery from left to right control, 1X (0.375 lb. /ac), 2X (0.75 lb. /ac) and 4X (1.5 lb. /ac) showing increasing damage with increasing rate. (Photo by: H. Mathers).

The only other crop that was damaged at Klyn's was *Hydrangea paniculata* 'Unique' following applications of Tower + pendulum (Fig.14). The Tower + pendulum resulted in significant stunting that persisted for the life of the trial (Table 10).

Fig. 14. *Hydrangea paniculata* 'Unique' left is a control plant and right is plant that received an application of Tower + pendulum (21 oz. + 48 oz., respectively). Photo by: H. Mathers.

Table 10. Phytotoxicity of several herbicides on selected containerized ornamentals at Klyn Nursery.

Azalea viscosum

Trmt	Rate/ac	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	4 WA2T	
Biathalon	100 lbs	0.4		0.0		0.0		3.8	**	--	0.0	
Biathalon	200 lbs	0.0		0.0		0.0		3.8	**	--	0.0	
Biathalon	400 lbs	3.8	**	0.0		3.2	**	4.3	**	--	0.0	
Untreated	--	0.0		0.0		0.0		2.0		--	0.1	

Hemerocallis 'Stella d'Oro'

Trmt	Rate/ac	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	4 WA2T	
Biathalon	100 lbs	0.0		3.1		0.0		0.0		--	0.3	
Biathalon	200 lbs	0.0		3.3		0.0		0.0		--	0.1	
Biathalon	400 lbs	1.1	**	3.0		0.0		0.0		--	0.2	
Untreated	--	0.0		3.3		0.0		0.0		--	0.1	

Viburnum p. 'St. Veverne'

Trmt	Rate/ac	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	4 WA2T	
Indaziflam	200 lbs	2.4		2.9		3.2		3.1		--	--	
Indaziflam	400 lbs	2.8		1.6		2.8		3.3		--	--	
Indaziflam	800 lbs	4.3		2.3		3.3		3.6		--	--	
Untreated	--	3.4		1.9		2.5		2.9		--	--	

Hydrangea p. 'Unique'

Trmt	Rate/ac	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	4 WA2T	
FreeHand	150	0.0		0.2		0.0		1.0		--	1.0	
FreeHand	300	0.0		0.2		0.0		2.3	**	--	0.8	
FreeHand	600	0.0		0.6		0.0		3.3	**	--	0.4	
Tower	21 oz	0.5		1.9	**	1.5	**	6.0	**	--	0.6	
Tower	42 oz	0.0		0.6		1.3	*	0.0		--	0.7	
Tower + Pendulum	21 oz + 48 oz	5.3	**	3.8	**	4.3	**	5.7	**	--	3.4	**
Tower + Pendulum	42 oz + 96 oz	2.5	**	0.9	*	2.3	**	0.0		--	1.0	
Untreated	--	0.0		0.2		0.0		0.0		--	0.2	

Rosa 'Mini Rainbow'

Trmt	Rate/ac	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T	4 WA2T	
F6875	0.375 lb ai	5.4	**	4.3	**	4.6	**	0.3		--	4.4	
F6876	0.75 lb ai	6.7	**	4.9	**	5.3	**	1.2	**	--	4.4	

F6877	1.5 lb ai	7.8	**	6.3	**	7.2	**	2.1	**	--	4.4
Untreated	--	0.0		1.3		1.3		0.2		--	4.6

Buxus 'Winter Gem'

Trmt	Rate/ac	1 WAT		2 WAT		4 WAT	1 WA2T	2 WA2T	4 WA2T
F6875	0.375 lb ai	1.6		0.8		0.0	0.0	--	0.0
F6875	0.75 lb ai	2.7	**	0.9		0.0	0.0	--	0.4
F6875	1.5 lb ai	3.9	**	1.8	**	0.0	0.0	--	0.8
Untreated	--	0.0		0.0		0.0	0.0	--	0.3

Thuja nigra

Trmt	Rate/ac	1 WAT		2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Indaziflam	200 lbs	0		0	0	0	--	0
Indaziflam	400 lbs	0		0	0	0	--	0
Indaziflam	800 lbs	2.5	**	0	0	0	--	0
Untreated	--	0		0	0	0	--	0

Losely Nursery

Field trials at Herman Losely & Son, Inc., Perry, OH showed little results (Table 11). There was little weed pressure during the time period of the trial and thus efficacy ratings were high even in the controls. All products tested resulted less phytotoxicity than the control (Table 11).

Table 11. Phytotoxicity and efficacy of several herbicides on *Taxus 'Runyon'* at Losely Nursery

		2 WA1T		4 WA1T		1 WA2T		2 WA2T		4 WA2T			
Treatment	Rate/ac	Phyto	Eff	Phyto	Eff	Phyto	Eff	Phyto	Eff	Phyto		Eff	
Biathalon	100 lbs	0.3	9.8	2.0	10.0	0.8	10.0	0.0	9.8	0.0		8.8	ab
Tower + Pendulum	21 oz + 2 qt	0.0	9.8	1.8	9.8	0.0	10.0	0.0	10.0	2.5	**	10.0	a
Indaziflam	200 lbs	0.0	10.0	1.8	10.0	1.0	10.0	0.5	10.0	0.0		10.0	a
Untreated	--	1.0	9.3	2.8	9.0	2.3	8.5	1.8	8.3	0.0		7.5	b

Sunleaf Nursery

Field trials at Sunleaf Nursery, LLP, Madison, OH revealed no phytotoxicity. SureGuard (12 oz. /ac) and V-10336 (30 oz. /ac) both provided commercially acceptable weed control after 10 weeks (Table 12). Despite reapplications at 6WAT of Biathlon (200 lbs. /ac), Barricade + Goal and Tower + pendulum these products provided below commercially acceptable control at 10 WAT. However, Biathlon (200 lb /ac) applied in the November 2011 provided excellent control into May 2012 (data not shown). Averaged over all evaluation dates Barricade +Goal also provided commercially acceptable control in these spring trials (Fig.15) as did Tower + Pendulum both of these products could be considered as alternative products to SureGuard in this operation.

Table 12. Weed control of several ornamental herbicides in a field setting at Sunleaf Nursery near Madison, OH in 2012.

Treatment	Rate/ac	1 WAT[z]	2 WAT	4 WAT	7 WAT	8 WAT	10 WAT
Biathalon✓	200 lbs	8.5[yx] bc	8.0 abcd	5.8 d	4.3 d	3.3 d	3.2 d
Barricade + Goal✓	21 oz + 48 oz	9.4 a	8.5 ab	7.0 cd	7.0 ab	6.8 ab	6.3 b
Tower + Pendulum✓	21 oz + 64 oz	8.9 abc	7.8 bcd	8.5 ab	7.5 a	6.8 ab	6.5 b
SureGuard	12 oz	8.4 bc	8.3 abc	7.5 bc	7.9 a	7.1 ab	7.4 ab
V-10336	7.5 oz	8.4 bc	7.5 cd	6.8 cd	5.4 c	4.2 d	4.3 cd
V-10336	15 oz	8.8 abc	8.2 abc	7.3 bc	7.1 ab	6.0 bc	6.7 ab
V-10336	30 oz	9.1 ab	8.7 a	9.0 a	8.3 a	7.8 a	8.1 a
Tower	21 oz	8.6 bc	7.9 bcd	6.4 cd	5.7 bc	4.4 cd	4.8 c
Untreated	--	8.2 c	7.3 d	6.2 cd	5.2 c	3.5 d	1.4 e

✓ indicates product was reapplied at 6 WAT

z = weeks after treatment

y = Ratings are based on a 0-10 scale with 0 being no weed control, 10 perfect weed control and $\geq$7 commercially acceptable.

x = Ratings followed by * and ** are significantly different from the control at specified date based on Dunnett's t-test (α = 0.10 and 0.05, respectively).

Fig. 15. Goal + Barricade (21 + 48 oz. /ac) (10 WAT) (left) (rating 6.3) compared to Biathlon 200 lbs. /ac (10 WAT) (right) (rating 3.2) at Sunleaf Nursery, Madison, OH. (Photos by: L. Case).

Studebaker Nursery

Container, field rows (Fig. 2 and 16) and liner bed trials were conducted at Studebaker Nurseries, New Carlisle, OH. All products tested in field rows showed minimal or no persisting injury (Table 13) and more efficacious than their controls (Table 13).

Table 13. Phytotoxicity and weed control of several herbicides on field rows of *Taxus* 'Runyon' and two cultivars of *Buxus* at Studebaker Nursery.

Taxus 'Runyon'

Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Tower	21 oz	0.0	0.0	0.3	0.6	0.5
Tower	42 oz	0.0	0.0	0.0	1.3	1.0
Tower + Pendulum	21 oz + 2 qt	1.3	0.5	0.0	1.1	1.6
Indaziflam	200 lbs	0.5	0.3	0.3	0.8	0.5
Gallery	1 lb	1.0	0.3	1.0	2.5 **	3.1 **
Gallery	2 lb	0.0	0.0	0.3	1.1	1.4
F6875	0.375 lb ai	0.0	0.5	0.0	0.4	0.4
Biathalon	100 lbs	0.8	0.8	0.8	1.5	0.3
Untreated	--	0.0	0.0	0.0	0.6	0.6

Buxus 'Green velvet'						
Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Tower	21 oz	--	2.7	2.7	1.5	0.6
Tower	42 oz	--	1.0	1.3	2.3	0.3
Tower + Pendulum	21 oz + 2 qt	--	2.3	2.3	1.8	0.5
Indaziflam	200 lbs	--	2.5	2.3	2.1	0.9
Gallery	1 lb	--	3.0	2.5	3.0	1.0
Gallery	2 lb	--	2.0	2.5	2.7	2.5
F6875	0.375 lb ai	--	2.3	2.0	1.4	0.4
Biathalon	100 lbs	--	2.8	2.5	3.0	2.0
Untreated	--	--	2.8	2.5	1.4	0.5

Buxus 'Northern charm'						
Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Tower	21 oz	3.5	4.5	1.5	1.1	0.0
Tower	42 oz	4.3	4.8	2.8	2.1	0.5
Tower + Pendulum	21 oz + 2 qt	4.0	4.5	2.8	1.3	0.6
Indaziflam	200 lbs	5.0	5.5	2.5	1.3	1.0
Gallery	1 lb	4.3	4.8	3.0	2.0	1.1
Gallery	2 lb	3.3	4.8	1.5	1.6	1.0
F6875	0.375 lb ai	3.7	3.8	2.0	1.8	0.3
Biathalon	100 lbs	5.0	5.3	3.5	2.3	1.0
Untreated	--	4.5	5.0	3.0	1.9	0.5

Weed control						
Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Tower	21 oz	8.8 ab	8.5 a	8.0 a	6.6 a	5.9 a
Tower	42 oz	9.4 a	8.0 ab	7.2 ab	5.4 a	5.3 a
Tower + Pendulum	21 oz + 2 qt	9.1 ab	7.5 ab	5.5 b	5.2 a	4.8 a
Indaziflam	200 lbs	9.0 ab	7.4 ab	6.3 ab	5.7 a	4.9 a
Gallery	1 lb	8.5 bc	7.6 ab	6.9 ab	6.0 a	5.6 a
Gallery	2 lb	9.1 ab	7.6 ab	6.7 ab	6.1 a	6.1 a
F6875	0.375 lb ai	8.9 ab	7.9 ab	6.8 ab	5.3 a	4.5 a
Biathalon	100 lbs	6.8 d	6.7 ab	6.4 ab	5.6 a	5.4 a
Untreated	--	6.9 cd	6.3 b	5.3 b	2.6 b	2.4 b

Three products provided an average efficacy over all evaluation dates of seven or higher (commercially acceptable, Gallery 2 lbs. /ac (Fig. 16), Tower 21 oz. /ac and Tower 42 oz. /ac. Because the weed pressure was so high on these sites these three products should all be considered commercially viable herbicide alternatives.

Fig. 16. Gallery 2 lbs. /ac applied at Studebaker Nursery, New Carlisle, OH on Taxus ‘Runyon’ showing exceptional weed control 2 WAT. (Photo by: H. Mathers).

Over all evaluation dates Tower + Pendulum (21 oz. + 2 qt. /ac) provided excellent weed control in *Buxus* and *Taxus* liner beds at Studebaker's. The granule version of Tower + Pendulum (FreeHand -200 lbs. /ac) also performed very well up to 4 WAT (Fig. 17) when it dropped just below commercially acceptable (Table 14).

Table 14. Phytotoxicity and weed control of several herbicides in *Taxus* and *Buxus* liner beds at Studebaker Nursery

Taxus 'Runyon'						
Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
FreeHand	200 lbs	1.0	0.8	1.8	1.0	0.3
Tower + Pendulum	21 oz + 2 qt	1.0	2.0	2.3	2.8 **	2.3 **
Indaziflam	200 lbs	0.0	0.8	2.8	1.5	1.8 **
Tower	21 oz	0.5	1.3	2.3	0.8	0.5
Untreated	--	1.0	1.5	1.0	0.5	0.0
Buxus 'Green Velvet'						
Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
FreeHand	200 lbs	1.0	1.0	0.5	0.5	0.3
Tower + Pendulum	21 oz + 2 qt	1.0	0.8	1.3 **	1.0	0.8
Indaziflam	200 lbs	0.0	0.5	0.0	1.5	1.0
Tower	21 oz	0.5	0.8	0.5	0.5	0.8
Untreated	--	1.0	0.3	0.0	0.5	1.0
Weed control						
Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
FreeHand	200 lbs	8.9 ab	7.5 bc	6.5 bc	6.0 ab	5.5 ab
Tower + Pendulum	21 oz + 2 qt	9.9 a	9.9 a	9.0 a	6.8 a	6.6 a
Indaziflam	200 lbs	9.1 ab	8.4 b	7.0 bc	6.6 a	6.4 ab
Tower	21 oz	8.3 b	8.0 bc	6.4 bc	5.0 b	4.9 b
Untreated	--	8.8 ab	7.0 c	5.5 c	2.0 c	1.3 c

Fig. 17. FreeHand applied at (200 lbs. /ac) (left) compared to control at 2 WAT in Studebaker Nursery liner beds. Note the control is showing emergence of several problematic weeds including bindweed and Marestail which are being controlled by the FreeHand application. (Photo by: H. Mathers)

The container trials at Studebaker indicated that Indaziflam could be used at all rates without injury on *Euonymus alatus* 'Compacta' and at the 1X rate of 200 lbs. /ac on *Viburnum* X'Juddi' (Table 15). Increasing the rate on *Viburnum* resulted in significant leaf deformation (Fig. 18).

F6875SC was non-injurious to *Euonymus alatus* 'Compacta'; however, it was very injurious to Viburnum X'Juddi' (Fig. 19) and *Hydrangea paniculata* 'Little Lamb' (Fig. 20) (Table 15). Biathlon provided significant injury on Hemerocallis 'Stella d'oro' at the 1X rate (Fig. 21); however, the plants seemed to be growing out of the injury by the end of the trial (Table 15). *Rosa* 'Knock out,' and *Taxus* 'Runyon' experienced no injury from Biathlon and Tower, respectively (data not shown). The *Buxus* 'Green velvet' experienced significant frost injury during the trial period and treatment effects from Indaziflam were indiscernible (data not shown).

Table 15. Phytotoxicity of several herbicides on containerized ornamentals at Studebaker Nursery

Euonymus alatus 'Compacta'

Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Indaziflam	200 lbs	0.0	0.0	3.1 **	0.2	1.1
Indaziflam	400 lbs	0.0	0.0	3.3 **	0.1	0.3
Indaziflam	800 lbs	0.0	0.0	4.4 **	1.1 **	0.8
F6875	0.375 lb ai	0.0	0.0	0.8	0.2	0.3
F6875	0.75 lb ai	0.0	0.0	0.8	0.1	0.3
F6875	1.5 lb ai	0.0	0.0	0.8	0.1	0.3
Untreated	--	0.0	0.0	1.1	0.2	0.5

Viburnum 'Juddi'

Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Indaziflam	200 lbs	0.5	0.7	1.2	0.9	0.2
Indaziflam	400 lbs	2.3	2.3	1.3	1.5	1.6
Indaziflam	800 lbs	5.6 **	6.1 **	5.0	4.0 **	4.0
Untreated	--	0.3	0.4	0.7	0.5	1.3

Hydrangea paniculata 'Little lamb'

Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
F6875	0.375 lb ai	6.9 **	7.3 **	6.9 **	2.8 **	1.6 **
F6875	0.75 lb ai	7.6 **	7.7 **	7.9 **	3.5 **	2.5 **
F6875	1.5 lb ai	8.3 **	8.5 **	8.3 **	4.1 **	3.9 **
Untreated	--	0.0	0.0	0.0	0.0	0.0

Hemerocallis 'Stella d'oro'

Trmt	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T
Untreated		0.0	0.0	0.0	0.3	0.4
Biathlon	100lbs	4.1 **	6.0 **	6.2 **	2.3 *	1.3 *

Fig. 18. Indaziflam 4X (800 lbs. /ac) applied on to *Viburnum* X'Juddi' caused significant leaf deformation at Studebaker Nursery 4 WAT. (Photo by: H. Mathers).

Fig. 19. F6875SC 4X (1.5 lb. /ac) (right) applied on *Viburnum* X'Juddi' showing significant leaf and growing point deformation versus the control (left) at Studebaker Nursery (4WAT). (Photo by: H. Mathers)

Fig. 20. F6875SC 4X (1.5 lb. /ac) applied on *Hydrangea paniculata* 'Little Lamb' (left) compared to control (right) showing considerable leaf burn, chlorosis, stunting and leaf deformation at all rates at Studebaker Nursery (4 WAT) (Photo by: H. Mathers).

Fig. 21. Biathlon 1X (100 lbs. /ac) applied at *Hemerocallis* 'Stella d'oro' caused chlorosis and necrosis of foliage in leaf whorls possibly associated with the suspension of the granules 4WAT. Damaged lessened after 8 weeks at Studebaker Nursery. (Photo by: H. Mathers).

Table 16. Summary of all herbicides and crops that experienced **no phytotoxicity** at the seven sites in 2012.

Herbicide	No phytotoxicity	Comments
Indaziflam	*Buxus* 'Green velvet'	
	Rosa 'Knockout'	
	Berberis thunbergii 'Crimson pygmy'	
	Itea 'Little Henry'	
	Viburnum plicatum 'St. Keverne'	
	Viburnum X 'Juddi'	1X only
Biathlon	*Rosa* 'Knockout'	(North Branch and Studebaker)
	Hydrangea macrophylla 'Endless Summer'	1 application only Wash off immediately
	Hydrangea arborescens 'Invincibelle spirit'	
	Azalea viscosum	
	Hemerocallis 'Stella d oro'	OK at Klyn, not at Studebaker's
FreeHand	*Rhododendron* 'Nova Zembla'	
	Azalea 'Karen'	
	Azalea viscosum	
	Hydrangea paniculata 'Unique'	
	Taxus 'Runyon'	Field
	Buxus 'Green Velvet'	Field
Tower	*Hydrangea paniculata* 'Unique'	
	Taxus 'Runyon'	
Tower + pendulum	*Taxus* 'Runyon'	Field
	Buxus 'Green Velvet'	Field
Ronstar	*Rhododendron* 'Nova Zembla'	
	Azalea 'Karen'	
	Weigela 'Rainbow sensation'	
Gallery	*Itea* 'Little Henry'	
	Spirea 'Neon flash'	
	Kalmia 'Olympic fire'	
	Hydrangea paniculata 'Limelight'	
F6875SC	*Buxus* 'Winter Gem'	

	Thuja nigra	
	Euonymus alatus 'Compacta'	

Evaluation of liverwort control products at two Michigan nurseries

Principle investigators: Dr. Hannah Mathers and Luke Case

Significance to the industry. Liverwort has been an ongoing issue for nursery growers for many years. The extent of the infestations has for the most part been limited to the propagation houses in the Eastern Midwest. Liverwort thrives in high humidity, moderate temperatures in substrates that tend to be high in fertility; however, liverwort can also survive desiccation. Although not as big of a problem in the Midwest as in the Pacific Northwest, liverwort has been a headache for many nurseries, and they have spent countless dollars in hand labor for removal prior to shipping or selling. The objectives of this study was to evaluate various control mechanisms for liverwort control and phytototoxicity on container crops.

Materials and Methods. The trials were set up at two locations near Grand Haven, MI; Northland Farms and Spring Meadow Nursery. Spring Meadow is a propagation nursery with most of their operation under a controlled environment. Northland Farms is a wholesale supplier of larger trees and shrubs; it has a few greenhouses for propagation, but most stock is overwintered in polyhouses, with some having minimum heat. The trials at Northland Farms were set up in minimum heat houses. The trials were initiated on 7 February 2012. Products evaluated included SureGuard (flumioxazin, Valent U.S.A.) at 3 and 4 oz/ac, MilStop applied as a liquid at the rate of 2.5 lbs/100 gallons water, MilStop (BioWorks) applied as a granule at 10 g/ft^2, baking soda applied at 10 g/ft^2 and 2.24 g/ft^2 (Northland Farms), and WeedPharm (Pharm Solution, Inc.) at 5% or 10% v/v. All liquid treatments were applied with a CO_2 backpack sprayer delivering 50 gal/ac. Two passes were made over the top of the plant material to deliver the desired rate of 100 gal/ac. At Spring Meadow, the granule forms of MilStop and baking soda were applied by hand over the top. At Northland Farms, the granule form of MilStop was applied by hand and the baking soda was applied with a hand cranked air duster. All treatments with the exception of baking soda at Northland Farms were reapplied at 6 WA1T (weeks after first treatment). Species selected for phytotoxicity at Spring Meadow included *Hydrangea arborescens* 'Invincibelle Spirit', *Ilex verticillata* 'Winter Red', *Viburnum rhytidophyllum* 'Cree', *Euonymus alatus* 'Unforgettable Fire', and *Syringa patula* 'Miss Kim'. Species selected for phytotoxicity at Northland Farms included *Hosta tardiana* 'Halcyon', *Dryopteris erythrosora*, *Perovskia atriplicifolia*, *Liriope spicata*, and *Syringa meyeri* 'Palibin'. Evaluations of control and phytotoxicity were taken at 1 WA1T, 2 WA1T, 4 WA1T, 1 WA2T (weeks after second treatment), 2 WA2T, and 4 WA2T. Phytotoxicity visual ratings were based on a 0-10 scale with 0 being no phytotoxicity and 10 death with $\leq$3 commercially acceptable. Liverwort control ratings were based on a 0-10 scale with 0 being no control and 10 perfect control with $\geq$7 commercially acceptable. The trials were set up in a completely randomized design for each species with 12 replications/treatment at Spring Meadow and 4 replications/treatment at Northland Farms. For phytotoxicity, treatments were compared to the untreated control using Dunnett's t-test with $\alpha = 0.05$ and 0.10. For liverwort control, treatment means were separated using lsmeans with α = 0.05. Statistics were analyzed using SAS® software using the Proc Mixed method.

Results and discussion.

Liverwort control. All treatments with the exception of the MilStop applied as a liquid provided some level of liverwort control (Table 1). MilStop is marketed as a fungicide when applied as a liquid at the tested rates, and in this trial, it was not an effective treatment to control liverwort. On the contrary, when MilStop is applied without water, right out of the bag, it controlled liverwort very well (Table 1, Figure 1). However, Milstop in its granule form has an inhalation hazard and is NOT labeled to be applied as such. WeedPharm will control liverwort, both at 5% and 10%, with the 10% solution having better control, but in most cases the two are not significantly different from each other. From this trial, the 5% solution would be a better choice, especially in terms of economics. However, with WeedPharm, just like many other “contact” control herbicides, thorough coverage is necessary, and whenever the liverwort was covered by plant foliage, control decreased. WeedPharm also seems to work better under higher temperatures, as seen with the differences between Spring Meadow and Northland Farms, and also the differences at Northland Farms from the first application to the second application. Although baking soda does not have a label for any form of weed control, a few nurseries use it for liverwort control, and thus was added to the trial. It does exceptionally well for control, although residual is limited. SureGuard has shown to control liverwort in other trials (data not shown; see earlier Yearly Research Reports). The IR-4 protocol suggested using a rate of 4 oz/ac; a rate of 3 oz/ac was also added as an extended measure at Spring Meadow. In terms of control, the two rates were not significantly different from each other at any evaluation (Table 1). SureGuard is slow to control liverwort, but once gone, SureGuard provides some residual for liverwort control.

Phytotoxicity. All species were dormant at the first application at Spring Meadow, and all but *Dryopteris* and *Liriope* were dormant at Northland Farms at the first application, which is why there are no ratings for the first two evaluations except for those two species (Table 2). When applied at 10 g/ft^2, baking soda is phytotoxic to all five of the species tested at Spring Meadow Nursery (Table 2). However, when applied at 2.2 g/ft^2, phytotoxicity was only noticed on *Liriope* at Northland Farms, and the damage was still commercially acceptable. After the first application, SureGuard at both rates provided significant damage on only *Hydrangea* and *Ilex* at Spring Meadow, but the damage was still commercially acceptable. The damage that SureGuard provided at both rates after the second application is quite noticeable in many of the species tested (Table 2), which provides evidence that SureGuard may be applied as a dormant application on many species that are normally injured by SureGuard when applied during the growing period. However, even after the second application, SureGuard did not injure *Viburnum* or *Dryopteris*. When applied as a liquid, MilStop provided no real damage on any of the species tested at Spring Meadow, which is not surprising. MilStop did cause damage to 6 of the 10 species tested when applied as a granular (Table 2). WeedPharm caused significant damage, with the higher rate causing more damage than the lower rate (Table 2). *Drypopteris* and *Viburnum* were the only species not significantly damaged by WeedPharm. WeedPharm is acetic acid, which causes leaf burning, but eventually many plants will grow out of the damage if not too severe.

From these trials, it can be concluded that when applied as a dormant application, SureGuard can be an effective product for control of liverwort with a lasting residual when applied at 3 or 4 oz/ac. Lower rates should be evaluated; however, the residual may not be as long with lower rates. SureGuard should NOT be applied to actively growing material unless the species is already on the product label as safe. MilStop and baking soda are also two other materials that warrant consideration for liverwort control. However, both products are not currently labeled, so any application would be considered off label. MilStop also has some applicator exposure issues as a granular formulation, so this would also have to be taken into consideration. However, both products are very effective for liverwort control, and further research is needed for MilStop to get a good rate for lowered phytotoxicity. At approximately 2 g/ft^2, baking soda is quite effective with low phytotoxicity, but more species need to be tested at this rate. WeedPharm could also be applied to many species in the dormant stage, but even at 5%, it will cause leaf burning on many crop species.

Table 1. Liverwort control from various products at Spring Meadow Nursery and Northland Farms near Grand Haven, MI.

Spring Meadow							
Treatment	Rate	1 WAT^z	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Baking Soda	10 g/ft^2	9.6^{yx} a	9.6 ab	9.8 a	10.0 a	10.0 a	10.0 a
MilStop	2.5 lbs/100 gal	4.0 c	4.1 c	4.8 c	4.6 b	5.1 b	4.5 b
SureGuard	3 oz/ac	6.7 b	8.5 b	10.0 a	10.0 a	10.0 a	10.0 a
SureGuard	4 oz/ac	6.3 b	8.6 b	9.9 a	10.0 a	10.0 a	10.0 a
WeedPharm	5%	9.0 a	8.8 b	7.9 b	9.2 a	9.3 a	9.1 a
WeedPharm	10%	9.7 a	9.8 a	9.3 a	10.0 a	9.9 a	9.7 a
MilStop	2.5 tbsp/flat	9.8 a	9.9 a	9.3 a	9.9 a	10.0 a	9.6 a
Untreated	--	3.5 c	3.2 c	3.9 d	4.5 b	4.6 b	4.6 b
Northland Farms							
Treatment	Rate	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
SureGuard	3 oz/ac	5.3 cd	5.9 b	7.2 b	8.2 a	8.4 a	9.1 a
WeedPharm	5% v/v	6.8 bc	6.6 b	7.9 b	9.2 a	9.0 a	8.8 a
MilStop	5 g/ft^2	9.8 a	9.8 a	9.5 a	9.1 a	9.5 a	9.6 a
Baking Soda	2.2 g/ft^2	8.0 ab	8.5 a	7.9 b	5.2 b	5.1 b	--
Untreated	--	3.7 d	3.5 c	3.2 c	2.0 c	2.1 c	1.5 b

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

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

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

Table 2. Phytotoxicity of several ornamental species from various liverwort control products at two nurseries near Grand Haven, MI.

Hydrangea Invicibelle Spirit							
Treatment	Rate	1 WAT[z]	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Baking Soda	10 g/ft^2	--	--	7.8[yx] **	7.8 **	8.3 **	8.7 **
MilStop	2.5 lbs/100 gal	--	--	0.1	2.9 *	2.3	0.0
SureGuard	3 oz/ac	--	--	2.4	6.2 **	9.5 **	9.6 **
SureGuard	4 oz/ac	--	--	2.9 *	5.7 **	9.3 **	8.2 **
WeedPharm	5%	--	--	1.0	4.6 **	4.5	1.3
WeedPharm	10%	--	--	1.2	4.3 **	3.7	3.0 **
MilStop	2.5 tbsp/flat	--	--	1.0	3.0 **	3.9	2.2 **
Untreated	--	--	--	0.8	0.8	2.8	0.0
Ilex verticillata 'Winter red'							
Treatment	Rate	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Baking Soda	10 g/ft^2	--	--	3.0 **	4.3 **	4.9 **	4.5 *
MilStop	2.5 lbs/100 gal	--	--	1.9 *	4.4 **	4.0 **	2.2 **
SureGuard	3 oz/ac	--	--	2.0 *	5.4 **	9.9 **	7.2
SureGuard	4 oz/ac	--	--	1.9 *	5.9 **	9.7 **	6.2
WeedPharm	5%	--	--	0.4	4.7 **	4.8 **	4.5 *
WeedPharm	10%	--	--	1.3	4.9 **	4.8 **	7.3
MilStop	2.5 tbsp/flat	--	--	3.3 **	4.7 **	4.6 **	7.7
Untreated	--	--	--	0.0	0.1	1.8	7.9
Viburnum rhytidophyllum 'Cree'							
Treatment	Rate	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Baking Soda	10 g/ft^2	--	--	10.0	8.9	--	10.0 **
MilStop	2.5 lbs/100 gal	--	--	0.0	1.5 **	--	0.6 **
SureGuard	3 oz/ac	--	--	4.3	6.9	--	7.1
SureGuard	4 oz/ac	--	--	6.0	6.4	--	6.5
WeedPharm	5%	--	--	4.0	5.8	--	5.7
WeedPharm	10%	--	--	4.8	7.3	--	7.1
MilStop	2.5 tbsp/flat	--	--	--	8.7	--	9.2
Untreated	--	--	--	5.0	5.8	--	5.9
Euonymus 'Unforgettable fire'							
Treatment	Rate	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Baking Soda	10 g/ft^2	--	--	4.7	4.4 **	4.3 **	5.3 **
MilStop	2.5 lbs/100 gal	--	--	3.5	0.1 **	2.3 **	3.3
SureGuard	3 oz/ac	--	--	4.3	7.4	7.7	8.8 **
SureGuard	4 oz/ac	--	--	4.4	6.4	6.8	9.5 **
WeedPharm	5%	--	--	1.9	5.3 **	5.2 **	4.3
WeedPharm	10%	--	--	4.3	7.8	7.9	4.3
MilStop	2.5 tbsp/flat	--	--	4.8	7.1	7.0	4.2
Untreated	--	--	--	3.7	8.8	9.0	2.9

Table 2, cont.

Syringa patula 'Miss kim'													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
Baking Soda	10 g/ft^2	--		--		0.0		3.7	**	4.8	**	8.4	**
MilStop	2.5 lbs/100 gal	--		--		2.8	**	0.9		1.8	*	1.5	
SureGuard	3 oz/ac	--		--		0.0		4.8	**	9.0	**	6.0	**
SureGuard	4 oz/ac	--		--		0.0		5.2	**	9.0	**	6.3	**
WeedPharm	5%	--		--		0.0		0.0		3.5	**	3.0	**
WeedPharm	10%	--		--		0.8	*	3.8	**	5.4	**	5.0	**
MilStop	2.5 tbsp/flat	--		--		0.0		1.3		1.3		0.2	
Untreated	--	--		--		0.0		0.0		0.0		0.0	
Hosta 'Halcyon'													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz/ac	--		--		--		3.3	**	3.5	**	5.0	**
WeedPharm	5% v/v	--		--		--		4.0	**	3.0	**	2.0	
MilStop	5 g/ft2	--		--		--		3.0	**	2.8	**	2.8	
Baking Soda	2.2 g/ft2	--		--		--		0.0		0.0		--	
Untreated	--	--		--		--		0.0		0.3		0.8	
Autumn Fern													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz/ac	0.0		0.0		0.0		0.8		1.5		3.0	
WeedPharm	5% v/v	0.8		1.3		2.3		2.8		2.3		0.8	
MilStop	5 g/ft2	3.0	**	2.8	**	5.3	**	5.0	**	5.0	*	6.3	**
Baking Soda	2.2 g/ft2	0.3		0.5		2.3		1.3		0.3		--	
Untreated	--	0.0		0.0		2.0		1.5		2.0		2.0	
Russian sage													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz/ac	--		--		--		5.8	*	7.3		6.5	*
WeedPharm	5% v/v	--		--		--		7.0	**	6.5		6.0	*
MilStop	5 g/ft2	--		--		--		8.5	**	8.3		5.0	
Baking Soda	2.2 g/ft2	--		--		--		0.0		2.5		--	
Untreated	--	--		--		--		0.0		2.5		0.0	
Liriope spicata													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz/ac	0.0		0.0		0.0		4.5	**	4.3	**	4.0	**
WeedPharm	5% v/v	0.0		0.0		0.0		2.8	*	3.5	**	3.0	*
MilStop	5 g/ft2	5.5	**	7.5	**	6.8	**	5.8	**	5.8	**	6.3	**
Baking Soda	2.2 g/ft2	1.5		2.8	**	1.8	**	1.0		2.0		--	
Untreated	--	0.0		0.0		0.0		0.0		0.0		0.0	

Table 2, cont.

Dwarf Korean lilac

Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz/ac	--		--		--		7.5	**	9.8	**	9.8	**
WeedPharm	5% v/v	--		--		--		4.3	**	6.0	**	5.3	**
MilStop	5 g/ft2	--		--		--		3.3	**	3.0	**	2.5	**
Baking Soda	2.2 g/ft2	--		--		--		0.0		0.0		--	
Untreated	--	--		--		--		0.0		0.0		0.0	

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

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

x = Treatment means followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)

Figure 1. Milstop granular on *Viburnum* at 10 WAT.

Figure 2. Baking soda on *Euonymus* at 10 WAT.

Figure 3. WeedPharm at 5% v/v on *Viburnum* at 10 WAT.

Figure 4. SureGuard at 4 oz/ac on *Viburnum* at 10 WAT.

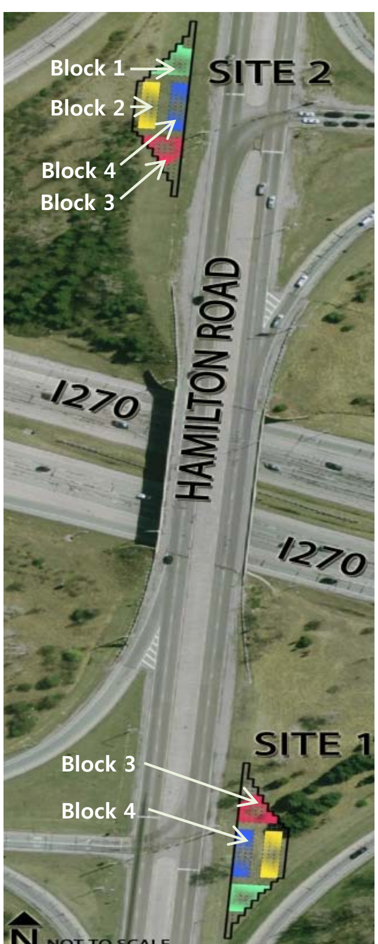
Greening the Highways: Out-plant survival of deciduous trees in stressful environments in Gahanna, Ohio

Dr. Hannah Mathers and Michele Bigger

Significance to the Industry.

Population pressures and increases in urban density are causing decreases in natural forested land (UNEP, 2009). Forests and trees offer many benefits including the opportunity to mitigate some urban environmental concerns (Nowak et al., 2002). A tree's benefits are greatest when a tree is mature, around 20 to 30 years of age. However the average urban trees lifespan is generally less than 15 years (Mathers et al., 2011). A second common challenge for creating an urban forest is finding available land. Often underused right-of-way (ROW) lands adjacent to roadways offer spatial opportunities to build the urban forest. Ohio alone has 266,000 acres of ROW land (Perlik, 2012). Furthermore, it is estimated that in the US, 90% of the population lives within 5 mile (8 km) distance of a highway (Slater, 1996). Successful highway greening installations could impact the industry both economically and environmentally. However, these unique landscapes can be highly stressful environments detrimental for both plant growth and survival. Opportunities to see beneficial environmental impact lie in understanding survival through species selection, growth, and adaptations.

These are the second group of sites planted for the North American Greening the Highways project. This long term research had three objectives. 1.) Evaluate survival of deciduous trees in a highway environment. 2.) Explore Geohumus®, (Geohumus International, GmbH & Co. KG, Frankfurt, Germany) a media amendment added during production for increasing out-plant survival, reduced water stress, and improved height and caliper growth. 3) Evaluate different production environments for increasing out-plant survival and deciduous tree growth. In addition, baseline data will be taken at the Gahanna sites for calculating carbon sequestration potential of this landscape design system. This summary will focus on objectives 1 and 2 for the initial year of the study.



Materials and Methods.

In June 2011 two sites were planted with trees along Interstate 270, in Gahanna, Ohio. Site one is at the south end of the intersection of Hamilton Road (SR 317) and Interstate 270. Site two is at the north end of the intersection of Hamilton Road (SR 317) and Interstate 270 (figure 1).

This study was integrated into a planned gateway entrance for the city of Gahanna. Landscape design was done by Bird-Houk, a Division of OHM, (Gahanna, Ohio). Construction Administration was done by the City of Gahanna. Trees included in the study were planted using a randomized complete block design. There are four blocks at each of the two sites (Figure 1). Four species of trees were installed (as described below). Each block contains thirteen trees of each species, for a total of 208 trees at each site. Additional trees of the same species were planted at the perimeter of each site to complete the intended design (Figure 2).

Site preparation included clearing and grubbing of existing organic and inorganic debris. An amendment of decomposed chipped tree material (City of Gahanna, Gahanna, OH) was and both sites and completely roto-tilled in with a John Deere 5325 tractor (Deere and Company, Moline, IL) to a depth of 10"-12" (25.4-30 cm) (table 1). Plants were installed using a power auger, Toro Dingo (The Toro Company, Bloomington, MN) with 12" (30 cm) auger attachment, in an orthogonal pattern (figure 2), 6’-0” (2.8m) on center (Figure 2). A 12’-0” (3.6 m) space differentiates blocks.

Fig 1: Site Location

Site Image: Google Earth

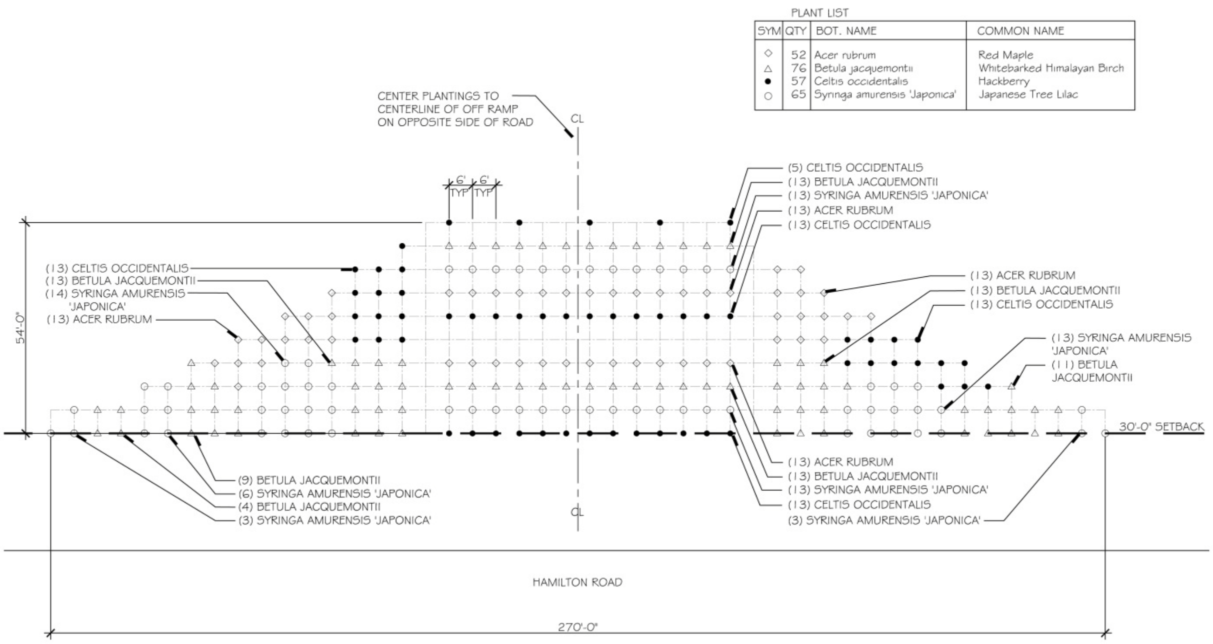


Fig 2: Site 2 layout (not to scale). Site 1 layout is similar in terms of design layout. Trees with the quantity thirteen (13) are included in the study, with the exception of 14 Syringa amurensis ‘Japonica’ on the left side, where only 13 trees of the 14 are in the study. All other trees called out on this plan were installed with the purpose of completing the gateway design intention.

Trees were watered in and staked following planting. One bamboo stake was installed at each tree for support. Smaller trees were staked with ½” (12.7 mm) diameter bamboo; larger material received a ¾” (19 mm) diameter bamboo. Trees were attached to bamboo with tape, by a tapener (Max Tapener HT-B2(N), MAXCO., LTD, Japan). Subsequent watering was done on an as needed basis. Shredded hardwood mulch was installed across each site in planting bed fashion by Ameriscapes (New Albany, OH). Finished product size was approximately 3/8” (10 mm) to 3½” (90 mm). Mulch specification called for 3” (76.2 mm) depth; however depth of mulch did vary across the sites from 1” (25.4 mm) to 3” (76.2 mm). Mulch was applied two weeks following installation of plant material. Trees were fertilized one time, with Osmocote Pro® 22-3-8 with minors (Everris International B.V., Geldermalsen, The Netherlands), at a medium rate of 63 g/plant. Due to a backorder in fertilizer, site 1 was fertilized 5 weeks following planting, site 2 received fertilizer 12 weeks after planting. Weed control was done on an as needed basis. Three chemicals have been used for weed control, 2 non-selective glyphosate based products, Prosecutor® (Lesco®, Stongsville OH) and Aquaneat® (Nufarm Specialty Products, Burr Ridge, IL). The pre-emergence herbicide product Rout®, Oxyfluorfen + Oryzalin (Everris International B.V., Geldermalsen, The Netherlands) was also applied. Further maintenance included re-staking, re-taping, and pruning of suckers.

Plants grown in a peaked or flat roof Cravo®, retractable roof greenhouse (Cravo Equipment Ltd., Brandford, Ontario, Canada), or outside on a gravel pad were provided by Ohio State University (Columbus, OH). All of these plants were grown in 3 gallon (11.4 L) black plastic containers. Species included Red Maple *Acer rubrum*, White Himalayan Birch, *Betula jacquemontii*, Hackberry, *Celtis occidentalis*, and Japanese Tree Lilac, *Syringa amurensis* ‘Japonica’. These were two year old liner material at the time of planting and averaged ½” (12.7 mm) caliper and

5'-6' height (152-182 cm). In addition one replicate of each species in each block for both sites was a designated to be bare root material bought by a local nursery. Complications arose with finding locally available similar material, size, and in bare root stock, due to this substitutions were made and bare root material for Syringa was completely removed the study. Species included were bare root material of Redpointe® Maple, *Acer rubrum* 'Frank Jr.', and White Himayalan Birch, *Betula jacquemontii*, and 2.14 gallon (8.1 L), utility containers of Hackberry, *Celtis occidentalis* . Ages of this plant material is unknown. Trees provided by Ohio State University were amended with a water stress reducing material, Geohumus® at four percentages by container volume: 0%, 0.5%, 1%, and 2%. Geohumus® amendments were incorporated when tree seedlings were initially potted into 3 gallon containers.

	Site 1	Site 2
Bed Size	0.2 ac (0.08 ha)	0.2 ac (0.08 ha)
Bed Layout	East-West	East - West
Average Bed Slope	8.2%	6.9%
Aspect	East	West
Roads Adjacent to Beds	Ramp to I-270 E & Hamilton Road	Ramp to I-270 W & Hamilton Road
Average Distance Middle of Bed to Road Surface	I-270E: 45.2 m (148.3 ft.) Hamilton Rd: 16.5 m (54.0 ft.)	I-270 W: 22.7 m (74.7 ft.) Hamilton Rd: 16.6 m (54.3 ft.)
Speed Limit of Adjacent Roadway	45 mph (72 km/hr.)	45 mph (72 km/hr.)
Daily Vehicle (Veh) Volume	I-270E: 15,500 Veh/day Hamilton Rd: 27,200 Veh/day	I-270 W: 7,000 Veh/day Hamilton Rd: 27,200 Veh/day
Observed Drainage	Very Poor: Wetlands to backside Surface Drainage Patterns Noticeable	Surface Drainage Patterns Noticeable
Soil Type	Sand/Shale/Clay	Loam /Clay
Mulch	Generic Shredded Bark Mulch Size: 10 mm - 90 mm	Generic Shredded Bark Mulch Size: 10 mm -90 mm
Soil Amendment	Decomposed Wood Chips	Decomposed Wood Chips
Average Soil pH	7.6-8.1	7.4-8.0
Average Soil Sodium (Na)	729.51 ppm	196.48 ppm
Average Soil Zinc Levels	58.68 ppm	13.85 ppm
Average Dry Soil Bulk Density	1.51 g/cm^3	1.42 g/cm^3
Average Dry Soil Bulk Density Corrected for Gravel	1.33 g/cm^3	1.38 g/cm^3
Average Soil Gravimetric Water Content	0.23 g/g	0.26 g/g
Weed Pressure	Medium	High

Table 1: Site characteristics. Site measurements and slope analysis was conducted base off of survey material provided by the City of Gahanna and design drawings produced for the project. Average pH, Sodium (Na), and Zinc levels were sampled prior to installation in April of 2011. Average dry, corrected dry, and gravmetric water content was sampled following installation in October 2011.

Results and Discussion.

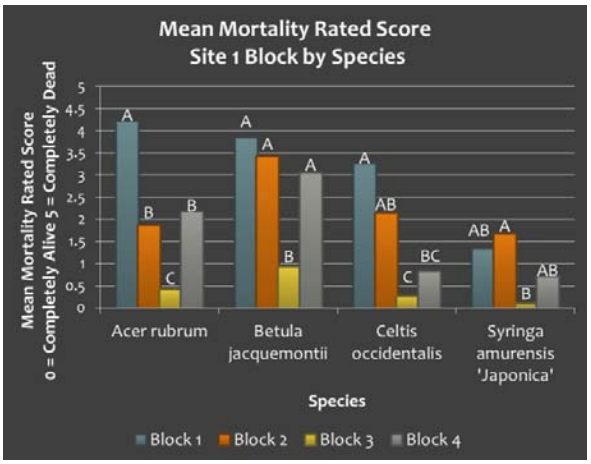


Fig. 3

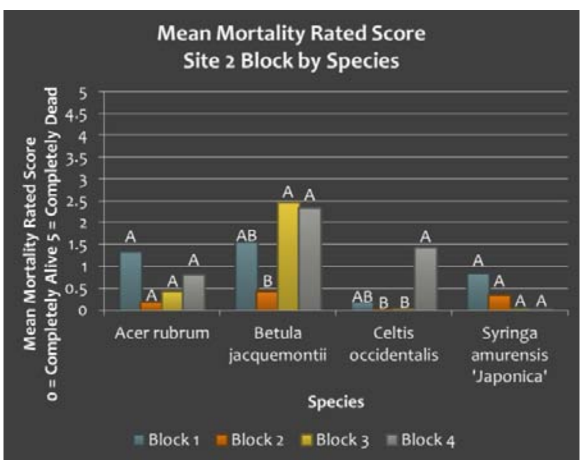


Fig.4

Figures 3 & 4. Visual mortality mean rated score within species by site and block. Plants were installed June 2011. Sites are located at the intersection of Hamilton Road and I-270 in Gahanna Ohio. Ratings were taken May 24, 2012, approximately 47 weeks after planting (WAP). Trees were visually assessed for mortality by a rated score 0-5, 0=completely alive 3=plant had 50% dieback 5 = complete death). Visual assessment was for the total above ground plant. Visual mortality mean rated score is

Plant Counts	**Site 1**	**Site 2**
Acer rubrum	Dead/Total	Dead/Total
Block 1	8/12	2/11
Block 2	3/11	0/12
Block 3	0/12	1/12
Block 4	3/12	1/10
Betula jacquemontii		
Block 1	9/12	3/12
Block 2	8/12	1/12
Block 3	2/12	4/9
Block 4	5/12	5/12
Celtis occidentalis		
Block 1	7/12	0/12
Block 2	3/12	0/12
Block 3	0/12	0/12
Block 4	1/11	2/12
Syringa amurensis 'Japonica'		
Block 1	3/12	1/12
Block 2	3/12	0/12
Block 3	0/11	0/10
Block 4	1/11	0/12

Table 2: Plant breakdown for morality ratings.

the average of mortality ratings per site, block & species (Table 2). 373 total plants were rated. Means are pooled over treatment and production method. Means followed by different letters represent significant statistical differences by Fisher's Least Significant Difference (LSD) at $\alpha = 0.05$ level using ANOVA.

47 WAP, *Syringa* had the highest survival rate (91.3%). *Acer* (-10.9%) *Betula* (-31.1%) and Celtis (-5%) had decreased survival rates when compared with *Syringa*. All species experienced greater mortality in site 1 vs. site 2 (Figs 3 & 4, Table 2). Both sites have more than adequate slope for drainage; however severe compaction and large concentrations of rocks and shale (Table 1) result in significant drainage constraints. Site 1 is graded with a low point entering the wetlands between blocks 1 & 2. Surface drainage patterns are visible at both sites with mulch movement. Both CEC (Table 3) and average bulk density (Table 2) reinforce drainage and compaction conclusions.

		Bray -P1	Ammonium Acetate Extract				Base Saturation		
Site	pH	P (lbs/ac)	K (lbs/ac)	Ca (lbs/ac	Mg (lbs/ac)	CEC Meq/100g	% Ca	%Mg	% K
1	7.8	9.6	181.6	6703.8	340.0	18.4	90.8	7.9	1.3
2	7.8	19.4	225.2	5260.0	560.6	15.8	83.2	14.9	1.8

Table 3: Average initial soil test results. Soil samples were taken April 2011, prior to installation.

Site 1's pH ranged from 7.6 to 8.0, whereas site 2 ranged from 7.4 to 8.0. Average soil pH is alkaline, which is expected with limestone bedrock, and construction material debris. Nutrients are most available in a mineral soil between the pH of 6.0 to 7.5 (Mathers, 2012, Rosen et al., 2008). As the soil becomes more alkaline minor nutrients become unavailable (Mathers, 2012). This was apparent at both sites as boron, copper, and molybdaenum were deficient in the soil at both sites, furthermore in site 2, zinc was also deficient (data not shown). Site 1 receives strong westerly wind. Site 2 is protected by a vegetation buffer. Vehicles add additional air velocity to both sites. This could influence the larger concentration of zinc in site 1 verses site 2 (data not shown). Zinc is commonly comes off of vehicles. Phophorous and potassium levels are low as ideal values are generally in the range of 50 – 100 lbs./ac and 250-400 lbs./ac. Respectively (Zondag, 2012). Conversely, Magnesium levels are high, with ideal values in the range of 150 – 250 lbs./ac (Zondag, 2012). Magnesium has an antagonistic relationship with potassium (Mathers, 2012), which may be causing the low potassium levels. Calcium levels generally are acceptable as they are over 800 lbs./ac. (Zondag, 2012). CEC indicates that soil texture is a mixture of silts and clays. Base saturate indicates that percent calcium is slightly high, ideal values are between 40%-80%. The more extreme case in site 1 of the Ca:Mg ratio of 11:1 may be an indicator for nutrient challenges. Alfalfa is the model crop for ornamentals (Mathers, 2012), and although Ca:Mg ratios vary, most agronomic crops prefer ranges of 6:1 to 10:1 (LaBarge & Lindsey, 2012).

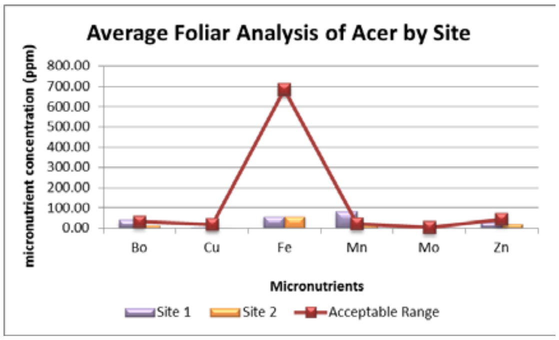


Fig.5

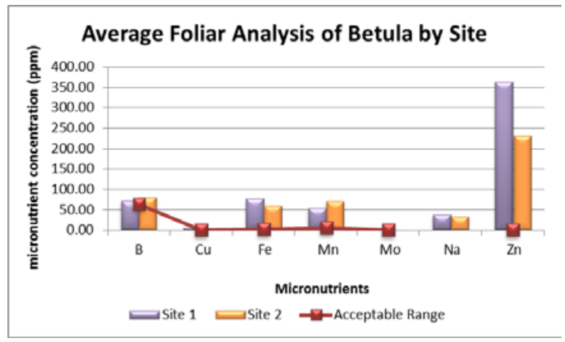


Fig.6

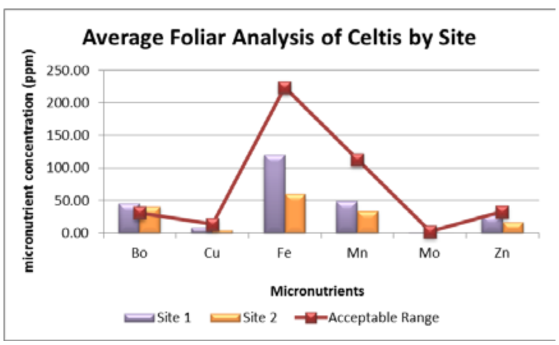


Fig.7

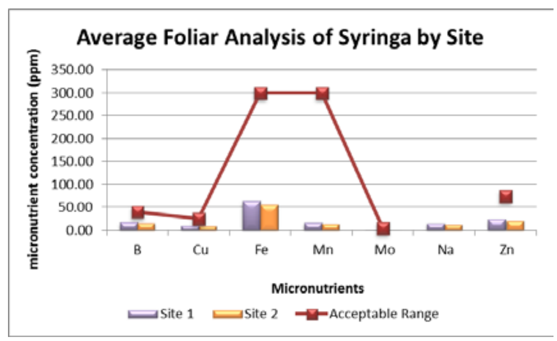


Fig.8

Figures 5-8. Average foliar analysis results by species by site with reference sufficient nutrient levels needed. Plants were installed June 2011. Sites are located at the intersection of Hamilton Road and I-270 in Gahanna Ohio. Samples of first fully developed leaves were taken July 3, 2012, approximately 52 weeks after planting (WAP). Plants had received one fertilizer treatment of Osmocote Pro® 22-3-8 with minors 5 WAP (Site 1) and 12 WAP (Site 2). At least one sample from each block for each species was sampled. Average foliar analysis is a composite of the 4 samples per species per site. Reference levels are taken from Jones et al., 1991. Reference for *Acer* was *Acer rubrum*, reference for *Betula* was *Betula papyrifera*, reference for *Celtis* was general deciduous trees, and reference for *Syringa* was *Syringa* spp.

Maple (*Acer*):

Low survival in site 1, blocks 1 and 2 we believe are a result of poor drainage. Holding of water in the ground for long periods of time was observed on multiple occasions. Similar mortality trends were seen for all species in these blocks. Site 1 block 4 may be a result of two factors first; red maples are known to be shallow rooted, to the point of roots appearing at the ground surface as they mature (Plantfacts, 2002). Red maple generally prefers wetter conditions, however can adapt to drier urban environments. This said like the birch described below, desiccation can be an issue, however unlike the birch, Red maple is not noted to be drought intolerant (Plantfacts, 2002). Excess drying winds from the west hitting block 4 of site 1 could influence Red maple survival. Secondly block 4 experienced mechanical injuries from an errant vehicle, between December 2011 and mid-February 2012. One maple was killed in the accident, a second received trunk wounding, and it is known Red maple is particularly sensitive to wounding (Walters & Yawney, 1990). Maples on both sites exhibited interveinal chlorosis, premature fall color, and leaf scorch. Red maple is known to prefer more acidic soil (Plantfacts, 2002). These symptoms of nutrient availability concerns coincide with the average soil and foliar analysis (Table 3, Figure 5).

Birch (*Betula*):
Birch had the greatest mortality rating of all species in both sites (Table 2). Birch is known to have a very shallow root system it can be extensive with favorable soil conditions (SelecTree, 2012, Safford et al., 1990), however in these sites root development could be hindered by soil compaction. At site 1 bulk density measures (before correction for gravel) ranged from 1.23 g/cm^3 to 1.90 g/cm^3. Likewise at site 2, bulk density ranged from 1.3 g/cm^3 to 1.99 g/cm^3. High soil bulk densities are common in urban environments (Smith et al., 2001). Furthermore it is known that bulk densities of greater than or equal to 1.8 g/cm^3 significantly hinder root development and growth (Zisa et al., 1980). High mortality seen in Site 1 & 2 block 4 could be a response to westerly winds. Birch is known to not be drought tolerant (Table 2, (SelecTree, 2012)). Ohio experienced a dry winter and continued drought throughout the 2012 growing season. Structural stability is also an issue with Birch mortality. Shoot growth habit of young Birch trees is more open compared with Lilac which grows more linearly. Open canopy habit with wind can result in greater force on the above ground portion of the plant (Minta, 2005) without proper roots for support the tree snaps at the base. This was seen in a few occasions at Site 1. Betula is also a nutrient sensitive species (Safford et al., 1990). Birch is also moderately sensitive to salt (SelecTree, 2012). Average soil salt analysis (Table 1), and foliar test (Figure 6) show most micronutrients are very high, compared to the acceptable concentrations High concentrations can hinder root development (Figure 6, (Safford et al., 1990, Gillman & Watson, 1994))

Hackberry (*Celtis*):
Hackberry has long been known for urban and poorly drained soils tolerance (Gillman & Watson, 1993, Dirr 1990). However, again large death was seen with Hackberry in site 1 in blocks 1 and 2. Mature tree are noted to have periodic flooding resistance, whereas younger trees can be injured if flooding is extended to periods of 60 days or greater (Krajicek and Williams, 1990). Furthermore, trees have been able to survive the first season following long term flooding, but survival decrease significantly with the second season (Krajicek and Williams, 1990). The hackberry, which did not survive in site 2, the evaluator believes, were results from desiccation. Hackberry roots, again like maple and birch are known to be predominantly near the ground surface, although roots are known to be strong (Krajicek and Williams, 1990). These plants were also smaller in stature when installed and root systems may have been less developed. The Hackberry in site 2 are closest to the pavement edge, enabling extra exposure to wind and particulates.

Lilac (*Syringa*):
Lilac was the only species to have a Geohumus® treatment effect (data not shown). With the addition of 1% Geohumus® by container volume there was a 19% increase in height at the time of planting. No further treatment effects were seen for any species at 16 or 55 weeks. This indicates Geohumus® could be aiding in the production of the plant, and when added to container media, roots could be adapting to more efficient water use enabling more shoot growth. Lilac had the lowest rated mortality ratings (highest survival) of all species at both sites (Figures 3, 4, & Table 2). Lilac is known for urban tolerance, it can

handle slightly alkaline soil, compacted soil, drought conditions and has a moderate soil salt tolerance and high aerial salt tolerance (Gillman & Watson, 1994). Japanese tree lilac is starting to be seen as slightly aggressive in its growth pattern, but has not been listed on any state or national lists as an invasive, unlike Common Lilac, *Syringa vulgaris* (Invasive.org, 2010). Slightly higher and only difference in mortality at site 1 is predicted to be because of severe drainage problems in blocks 1 and 2. No symptoms of iron or manganese deficiencies were observed. With that exception foliar analysis was generally more in line with reference standards (Fig. 8).

Conclusions.

White Himalayan Birch, Betula jacquemontii is not being recommended for highway landscape planting. Mortality has been high both in these US sites and ongoing studies in Ontario Canada. Furthermore in the studies along highway 401 in Canada, Paper Birch, Betula papyrifera, and Cherry Birch, Betula lenta have also shown low survival rates. Studies in Canada were initiated in 2010.

Geohumus® may have a greater impact in the production phase than in out-plant of deciduous tree material. Impacts on are indicated to be species specific. Further studies are being done in regards to the impact of Geohumus®

In Ohio, site compaction, nutrient availability, drainage and pH seem to be significant factors contributing to survival outcomes. This would indicate the importance of proper site preparation including soil testing prior to planting landscapes with stressful conditions. Knowledge of the landscape may impact survival greatly giving a better understanding to right-tree right place.

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Tree liner production in Columbus, Ohio

Principle investigators: Phoebe E Gordon and Hannah M Mathers

Significance to the industry. Many landscape trees are subjected to a variety of stresses, particularly young trees in the urban landscape. Small volumes of poor soil, pollutants, lack of adequate water, and mechanical stresses can compound with root deformities already present that make these trees doomed for failure, even if they receive adequate care post-planting. Root deformations can be caused by growing trees in closed plastic containers. When roots meet the side of a container wall, they are deflected. Commonly, the deflection is downward, which can cause structural failures due to the creation of a pivot point once out-planted. More rarely, these deflections can turn the root sideways, which, if at the surface of the root zone, can girdle the trunk and cause of vigor and death much later on.

The use of root pruning, via chemicals painted on the interior walls of the pot or via introduction of the root tips to air, has been put into practice recently in order to reduce deformations. Both types of pruning act by the same mechanism – killing the root tip. The plant responds to the loss of the root tip by generating several lateral roots, usually very close to the area of pruning. Some research has shown that root pruning can increase the size of above ground growth.

Retractable roof greenhouses (RRG) allow for plants to be exposed to outside conditions when growth is optimal by opening the roof to allow maximum exposure to photosynthetically active radiation (PAR), shade crops when PAR or heat reaches damaging levels, and have retractable sides that allow for air flow or prevent wind when wind speed is excessive. Because of the retractable roof and sides, they can also mediate temperatures in the summer and during the winter, making them useful for overwintering plants, both to prevent temperature extremes and to prevent premature bud break during sunny winter days that can prematurely raise temperatures inside a greenhouse structure.

Geohumus, a new water retention substance, is a polymer of organic and inorganic materials that retains water by storing it in its organic matrix. It expands up to 40 times its volume when fully hydrated, and releases water only by a difference in water potential via the root and the Geohumus. Geohumus has the potential to be a valuable post production product, reducing watering needs in commercial nurseries as well as aiding tree survival in outplanting.

The objectives of this experiment are to determine whether or not air pruning pots accelerate tree liner growth, how Geohumus or a combination of the two affect tree liner growth, and to observe any differences in growth between trees grown in the retractable roof greenhouse and outside.

Materials and Methods. The experiment was conducted during the 2011 growing season at The Ohio State University in Columbus, Ohio. The plants were either grown in the RRG (Cravo Equipment, Ltd., Brantford, Ontario, Canada) or outside in an uncovered hoop house. The RRG was set so that the structure would be totally closed below 70 ºF. The sides would remain open above that temperature, and if the temperature increased above 86 ºF, the top would close in order to shade the crop.

Gleditsia triacanthos and *Platanus occidentalis* were started from seed in spring of 2011 and germinated in flats. When they started to develop true leaves they were transplanted into one of five air pruning pots or left in germination trays. The air pruning pots were a Rootmaker® (8x10 cm square, 410 cm^3) (BRM), a small Rootmaker (5.5 cm x 10 cm, 180 cm^3) (LRM), Root Accelerator® (RA) (8x10 cm round 230 cm^3), Jiffy (12x10 cm round, 1230 cm^3), or Elle (7x7 cm round, 270 cm^3).

After six weeks of growth in the air pruning pots or flats all plants were transplanted into Classic 1200 #3 pots (11.4 L) (Nursery Supplies, Inc.), where they grew for the remainder of the season. They were organized into a randomized complete block design, with five blocks in each environment. They received three tablespoons of 8-9 month 19-5-8 Osmocote Pro with Minors (Everris International, The Netherlands) at transplant. Plants were watered via drip irrigation in both environments.

The plants were harvested mid-October, in the middle of senescence. Heights, shoot weight, root weight, leaf number, leaf area, and leaf weights, and the root systems were evaluated for presence of any deformities.

Data was analyzed using SAS (SAS Institute, Inc, Cary, NC) using an ANOVA program with only the main effects for all measurements aside from root deformities, which was arranged in a contingency table and analyzed using Fisher's exact test.

Results and discussion.

Gleditsia triacanthos. After six weeks in various pot types, height was significantly influenced. (Figure 1). Elle pots produced the tallest plants and Jiffy pots produced the smallest. However, once the plants were transplanted into #3 pots, any differences from starting pot type disappeared. The addition of Geohumus altered the dry weight shoot:root ratios of the plants (Figure 2); plants with no Geohumus had a higher shoot to root ratio and plants with 2% Geohumus had the lowest. Trees grown inside the RRG had a higher total leaf area and a lower leaf water content by horticultural inference. Starting pot type affected the presence of deformities (not shown).

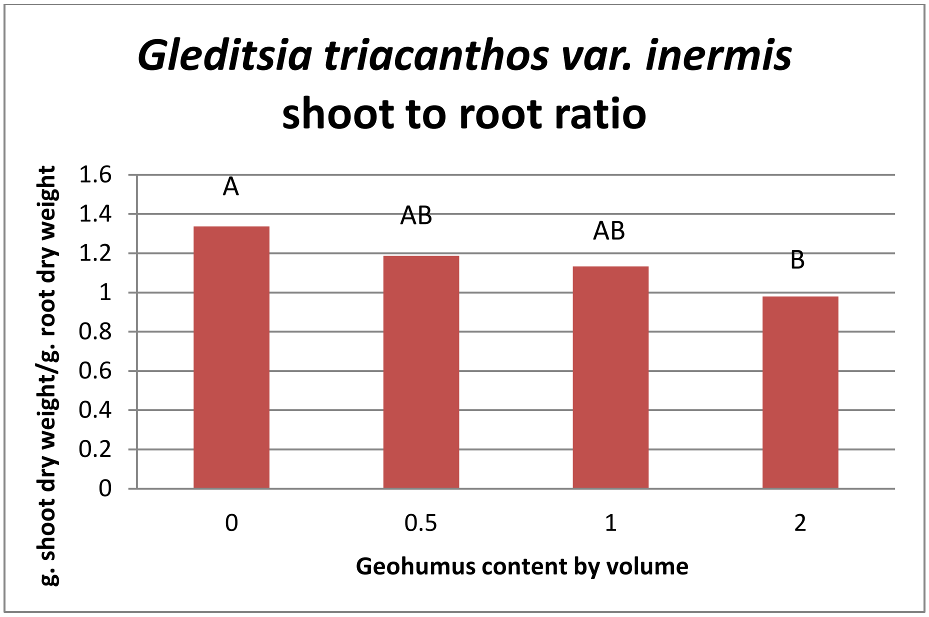


Figure 1: Shoot:root ratio of *Gleditsia tricanthos* var. inermis averaged across all other factors during the 2011 growing season. Letters denote significant differences.

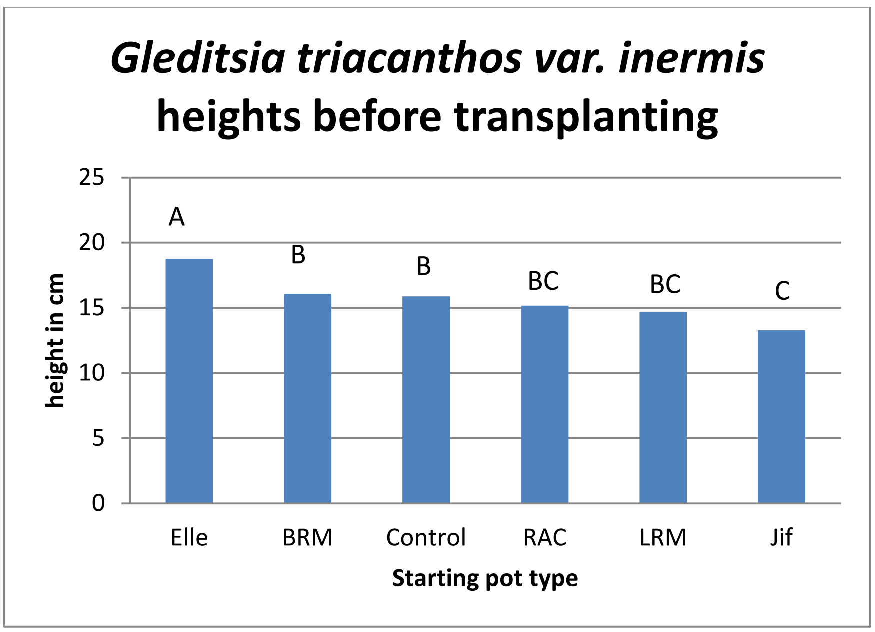


Figure 2: Height of Gleditsia triacanthos var. inermis from 2011 before up-shifting to 3-gallon sized pots. Abbreviations are as follows: Elle for Ellepot, BRM for the larger Rootmaker, RAC for Root Accelerator, LRM for the smaller Rootmaker, and Jif for Jiffy pot. Letters denote significant differences.

Platanus occidentalis

After six weeks in various starting pot types, there was no significant difference in height. Starting pot type continued to have no effect at the end of one growing season. The addition of 0.5% Geohumus, however, produced a significant effect in stem water content at α-value = 0.0557 at the end of the growing season (Figure 4), and 2% produced the lowest stem water contents. Plants grown in the RRG had higher fresh leaf weight, dry leaf weight, total leaf area, leaf total count, live leaf percentage, dry shoot:root ratio and lower fresh stem weight, dry root weight, stem water content. The effects cannot be statistically analyzed without two years of replication, but the data is significant by horticultural inference at this time. Starting pot type did not affect root deformities.

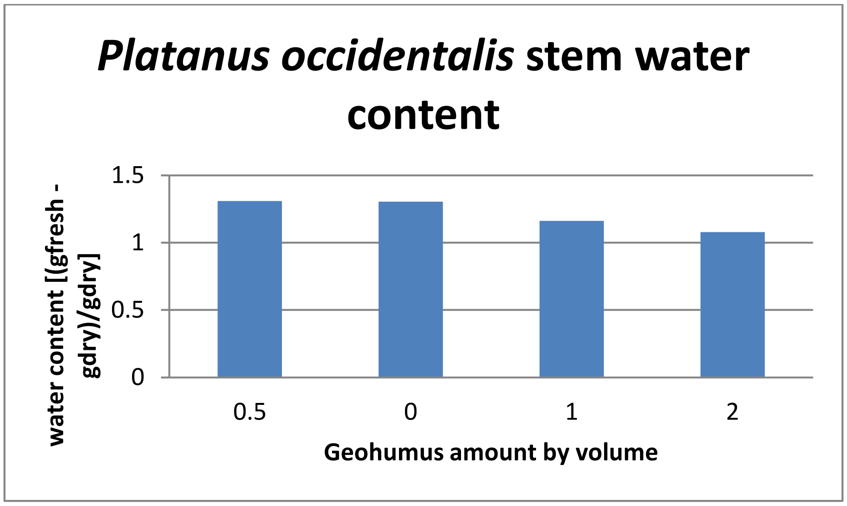


Figure 4:Stem water content of *Platanus occidentalis* during 2011. Test was almost significant with a α-value of 0.0557.

The Ellepot was the only pot that increased height growth in *G. triacanthos*, relative to the control. The Ellepot appeared to be a little better at holding water (personal observation, to be confirmed with a side study) which is possible as the Ellepot came with its own media. This decrease in drying between waterings relative to the other pots could account for the difference in heights. The BRM, LRM, and RAC experienced greater drying between waterings due to sloped sides – water that was not applied directly in the middle would often leave the pot a few centimeters down the sides through the pruning holes (personal observation).

Any difference in height in *G. triacanthos* likely disappeared once transplanted because the difference in heights, while statistically significant, was likely not biologically significant. If it was indeed due to differences in the water holding capacities of the air pruning pots, then those differences would have disappeared once the trees were transplanted.

The lack of significant growth effects for *Platanus occidentalis* with starting pot type could be attributed to the fact that they were slow to start growing, and by the time they were transplanted many of the plants had not even expanded their roots to the pot wall.

Geohumus affected both species, albeit different ways. There was a negative correlation for shoot:root ratio of *G. triacanthos* – with less shoot to roots as the percentage of Geohumus increased. We speculate that, as stated by Geohumus, the granules of Geohumus provide a ‘favorable’ environment for roots – high in water and air. Geohumus also contains small amounts of micronutrients. The most likely explanation is that *G. triacanthos* has been found to be lacking in stomatal control, so it is possible that, during the hottest parts of the day, *G.*

triacanthos was unable to regulate water loss and was therefore depleting the available water supply in the pots before the next watering event. The roots of *G. triacanthos* could have been actively exploiting the inter-granular spaces of the Geohumus, reducing water stress, and increasing root growth due to higher photosynthetic potential.

P. occidentalis appears to have been affected by Geohumus via a change in stem water content. In general, the higher the concentration of Geohumus, the lower the stem water content. We speculate that Geohumus increased the available water in the substrate and released it as the plants required. This enabled *P. occidentalis* in the higher concentrations of Geohumus to continue transpiring after the plant available water had been depleted in the lower Geohumus content pots . Stem water storage occurs in many tree species, providing a quick supply of water for photosynthesis, before the roots are able to supply the water required for the day. The lower stem water content in *P. occidentalis* could have occurred because the plants in the higher concentrations of Geohumus were transpiring, therefore decreasing stored water, whereas plants in the lower Geohumus concentrations were maintaining their stored water via stomatal closure.

Though the results presented are only one year's worth and therefore no statistical comparisons between the retractable roof greenhouse and the outside environment can be made, horticultural inferences are evident. Of most interest was that total leaf area of *G. triacanthos;* and leaf mass, both dry and fresh, total leaf count, and percentage of live leaves in *P. occidentalis* were larger in the RRG than outside, showing that the RRG extended the growing season. The retractable roof structure can be altered so that it either prevents heat buildup or traps heat during the winter and can mediate temperature lows so it can be operated so that it will extend the growing season, preventing senescence.

Lower root weight in the RRG could be due to more available water from lower substrate temperatures. The RRG has been shown in the past (Schuch) to reduce pot temperatures, so the plants therefore might not need as much water and thus less root mass to supply water requirements.

There was a trend for *G. triacanthos* to have lower leaf water content inside the RRG than outside. A possible explanation for this is that during senescence, stomata become unresponsive (stay closed), so it is possible that the leaves inside the retractable roof stuctrure were at an earlier stage of senescence or even still photosynthesizing. The same could be said for *P. occidentalis* – fresh stem weight and stem water content were lower in the Retractable roof greenhouse, which could be explained by the fact that the leaves were still photosynthesizing inside, or that the leaves outside were in a later stage of senescence, thereby reducing the amount of water in the stem.

Air pruning pots, touted for reducing root deformations and shown to have some promising results in the literature, appear to have little influence on growth as the plant ages. There is precedence for this, as many studies done have shown that as a tree ages, root pruning treatments have little lasting effects aside from improved morphology. It is very likely that the story could be different had the root pruning treatments continued, especially for *P. occidentalis*; many plants of which had not entirely filled the media before transplanting. *P. occidentalis* could certainly benefit from pruning later on in life, or a larger pot, as many of the plants were severely pot bound. The aggressive root growth later in the season could have obscured any pot bourne reductions in root deformities, and the authors did not look at root fusing as it did not occur until after data collection that it was a symptom of crowded roots. There were many observations of fused roots in *P. occidentalis*, and further studies on later root crowding as a side effect of root pruning should be done.

Geohumus appears to make as little difference as air pruning the trees. While it did appear to decrease shoot:root ratios in *G. triacanthos*, this trait is not necessarily a positive as evidenced by the condition of the roots of *P. occidentalis* in this study. This is not a bad thing; however, Geohumus has the potential to shine as an amendment that will come in useful later down the road in sales or outplanting. Geohumus, if at levels high enough, could aid commercial nurseries in keeping plants looking good enough to sell with less watering, and, more importantly, survive in outplanting. Trees rarely get care once planted in an urban setting and survival during the first few years depends on how much water they get. If it is added to media as a preventative measure, it has the potential to save homeowners and municipalities money in terms of tree replacement.

While no objective conclusions can be drawn about the retractable roof greenhouse, it should be noted that it did appear to lengthen the growing season into the fall, and it can be used to extend the growing season into the spring as well, which can be useful in areas with short growing seasons. Retractable roof greenhouses are being used increasingly and are viewed favorably, aside from the cost of installation, as a superior option to growing nursery crops outside due to increased climate control and protection from adverse conditions.

The Impact of Glyphosate Overspray on the Bark of Green Bark Trees

Principal investigators: Laura Giese and Dr. Hannah Mathers

Significance to Industry. Bark cracking is a significant problem in the nursery industry, causing an estimated $6.6 million in damage to nursery stock annually, with an additional $14 million in damage to landscape trees (Mathers, 2008). Generally bark cracking is associated with cold injury, especially on the southwest side of trees; however there are other factors at play, including pre-set wounds and the differing susceptibilities of tree species. Cold temperatures and freeze/thaw cycles can exacerbate an existing crack or could start a crack from an existing wound, but are not the sole causal factor (Butin and Shigo, 1981). Bark splitting is most common in thin-bark (also referred to as green bark) and young trees, which are common in the nursery industry. The bark of green (or thin) bark trees is photosynthetically active, which makes it susceptible to glyphosate application. We speculate that the widespread use of glyphosate in the nursery industry and overspray onto the bark of young trees is a major contributor to the high frequency of bark cracks. The objectives of this research are as follows:

1. Demonstrate that glyphosate is taken up through the bark of green bark tree liners by using shikimic acid increase as a biomarker for exposure.
2. Determine if there is a connection between glyphosate overspray onto green bark and bark cracking in subsequent years.

Materials and Methods

The ongoing trial started in spring of 2012 and is being conducted at The Ohio State University in Columbus, OH. The trees are being grown in a retractable roof greenhouse (RRG) (Cravo Equipment Ltd., Brantford, Ontario, Canada). During the growing season the RRG was set to close completely below 70 °F during the day and below 50 °F at night. All trees were irrigated with a drip system, which was programmed for three-five minute irrigation events daily and delivered 295mL/min with a coefficient of variation of 14% between emitters.

One species of tree was chosen for the trial, *Syringa reticulata*, for its green bark and lenticels, which make it an ideal test subject. All trees were fertilized on March 20, 2012 with 62g (medium rate) of 8-9 month Osmocote® 19-5-8 per 3 gallon container, then upshifted to 7 gallon containers on March 30.

Glyphosate Spray Treatments

Two different glyphosate products were investigated: Aquamaster® (Monsanto Co., St. Lous, MO) and RoundUp Pro® (Monsanto Co.). Treatments were applied at 0.42 qt/acre, which is about 40% of the recommended application rate, intended to simulate overspray as it may happen in a nursery setting. Three different application timings were investigated: one group of trees was sprayed on November 2, 2011, another group was sprayed on June 25, 2012, and another group was sprayed at both of these times. Two spray locations were also included; one over-the-top to maximize the exposure of the canopy; and a separate group was sprayed only on the bark, two to three inches above the surface of the media. There was also a control group for every treatment group.

Sample Collection and Measurements

Leaf samples were taken from the trees after the June 25 spray event but none were taken after the November 7 spray because the trees were rapidly senescing by then and not many leaves remained for sampling. Samples were taken at 0, 3, 7, 14, and 30 days post summer spray (DPSS). Fresh mass and leaf area were measured on the harvested leaves, and then they were combined into their respective treatment groups (i.e. all five replicate trees were harvested and their leaves were combined into one sample) and flash frozen by grinding coarsely in liquid nitrogen and held at -20°C until they were lyophilized. All samples were stored at -20°C after lyophilization. Water potential was also measured pre-dawn from two leaves on three trees chosen randomly within each treatment at 0, 3, 7, 14, and 30 DPSS, using a Model 1505D Pressure Chamber Instrument (PMS Instrument Company, Albany, OR).

The caliper of all trees was measured with a General Ultratech caliper at 6” above the surface of the media, and the height was measured using a telescoping measuring stick manufactured at The Ohio State University. These measures were taken five times during the 2012 growing season (June 6, July 12, August 2, September 11, and October 4).

Shikimic Acid Extraction

The lyophilized leaves were ground to pass a 20 mesh sieve with a small grinder (Arthur H. Thomas Co., Philadelphia, PA). Roughly 50mg of each sample was then measured into 2mL vials (Fisherbrand 02-682-558) with an analytical balance (Mettler AE100) for extraction and shikimic acid analysis.

The extraction was performed by adding 1.5mL of 0.25N HCl and a known amount of ^{13}C labeled glucose as an internal standard (99% atom ^{13}C, obtained from from Sigma-Aldrich) to each vial. The vials were subjected to shaking at 30Hz for 10 minutes with a bearing beater (Retsch model MM400). The vials were then sonicated for 15 minutes (Fisher Scientific FS60), followed by centrifugation at 17,000xg for 5 minutes (Thermo Scientific Sorvall Legend Micro17). Each supernatant was filtered through a 0.45µm filter with a regenerated cellulose membrane and diluted 50x with deionized water for shikimic acid analysis.

Liquid Chromatography Mass Spectrometry (LC-MS)

The shikimic acid analyses were carried out using a modified version of Matallo *et al*. (2009). The liquid chromatography (LC) was performed with a UHPLC (Ultra High Pressure Liquid Chromatography) 1290 (Agilent). Both the autosampler and the column temperature were kept at

25°C for all analysis. Metabolites were separated using a Gemini 5μm C18 250 x 4.6mm HPLC column (Phenomenex, Torrence, CA) and a guard column (Phenomenex) 4 x 3mm at a flow rate of 1 ml/min. A gradient was generated from 100% methanol + 0.1% formic acid (solvent A) and 100% water + 0.1% formic acid (solvent B). The gradient was defined as follows: A= 0-6 min 5 %, 6-6.1 min 90 %, 6.1-8.1 min 90 %, 8.1-8.5 min 5 %, 8.5-13 min 5 %.

The MS/MS analysis was performed with a hybrid Triple Quadrupole/Ion trap mass spectrometer QTRAP 5500 (AB Sciex). The mass spectra were acquired using Turbo Spray ionization in negative ion mode and metabolites were detected using multiple reaction monitoring (MRM) mode (see table below for details). The curtain gas was adjusted to 35 psi. The ion spray voltage, ion source gas 1 (nebulizing gas) and gas 2 (heating gas) were -4.5 kV, 60 psi and 45 psi respectively. The temperature of the source was 650°C. The [M-H]- were fragmented by Collision Activated Dissociation (CAD) set to medium. The entrance potential was constant for each transition and kept to -10 V. Analyte data were acquired and processed by Analyst 1.6.1.

Table 1. Specific metabolite-dependent MS parameters used for LC-MS/MS.

Analyte	Parent/product transition	DP* (V)	EP¶ (V)	CE# (V)	CXP§ (V)
Shikimate	173/92.8	-30	-10	-28	-45
[U-^{13}C]Glucose	184.9/60.9	-35	-10	-24	-7

* Declustering potential; ¶ Entrance potential; # Collision energy; § Collision exit potential

Data Analysis

All statistical analyses were performed using SAS (SAS Institute, Inc, Cary, NC), using the PROC MIXED procedure. The water potential measurements were analyzed by comparing the mean values at each time point. A linear regression analysis was performed for the height and caliper measurements; however there was little change between the five measurements taken over the 2012 growing season. The standard deviation of the slopes within treatments for height was larger than the actual slope for every treatment, likely due to large measurement variability compared to a small amount of change. The slopes of the caliper measurements showed less variability, however in order to directly compare these measures with the same method SAS was used to look at the change in caliper and height between the first and the last measures of the season instead of the slope of the change throughout the season.

The error bars on figures 1-4 show the coefficient of variation (CV) for the extraction and LC-MS/MS analysis of the samples. This was obtained by extracting one batch of leaves five separate times, analyzing each extraction, and calculating a CV from that data set. The sample chosen for this analysis was Aquamaster® sprayed over the top in summer of 2012 because it had an intermediate level of shikimic acid relative to the other samples (2214μg shikimic acid/g dry leaf tissue).

Results and Discussion

Water Potential

Only one significant difference was detected in all of the mean comparisons, between a control treatment and the over-the-top spray treatment with RoundUp Pro®, at 30 DPSS (data not shown). It is unlikely that this one difference is biologically relevant since there was no difference between these two treatments at any other time point taken, nor were there any differences noted between any of the treatments at any other time point.

Height and Caliper

The mean analysis for change in caliper over the 2012 growing season showed only two significant differences between all of the treatments. These two differences are shown in Table 2.

Table 2: Summary of statistically significant differences found in caliper measurements.

Herbicide	Spray time	Application location	Mean change in caliper
Aquamaster	November 2011	Over-the-top	5.6 a[z]
Aquamaster	June 2012	Over-the-top	5.6 a
Control	N/A	N/A	5.4 ab
Aquamaster	Both Nov 2011 and June 2012	Over-the-top	3.1 b

z = caliper measures followed by the same letter are not significantly different, based on lsmeans ($\alpha = 0.05$).

There were no other significant differences in caliper growth, including comparisons between treatments and control plants. It is interesting that these two differences are found within the same herbicide and application locations; however it is unclear what the biological relevance is to these particular Aquamaster® treatments, if any.

The mean analysis for change in height shows significant differences between the treatment of RoundUp Pro® applied to the bark both fall and summer and almost every other treatment. This particular treatment showed a relatively large increase in height, which is likely due to one erroneous measurement that skewed the mean height increase toward a higher value.

Shikimic Acid

Shikimic acid analyses show an increase in shikimic acid for those trees that were sprayed over the top, but not those that were sprayed on the bark only (Figures 1 through 4). The kinetics of shikimic acid increase and subsequent decrease are highly dependent upon dose and species; however the data collected in this experiment falls within expected ranges based on data from similar experiments (Anderson *et al*. 2001; Henry *et al*. 2007; Stasiak *et al*. 1992).

Figure 1: Bark application during summer of 2012 only. Aquamaster®, RoundUp Pro®, and control treatments at each time point, 0, 3, 7, 14, and 30 DPSS. Shikimic acid content is shown as μg shikimic acid per gram of dry leaf weight. Error bars show coefficient of variation of extraction and analysis, some are small relative to marker and difficult to see (CV=9.0%).

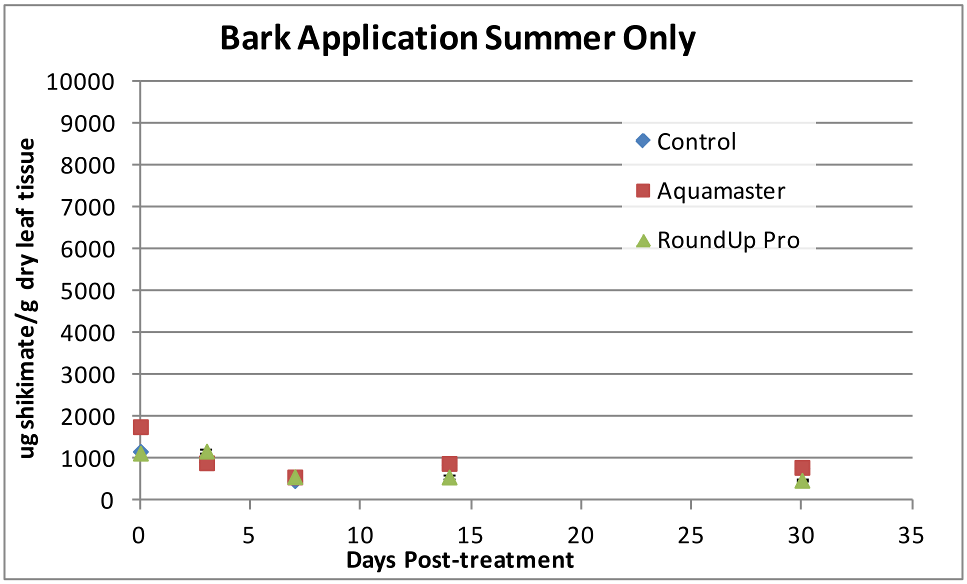


Figure 2: Bark application performed twice: during fall of 2011 and summer of 2012. Aquamaster®, RoundUp Pro®, and control treatments at each time point, 0, 3, 7, 14, and 30 DPSS. Shikimic acid content is shown as μg shikimic acid per gram of dry leaf weight. Error bars show coefficient of variation of extraction and analysis, some are small relative to marker and difficult to see (CV=9.0%).

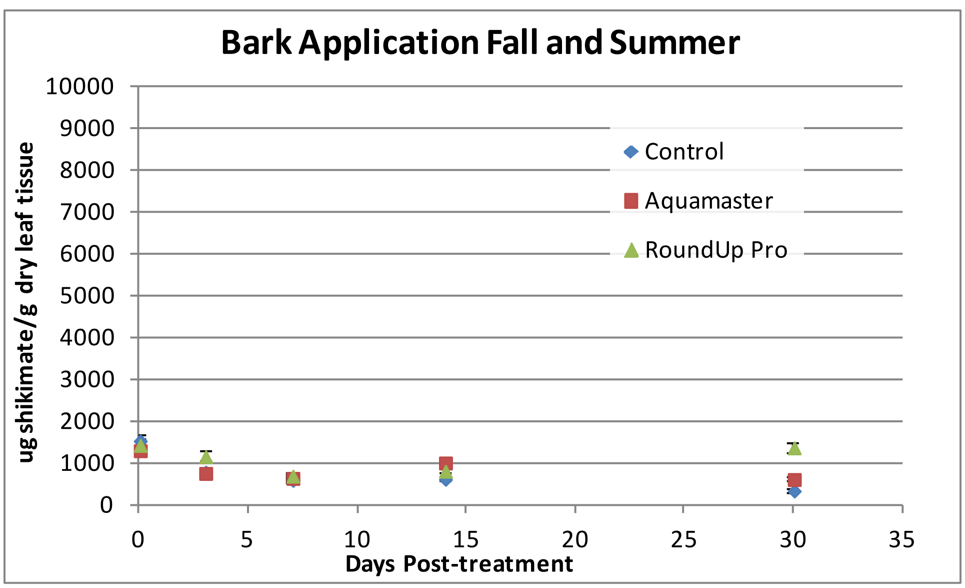


Figure 3: Over-the-top application during summer of 2012 only. Aquamaster®, RoundUp Pro®, and control treatments at each time point, 0, 3, 7, 14, and 30 DPSS. Shikimic acid content is shown as µg shikimic acid per gram of dry leaf weight. Error bars show coefficient of variation of extraction and analysis, some are small relative to marker and difficult to see (CV=9.0%).

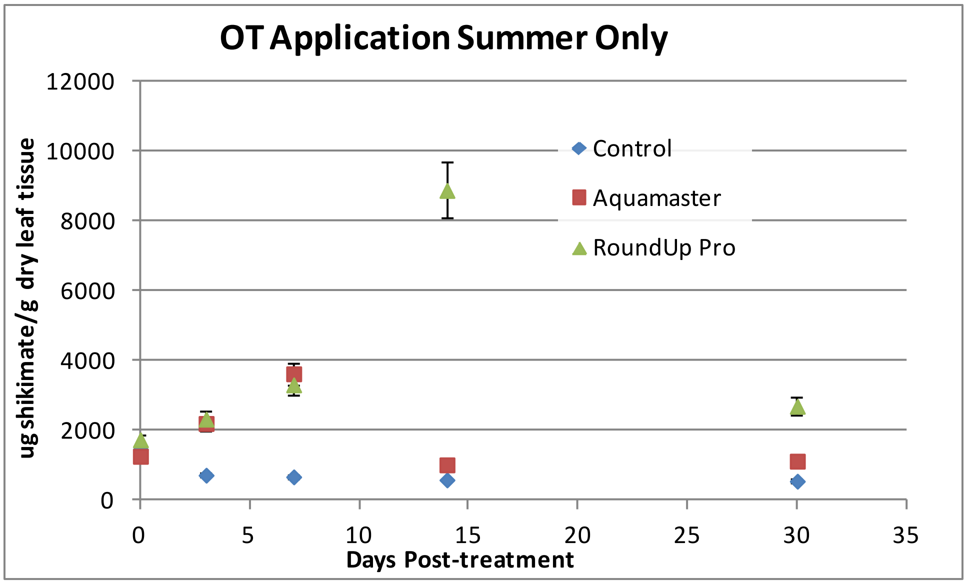
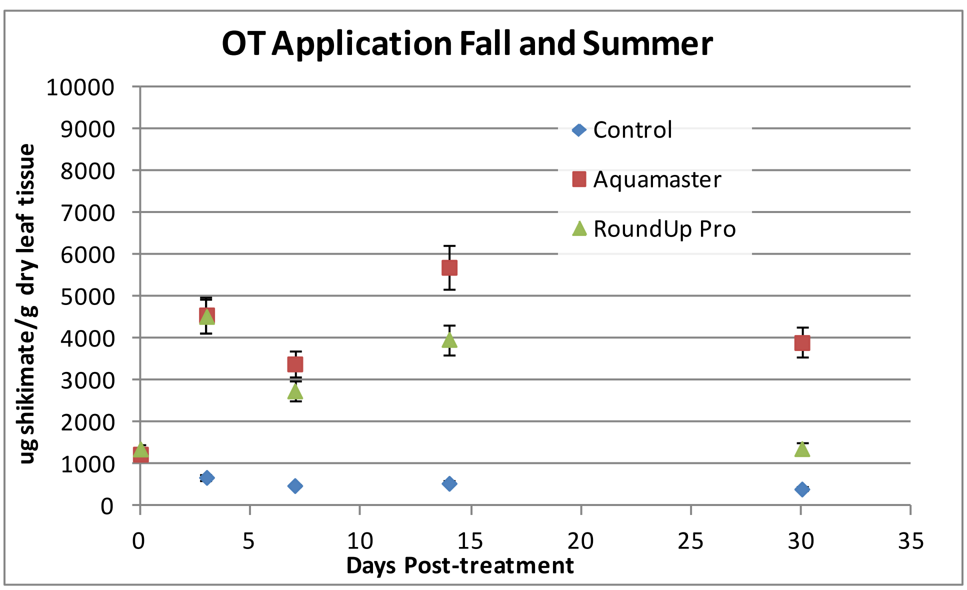


Figure 4: Over-the-top application performed twice: during fall of 2011 and summer of 2012. Aquamaster®, RoundUp Pro®, and control treatments at each time point, 0, 3, 7, 14, and 30 DPSS. Shikimic acid content is shown as µg shikimic acid per gram of dry leaf weight. Error bars show coefficient of variation of extraction and analysis, some are small relative to marker and difficult to see (CV=9.0%).



At this point in time, there is little difference in growth or phenotypic appearance; however, based on laboratory analysis, shikimic acid is elevated at approximately 3 days post spray on leaf treated trees only (over-the-top treatments). This study is ongoing, and we expect that the glyphosate treatments will result in distorted growth when the trees begin active growth again. More shikimic acid analysis will be performed when the trees leaf out again during the 2013 growing season. Future studies will be designed to confirm the presence of glyphosate in both the bark treated trees and the over-the-top treated trees.

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Jean-Christophe Cocuron of the Targeted Metabolomics Laboratory at The Ohio State University advised the analysis techniques and performed the LC-MS/MS work. His contributions were invaluable to this study.

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Phytotoxicity of Several Weed Control Products on Three Growth Stages of Canaan Fir in Ohio

Principal Investigators: Dr. Hannah Mathers, Deborah Holdren and Luke Case

Significance to the industry. Weed suppression/control is important in the Christmas tree industry. Competition from weeds impacts the growth rate and overall health of field grown conifers, especially when the trees are small. Some prevalent weed species are also difficult to control. Nursery growers use numerous methods to control weeds in the field including fire, mechanical removal and disturbance (mowing, tilling, etc.), biological control (livestock grazing), living mulch and chemical control (herbicide applications). Herbicides provide the most effective and economical way of reducing or eliminating weeds around the base of Christmas trees, especially during the early years of growth and establishment. Placement of herbicides and methods of application are important considerations for good weed control in the field. Of greater importance is the safety of the herbicide on the tree itself. Even minor chemical damage can render conifers grown for Christmas trees unacceptable.

The purpose of this study was to investigate the phytotoxicity and efficacy of herbicides and herbicide combinations to an untreated control on three growth stages of field planted Canaan fir (*Abies balsamea*).

Materials and Methods. Three sites at Timbuk Tree Farm in Granville, Ohio, each with a different age of Canaan fir, were used for the study. Site 1 was newly planted Canaan fir, site 2 was established one year old Canaan fir and site 3 was 3 year old Canaan fir. Site 1 was clean cultivated prior to initiation of the study and the herbicide was applied over the top. Site 2 had a living mulch of established white clover that was not disturbed and the herbicide was applied over the top. Site 3 had a 1.5 ft swath on both sides of the tree that was weeded just prior to application of the herbicide. The herbicides were applied as a directed spray towards the bottom of the tree at site 3.

There were three treatments and an untreated control, four replications and two subsamples completely randomized at each of the three sites. Treatments included a combination of 1.3 lb/ac Gallery (isoxaben) + 21 oz/ac Barricade (prodiamine), 21 oz/ac Tower (dimethenamid-p) + 2 qt/ac Pendulum (pendimethalin), and 8 oz/ac Westar (hexazinone + sulfometuron methyl). Treatments were compared to untreated control. All treatments were applied on September 13, 2012 using a CO_2 sprayer with a spray volume of 25 gal/ac using flat fan nozzles spaced 12 inches apart. Treatments were not watered in following application. Phytotoxicity and efficacy ratings were taken at 1, 2, and 4 WAT (weeks after treatment). Phytotoxicity was visually rated on a scale of 0-10 with 0 being no phytotoxicity, 10 being dead and ≤ 3 being commercially acceptable. Weed control (efficacy) was visually rated on a scale of 0 to 10 with 0 being no control, 10 being perfect control and ≥ 7 being commercially acceptable.

Results and Discussion.

Site 1.

Phytotoxicity. At 1 and 2 WAT there was minimal visible phytotoxicity noticed on the young Canaan fir. Some yellowing of needles at the growing point was noted, especially in the Westar treated plots (Figure 1); however, Westar did not cause significant injury (Table 1). At 4 WAT phytotoxicity ratings in treatments 1 and 2 were still commercially acceptable but the Westar provided unacceptable ratings. Some of the trees in the Westar treated plots were dropping needles, and needle discoloration ranging from yellow to brown was noted as well as dieback from the needle tips. The Westar label recommends treating trees that have been established in the field for at least one year and to trees that are dormant so these results were not surprising given the age of the trees on this site, and the trees were not yet dormant at time of application.

Efficacy. All treatments provided excellent weed control on site 1 over the three rating dates (Table 1). At 1 WAT there were virtually no weeds within the treatment area, resulting in perfect 10 efficacy ratings for all treatments. At 2 WAT some weeds were appearing in the untreated control plots but the treated plots exhibited excellent weed control again. At 4 WAT efficacy ratings were even better than at 2 WAT but this may have been influenced by frost that occurred between the 2 WAT and 4 WAT rating dates.

Site 2

Phytotoxicity. At 1 WAT all treatments provided acceptable phytotoxicity and continued to do so through the 2 and 4 WAT rating dates. There was some yellowing and needle drop at 4 WAT with Westar; however, it was still acceptable (Table 1).

Efficacy. Established white clover provided "living mulch" over much of site 2 except around the very base of the trees. There was some small nutsedge noted at 1 WAT and was off-color and dying by 4 WAT. All herbicide treatments and the untreated control plots received acceptable efficacy ratings (≥7) on all rating dates.

Site 3.

Phytotoxicity. All herbicide treatments provided acceptable levels of phytotoxicity on all 3 rating dates. Discoloration/phytotoxicity was noted and worsened over time. The phytotoxicity expressed itself as discoloration ranging from lite green to yellowing and browning of the needles as well as needle drop (figures 2, 3, and 4). Also observed was noticeable variability in the look of the Canaan firs from one tree to another which has been reported by Christmas tree growers. This might explain the variability in injury from one tree to another within the same treatment.

Efficacy. All herbicide treatments and combinations provided acceptable weed control/efficacy at 1 and 2 WAT. However, by 4 WAT, Gallery + Barricade, Tower + Pendulum and the untreated control had dropped well below the acceptable level of weed control. Westar continued to provide acceptable control (≥ 7) through 4 WAT.

There was noticeable variability in the discoloration/phytotoxicity ratings within treatments, for all treatments, on all sites. As mentioned earlier there were differences in the look of the Canaan

Fir from one tree to another (i.e. needle color, tree size and shape) with characteristic differences that might have influenced the sensitivity of one tree over another.

The environmental conditions prior to the onset of the study may also have influenced the effectiveness of the herbicides. The winter and spring of 2012 were very mild with trees breaking dormancy and leafing out up to two weeks early. Summer 2012 in Granville, Ohio was very hot and dry and the drought that resulted was one of the worst in documented history for many states. Under these conditions many herbicides will cause plant injury or perform poorly and pesticide labels caution against applications under these circumstances.

In spite of the environmental conditions leading up to the study the two combination treatments (provided acceptable levels of injury/phytotoxicity over the entire rating period and, with the exception of site 3 on the final rating date, Gallery + Barricade and Tower + Pendulum provided adequate weed control. Westar exceeded the acceptable level of injury on the young Canaan Fir (site 1) by the 4 WAT rating date and the highest ratings on the most mature trees (sites 2 and 3) by 4 WAT. Westar did provide acceptable efficacy at all three sites through 4 WAT.

Weed pressure was greatest on site 3.

This study should be repeated in 2013 using the late summer/early fall application timing. Follow up ratings on the 2012 study would provide additional data on the recovery and mortality of the Canaan Fir in all three growth stages used in the study.

We would like to thank Timbuk Tree Farm for support of this research.

Table 1. Efficacy and Phytotoxicity to three growth stages of Cannan Fir at three evaluation dates for herbicide and herbicide combinations at Timbuk Farms in Granville, OH

Site 1		Phytotoxicity			Efficacy		
Newly planted Cannan Fir							
Treatment	Rate/ac	1 WAT[z]	2 WAT	4 WAT	1 WAT	2 WAT	4 WAT
Gallery + Barricade	1.3 lb + 21 oz	0.8[yx]	1.9	2.8 **	10.0	9.8[wv] a	10.0 a
Tower + Pendulum	21 oz + 2 qt	0.5	1.5	1.5	10.0	9.3 a	9.9 a
Westar	8 oz	1.6	2.4	3.8 **	10.0	8.8 ab	9.9 a
Untreated	--	0.9	1.8	0.5	10.0	7.5 b	8.3 b
Site 2							
Established Cannan Fir with cover crop							
Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WAT	2 WAT	4 WAT
Gallery + Barricade	1.3 lb + 21 oz	0.6	0.9	0.9	9.3 ab	9.8 a	9.3
Tower + Pendulum	21 oz + 2 qt	1.8 **	2.0 *	2.1 **	8.6 b	9.3 a	9.0
Westar	8 oz	1.5 *	1.8	2.1 **	9.3 ab	8.8 a	9.9
Untreated	--	0.1	0.4	0.4	9.8 a	7.4 b	9.0
Site 3							
Established Cannan Fir with weeded rows							
Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WAT	2 WAT	4 WAT
Gallery + Barricade	1.3 lb + 21 oz	0.9	1.4	1.9	7.0	9.1 ab	5.4 b
Tower + Pendulum	21 oz + 2 qt	0.5	0.9	2.0	7.9	8.5 b	5.1 b
Westar	8 oz	0.9	1.5	2.9 **	7.6	9.1 ab	8.3 a
Untreated	--	0.1	0.3	0.4	7.6	9.4 a	4.9 b

z = weeks after treatment

y = Phytotoxicity visual ratings based on 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable

x = Treatments means for phytotoxicity followed by *,** are significantly different from the untreated control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)

w = Efficacy visual ratings based on 0-10 scale with 0 being no weed control and 10 perfect weed control with ≥7 commercially acceptable

v = Treatment means followed by the same letter in the same column for each site are not significantly different based on lsmeans (α = 0.05)

Figure 1. Herbicide injury/damage to Canaan Fir from Westar application (site 1) 1 WAT.

Figure 2. Herbicide injury/damage to Canaan Fir from Westar application (site3) 1 WAT.

Figure 3. Westar injury on well established Canaan Fir (site 3).

Figure 4. Westar herbicide injury 4 WAT (site 3).

Major weed control issues in Michigan nurseries

Principle investigators: Dr. Hannah Mathers and Luke Case

Significance to industry. With Michigan nurseries geographically unique weed problems, weeds with high reproductive potential and biomass production have been found through previous years of SCBG research. Estimates of 30,000 lb. /ac of weeds removed in hand weeding operations taking 1200 man hours/ac, at a cost of $18,000 have been calculated. Effective preemergence herbicide applications have been shown to cut these costs by 66% to $6,000/ac. Further research with difficult weed species such as Kik, marestail, mugwort and wild garlic is required to reduce these costs further and deplete the seed bank. Objectives of this proposal were to help growers understand what their current weed control program is really costing, how to decrease their weed control costs but increase their success, and why cutting weed control should be the last consideration for reducing production costs in these challenging economic times.

Timeliness: Sustainability is a common phrase in agriculture and horticulture today. Although the word sustainable often conjures thoughts of organic operations – this project focused on bio-rationale approaches with synthetic herbicides with the evaluation of new herbicides that have extended efficacy and require minimal applications. We also focused the project on other sustainable weed management features such as what causes nursery weed problems, what weeds growers had, an integrated system of prevention and bio-controls (especially for liverwort problems). Principles of crop rotation, herbicide rotation and MoAs, cover cropping, weed seed bank management, allelopathy and most fundamental good soil quality, fertility and drainage for a competitive crop have also been stressed in all presentations and literature that has come out of the project. We also emphasized what is not sustainable such as over use and misuse of postemergence herbicides. This project has been very timely as there is little research conducted in ornamental sustainable weed management although public pressure is requiring the nursery and landscape industries to use more sustainable practices.

Build on previous funding: Due to previous SCBG projects funded in 2009-10 and 2010-11 and now 2011-12, we were able to provide data to assist in the registration of two new herbicides for the ornamental industry. In addition to the registration of these two new product we showed growers the utilization of indaziflam (registered January 2013, as Marengo (OHP, Inc., Mainland, PA) at 0.11 lb. ai/ac and oxyfluorfen + prodiamine (registered as Biathlon) (OHP) at 2.75 lb. ai/ac in field and container operations as extended efficacy products and replacements to less sustainable preemergence herbicides currently used. In addition we also built on our research from previous SCBGs in liverwort control and were able to expand our research with sodium bicarbonate (Baking soda) to explore potassium bi-carbonate applied as a dust application, show it superior efficacy to anything currently on the market and submit an invention disclosure in 2012. The development of this new control has already generated tremendous demand inside and outside MI and would have never been discovered without these MI SCBGs.

Project Approach:

One hundred and fifty-seven trials were conducted in MI in 2012 at the three sites listed above, 75 liverwort, 59 container in-season and 23 field trials. Before this project, MI Nurseries had never used Biathlon or Indaziflam commercially. Indaziflam not only represents a new active ingredient but most importantly a little used mode of action for MI nursery growers. As a result of this project and building on past SCGBs we are actively advocating rotating Tower + Pendulum combination with SureGuard and Gallery/Barricade (Indaziflam) for field weed control. Each of the three host nurseries for the 2010-11 SCBG weed control trials [Berryhill Family of Nurseries (BFN), Grand Haven, MI (BFN, formerly Zelenka Nursery), Spring Meadow Nursery, Inc., Grand Haven, MI and Northland Farms Nursery, LLC, West Olive, MI) contributed in-kind donations of plant materials, facilities for herbicide testing (such as nursery fields, polyhouses and container yards), plant material maintenance and supplies (such as fertilizer, insecticides, pots and media) totaling approximately $4,000 per site. They also absorbed any costs regarding plant damage or losses caused by herbicides being tested at their sites. Two of the sites (BFN and Northland Farms) also served as hosts for a bus tour in August, 2012 highlighting this SCBG project.

Liverwort study.

Marchantia polymorpha L. (a thalloid liverwort) is a common plant pest in nursery and greenhouse production systems and one of the major weed issues we are addressing in this Specialty Crop Block Grant (SCBG). The presence of liverwort is considered unsightly and is often taken as an indication of reduced quality or plant vigor, all of which impacts the final valuation of the crop. It is estimated $650,000 is lost annually in MI nurseries due to ineffective liverwort control. In MI, the rapid growth and dissemination of liverwort has resulted in heavy thallus mats on the surface of pots, restricting water penetration, competing for nutrients, and providing habitat for other pests and disease vectors. To date there are no registered products that are used by nursery growers for effective liverwort control in enclosed structures. In our past SCBG we have also examined liverwort controls and found in the 2010-11 SCBG that Baking Soda (sodium bicarbonate) had potential for control and 1/3 the normal rates of SureGuard (flumioxazin, Valent U.S.A.) reduced phytotoxicity to the crop experienced at the full rate but still controlled liverwort. In this 2012 SCBG, we have evaluated SureGuard at ¼ the normal rate in an attempt to reduce phytotoxicity further but maintain liverwort control. We have also examined MilStop® (Potassium Bicarbonate 85%, BioWorks®, Victor, NY) because it is similar chemically to Baking Soda but may have potential to be registered as a herbicide; whereas, Baking Soda (a household product) may not.

We have identified SureGuard at 3 oz./ac (1/4 normal rate); WeedPharm™ (20% acetic acid) at 10% v/v (Pharm Solutions Inc., Port Townsend, WA), MilStop® (5 g/ ft^2) and Baking soda applied as a dusting (2.24 g/ ft^2)(per Northland Farms, West Olive, MI) can all be effective in controlling liverwort. However, WeedPharm will cause phytotoxicity as will SureGuard if not applied dormant. MilStop® is an OMRI listed sprayed broad spectrum fungicide (with **no** registration as an herbicide). Used as a spray MilStop® was non-effective for liverwort control. Baking soda is not registered for moss control. However, applications made at Northland Farms with a handheld crop duster (Fig. 1 A-C) were very efficacious with no phytotoxicity noted. The duster used at Northland Farms is quite old (Fig. 1. C); however, it is similar to a Dustin Mizer (Nitron Industries) that will be used in subsequent trials. Further work with rates of MilStop® and Baking Soda are warranted from this trial. Application made by hand at 10g/ ft^2 of Baking

Soda at Spring Meadow Nursery were 4.5 times higher and far more phytotoxic than the duster application method at Northland Farms.

Fig.1 A. Application of Baking Soda with Duster at 2.24g/ ft ^{2} Northland Farms, MI Feb. 7, 2012

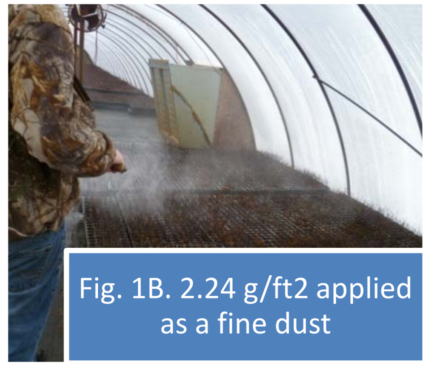


Fig. 1B. 2.24 g/ft2 applied as a fine dust

Fig. 1C. Baking Soda - 10g/ ft ^{2} Spring meadow Nursery, MI, Feb. 7, 2012

Fig.1D. Duster used at Northland Farms, MI

Liverwort product efficacy and phytotoxicity trials were initiated on dormant plant material on 7 February, 2012 at two nurseries; Spring Meadow Nursery, Grand Haven, MI (Fig. 2A) in a heated open-roof greenhouse (60°F) and Northland Farms, West Olive, MI (Fig. 2B) in an unheated polyhouse (34°F). Data has been collected from 3 evaluations; 1, 2, and 4 WAT (weeks after treatment). At Spring Meadow Nursery, treatments included MilStop® at 2.5 lb./100 gallons applied as a spray, MilStop® applied as a powder at 2.5 tsp./flat (5g/ft^2), SureGuard (flumioxazin, Valent U.S.A., Walnut Creek, CA) at two rates; 3 oz./ac (1/4 rate) and 4 oz./ac (1/3 rate), WeedPharm™ (Pharm Solutions, Inc., Port Townsend, WA) at two rates 5% and 10% v/v and baking soda at 10 gram/ft^2. The MilStop® powder application rate was calculated to apply a similar amount of product as applied for the registered fungicide spray rate. At Northland farms, treatments included SureGuard at 3 oz./ac (1/4 rate), WeedPharm™ at 5%, MilStop® at 5 gram/ft^2 and baking soda applied at 2.24 grams/ft^2 with a crop duster (Fig. 1D.). Liquids were applied in a spray volume of 100 gal/ac delivered with a CO_2 backpack sprayer equipped with 8003XR nozzles (Teejet, Inc., Wheaton, IL). All treatments were watered in according to IR-4 protocols within four hours after application.

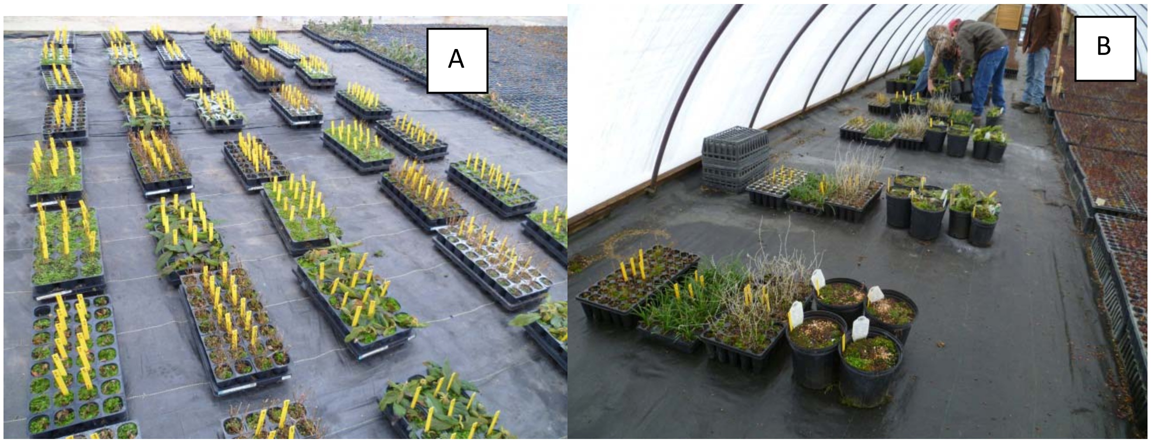


Fig. 2 (A and B). **A.** Liverwort trial initiation at Spring Meadow Nursery, Grand Haven, MI on Feb. 7, 2012 on dormant plants in trays of 4" containers of various species. **B.** Liverwort trial initiation at Northland Farms, West Olive, MI on Feb. 7, 2012 on dormant plants in trays of 2 1/4", 1 and 3 gallon containers of various species.

At Spring Meadow Nursery phytotoxicity was evaluated using hydrangea (*Hydrangea* 'Invincibelle spirit'), winterberry (*Ilex verticillata* 'Winter red'), dwarf burning bush (*Euonymus alata* 'Unforgettable fire'), lilac (*Syringa patula* 'Miss Kim') and viburnum (*Viburnum rhytidophyllum* 'Cree'). Viburnum and Hydrangea are key species we identified in our objectives to utilize in this SCBG. At Northland Farms phytotoxicity included hosta (*Hosta* 'Halcyon'), Autumn fern (*Dryopteris erythrosora*), liriope (*Liriope spicata*), Russian sage (*Perovskia atriplicifolia),* and Dwarf Korean lilac (*Syringa meyeri* 'Palibin'). Only the fern and liriope will be discussed as the hosta, Lilac and the Russian sage had not broken dormancy when this report was compiled.

Evaluations of control and phytotoxicity were taken at 1 WA1T, 2 WA1T, 4 WA1T, 1 WA2T (weeks after second treatment), 2 WA2T, and 4 WA2T. Phytotoxicity visual ratings were based on a 0-10 scale with 0 being no phytotoxicity, 10 death and ≤3 commercially acceptable. Liverwort control ratings were based on a 0-10 scale with 0 being no control, 10 perfect control and ≥7 commercially acceptable. The trials were set up in a completely randomized design for each species with 12 replications /treatment at Spring Meadow and 4 replications /treatment at Northland Farms. For phytotoxicity, treatments were compared to the untreated control using Dunnett's t-test with α = 0.05 and 0.10. For liverwort control, treatment means were separated using lsmeans with α = 0.05. Statistics were analyzed using SAS® software using the Proc Mixed method.

Liverwort control. All treatments with the exception of the MilStop® applied as a liquid provided some level of liverwort control (Table 1). MilStop® is marketed as a fungicide when applied as a liquid at the tested rates, and in this trial, it was not an effective treatment to control liverwort. On the contrary, when MilStop® is applied without water, right out of the bag, it controlled liverwort very well (Table 1) (Fig. 3 A and B). MilStop® in its granule form has an inhalation hazard and is NOT labeled to be applied in this form. WeedPharm™ will control liverwort; both at 5% and 10%, with the 10% solution having better control, but in most cases the two are not significantly different from each other. From this trial, the 5% solution would be a better choice, especially in terms of economics. However, with WeedPharm™, just like many other “contact” control herbicides, thorough coverage is necessary, and whenever the liverwort was covered by plant foliage, control decreased. WeedPharm™ also seems to work better under higher temperatures, as seen with the differences between Spring Meadow and Northland Farms (Table 1), and from the first application to the second application at Northland Farms (Table1). Although baking soda does not have a label for weed control, a few nurseries use it for liverwort control, and thus we added to the trial.

Baking soda provides exceptionally liverwort control (Fig. 4B), although residual is limited. SureGuard has shown to control liverwort in previous SCBGs. The IR-4 protocol suggested using a rate of 4 oz. /ac; a rate. The 3 oz. /ac was added in this SCBG trial. In terms of control, the two rates were *not* significantly different from each other at any evaluation (Table 1). SureGuard is slow to control liverwort but is the only product we have tested that provides residual control for liverwort (Table 1). For this reason it remains of high interest in these SCGB grant evaluations.

Phytotoxicity. All species were dormant at the first application at Spring Meadow, and all but *Dryopteris* and *Liriope* were dormant at Northland Farms (NF) at the first application. Thus, there are no ratings for the first two evaluations except for those two species at NF (Table 2). When applied at 10 g/ft^2, baking soda is phytotoxic to all five of the species tested at Spring Meadow Nursery (Table 2). However, when applied at 2.2 g/ft^2, phytotoxicity was only noticed on *Liriope* at Northland Farms, and the damage was still commercially acceptable (Fig. 4A). After the first application, SureGuard at both rates provided significant damage on only *Hydrangea* and *Ilex* at Spring Meadow, but the damage was still commercially acceptable (Table 2). The damage that SureGuard provided at both rates after the second application is quite noticeable in many of the species tested (Table 2), which provides evidence that SureGuard may be applied as a dormant application on many species that are normally injured by SureGuard when applied during the growing period. Even after the second application, SureGuard did not injure *Viburnum* or *Dryopteris* at the 3 or 4 oz. rate. When applied as a liquid, MilStop® provided no real damage on any of the species tested at Spring Meadow, which is not surprising. MilStop® did cause damage to 6 of the 10 species tested when applied as a granular (Table 2). Baking Soda was phytotoxic on active growth with 8 of 10 species. WeedPharm caused significant damage, with the higher rate causing more damage than the lower rate (Table 2). *Dryopteris* and *Viburnum* were the only species not significantly damaged by WeedPharm™. WeedPharm™ is acetic acid, which causes leaf burning, but eventually many plants will grow out of the damage if not too severe.

From these trials, it can be concluded that when applied as a dormant application, SureGuard can be an effective product for control of liverwort with a lasting residual when applied at 3 or 4 oz. /ac. Lower rates should be evaluated. Residual control at these lower rates may not last as long with higher rates; however, they provided exceptional control of the life of these evaluations. SureGuard should NOT be applied to actively growing material unless the species is already on the product label as safe. MilStop® and baking soda are two other materials that warrant further consideration for liverwort control. However, both products are not currently labeled, so any application would be considered off label. MilStop® also has some applicator exposure issues as a granular formulation, so this would also have to be taken into consideration. However, both products are very effective for liverwort control, and further research is needed for MilStop® to get a good rate for lowered phytotoxicity. At approximately 2 g/ft^2, baking soda is quite effective with low phytotoxicity, but more species need to be tested at this rate. WeedPharm™ could also be applied to many species in the dormant stage, but even at 5%, it will cause leaf burning on many crop species. The trial also provided evidence that liverwort infestations do cause growth reduction due to the thick thallus mat (Fig.5 B) and thus control is important (Fig. 5A).

Table 1. Liverwort control from various products at Spring Meadow Nursery and Northland Farms near Grand Haven, MI.

Spring Meadow							
Treatment	Rate	1 WAT^{z}	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Baking Soda	10 g/ft^2	9.6^{yx} a	9.6 ab	9.8 a	10.0 a	10.0 a	10.0 a
MilStop	2.5 lbs./100 gal	4.0 c	4.1 c	4.8 c	4.6 b	5.1 b	4.5 b
SureGuard	3 oz./ac	6.7 b	8.5 b	10.0 a	10.0 a	10.0 a	10.0 a
SureGuard	4 oz./ac	6.3 b	8.6 b	9.9 a	10.0 a	10.0 a	10.0 a
WeedPharm	5%	9.0 a	8.8 b	7.9 b	9.2 a	9.3 a	9.1 a
WeedPharm	10%	9.7 a	9.8 a	9.3 a	10.0 a	9.9 a	9.7 a
MilStop	2.5 tbsp./flat	9.8 a	9.9 a	9.3 a	9.9 a	10.0 a	9.6 a
Untreated	--	3.5 c	3.2 c	3.9 d	4.5 b	4.6 b	4.6 b
Northland Farms							
Treatment	Rate	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
SureGuard	3 oz./ac	5.3 cd	5.9 b	7.2 b	8.2 a	8.4 a	9.1 a
WeedPharm	5% v/v	6.8 bc	6.6 b	7.9 b	9.2 a	9.0 a	8.8 a
MilStop	5 g/ft^2	9.8 a	9.8 a	9.5 a	9.1 a	9.5 a	9.6 a
Baking Soda	2.2 g/ft^2	8.0 ab	8.5 a	7.9 b	5.2 b	5.1 b	--
Untreated	--	3.7 d	3.5 c	3.2 c	2.0 c	2.1 c	1.5 b

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

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

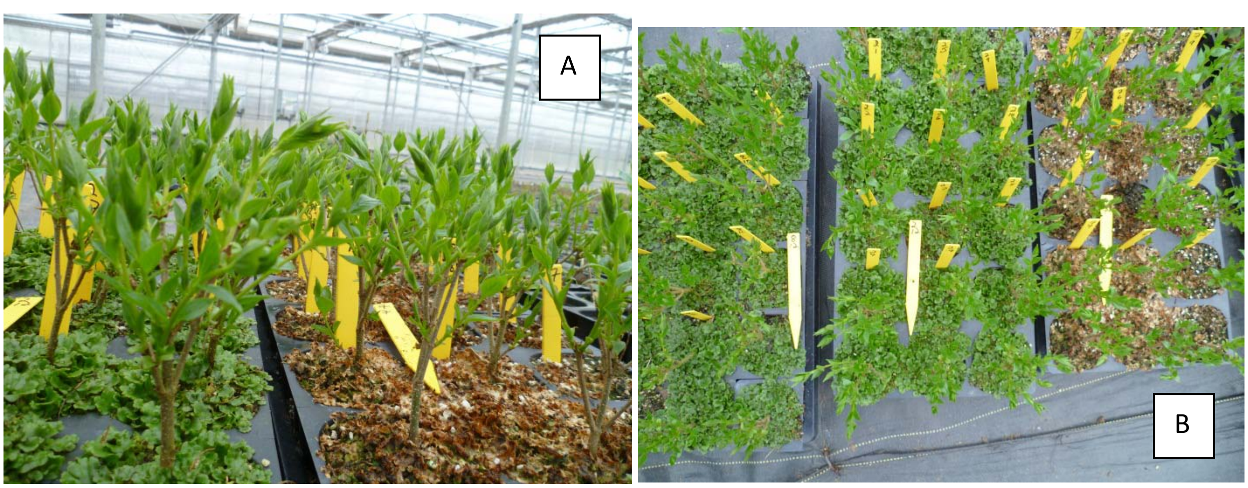


Fig. 3. (A and B). **A.** Side view of liverwort control with Dwarf Korean lilac (*Syringa meyeri* 'Palibin') at Spring Meadow Nursery at 2WAT left to right, MilStop® spray (2.5 lb./100 gallons) treatment and MilStop® powder (5g/ft^2) treatment. **B.** Top view of liverwort control with Dwarf Korean lilac (*Syringa meyeri* 'Palibin') at Spring Meadow Nursery at 2WAT left to right, Control, MilStop® spray and MilStop® powder.

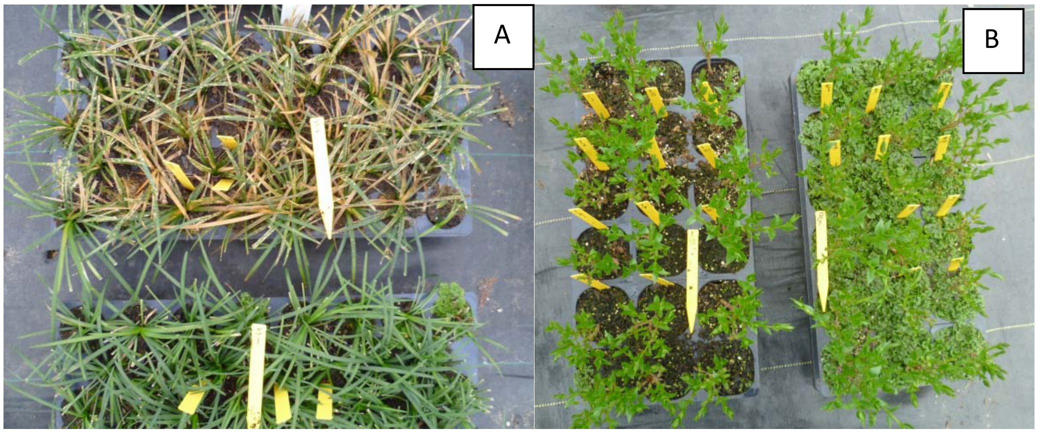


Fig. 4 A. Liriope (*Liriope spicata*) at Northland Farms 2 WAT showing contact burn symptoms from MilStop® powder application (top) versus control (bottom). **B.** Baking soda application at 10 g/ ft^2 at Spring Meadow Nursery 2WAT on Dwarf Korean lilac (*Syringa meyeri* 'Palibin') (left) versus control (right).

Table 2. Phytotoxicity of several ornamental species from various liverwort control products at two nurseries near Grand Haven, MI.

Hydrangea 'Invincibelle Spirit'							
Treatment	Rate	1 WAT[z]	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Baking Soda	10 g/ft^2	--	--	7.8[yx] **	7.8 **	8.3 **	8.7 **
MilStop	2.5 lbs./100 gal	--	--	0.1	2.9 *	2.3	0.0
SureGuard	3 oz./ac	--	--	2.4	6.2 **	9.5 **	9.6 **
SureGuard	4 oz./ac	--	--	2.9 *	5.7 **	9.3 **	8.2 **
WeedPharm	5%	--	--	1.0	4.6 **	4.5	1.3
WeedPharm	10%	--	--	1.2	4.3 **	3.7	3.0 **
MilStop	2.5 tbsp./flat	--	--	1.0	3.0 **	3.9	2.2 **
Untreated	--	--	--	0.8	0.8	2.8	0.0
Ilex verticillata 'Winter red'							
Treatment	Rate	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Baking Soda	10 g/ft^2	--	--	3.0 **	4.3 **	4.9 **	4.5 *
MilStop	2.5 lbs./100 gal	--	--	1.9 *	4.4 **	4.0 **	2.2 **
SureGuard	3 oz./ac	--	--	2.0 *	5.4 **	9.9 **	7.2
SureGuard	4 oz./ac	--	--	1.9 *	5.9 **	9.7 **	6.2
WeedPharm	5%	--	--	0.4	4.7 **	4.8 **	4.5 *
WeedPharm	10%	--	--	1.3	4.9 **	4.8 **	7.3
MilStop	2.5 tbsp./flat	--	--	3.3 **	4.7 **	4.6 **	7.7
Untreated	--	--	--	0.0	0.1	1.8	7.9

Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
Viburnum rhytidophyllum 'Cree'													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
Baking Soda	10 g/ft^2	--		--		10.0		8.9		--		10.0	**
MilStop	2.5 lbs./100 gal	--		--		0.0		1.5	**	--		0.6	**
SureGuard	3 oz./ac	--		--		4.3		6.9		--		7.1	
SureGuard	4 oz./ac	--		--		6.0		6.4		--		6.5	
WeedPharm	5%	--		--		4.0		5.8		--		5.7	
WeedPharm	10%	--		--		4.8		7.3		--		7.1	
MilStop	2.5 tbsp./flat	--		--		--		8.7		--		9.2	
Untreated	--	--		--		5.0		5.8		--		5.9	
Euonymus 'Unforgettable fire'													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
Baking Soda	10 g/ft^2	--		--		4.7		4.4	**	4.3	**	5.3	**
MilStop	2.5 lbs./100 gal	--		--		3.5		0.1	**	2.3	**	3.3	
SureGuard	3 oz./ac	--		--		4.3		7.4		7.7		8.8	**
SureGuard	4 oz./ac	--		--		4.4		6.4		6.8		9.5	**
WeedPharm	5%	--		--		1.9		5.3	**	5.2	**	4.3	
WeedPharm	10%	--		--		4.3		7.8		7.9		4.3	
MilStop	2.5 tbsp./flat	--		--		4.8		7.1		7.0		4.2	
Untreated	--	--		--		3.7		8.8		9.0		2.9	
Syringa patula 'Miss Kim'													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
Baking Soda	10 g/ft^2	--		--		0.0		3.7	**	4.8	**	8.4	**
MilStop	2.5 lbs./100 gal	--		--		2.8	**	0.9		1.8	*	1.5	
SureGuard	3 oz./ac	--		--		0.0		4.8	**	9.0	**	6.0	**
SureGuard	4 oz./ac	--		--		0.0		5.2	**	9.0	**	6.3	**
WeedPharm	5%	--		--		0.0		0.0		3.5	**	3.0	**
WeedPharm	10%	--		--		0.8	*	3.8	**	5.4	**	5.0	**
MilStop	2.5 tbsp./flat	--		--		0.0		1.3		1.3		0.2	
Untreated	--	--		--		0.0		0.0		0.0		0.0	
Hosta 'Halcyon'													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz./ac	--		--		--		3.3	**	3.5	**	5.0	**
WeedPharm	5% v/v	--		--		--		4.0	**	3.0	**	2.0	
MilStop	5 g/ft2	--		--		--		3.0	**	2.8	**	2.8	
Baking Soda	2.2 g/ft2	--		--		--		0.0		0.0		--	
Untreated	--	--		--		--		0.0		0.3		0.8	
Dryopteris erythrosora Autumn Fern													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz./ac	0.0		0.0		0.0		0.8		1.5		3.0	
WeedPharm	5% v/v	0.8		1.3		2.3		2.8		2.3		0.8	
MilStop	5 g/ft2	3.0	**	2.8	**	5.3	**	5.0	**	5.0	*	6.3	**
Baking Soda	2.2 g/ft2	0.3		0.5		2.3		1.3		0.3		--	

Untreated	--	0.0		0.0		2.0		1.5		2.0		2.0	
Perovskia atriplicifolia Russian sage													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz./ac	--		--		--		5.8	*	7.3		6.5	*
WeedPharm	5% v/v	--		--		--		7.0	**	6.5		6.0	*
MilStop	5 g/ft2	--		--		--		8.5	**	8.3		5.0	
Baking Soda	2.2 g/ft2	--		--		--		0.0		2.5		--	
Untreated	--	--		--		--		0.0		2.5		0.0	
Liriope spicata													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz./ac	0.0		0.0		0.0		4.5	**	4.3	**	4.0	**
WeedPharm	5% v/v	0.0		0.0		0.0		2.8	*	3.5	**	3.0	*
MilStop	5 g/ft2	5.5	**	7.5	**	6.8	**	5.8	**	5.8	**	6.3	**
Baking Soda	2.2 g/ft2	1.5		2.8	**	1.8	**	1.0		2.0		--	
Untreated	--	0.0		0.0		0.0		0.0		0.0		0.0	
Syringa meyeri 'Palibin'													
Treatment	Rate	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
SureGuard	3 oz./ac	--		--		--		7.5	**	9.8	**	9.8	**
WeedPharm	5% v/v	--		--		--		4.3	**	6.0	**	5.3	**
MilStop	5 g/ft2	--		--		--		3.3	**	3.0	**	2.5	**
Baking Soda	2.2 g/ft2	--		--		--		0.0		0.0		--	
Untreated	--	--		--		--		0.0		0.0		0.0	
z = WAT: weeks after first treatment; WA2T: weeks after second treatment													
y = Phytotoxicity visual ratings based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable													
x = Treatment means followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)													

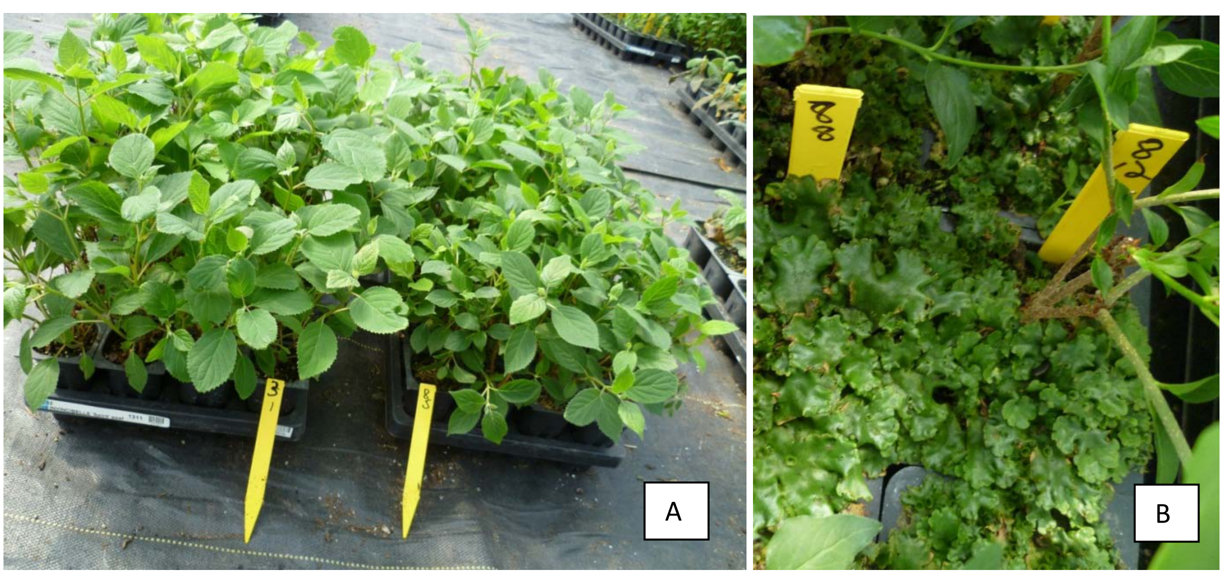


Fig. 5 (A and B). A. SureGuard at 3 oz. /ac (left) compared to the untreated control (left) showing a dramatic decrease in growth caused by the liverwort infestation 10 WAT on *Hydrangea* Invincibelle Spirit.' **B.** The thick thallus mat of a liverwort infestation is the cause of the growth reduction.

Preemergence herbicide efficacy, phytotoxicity from in-season container and field nursery trials:

Three cooperating nurseries located near Grand Haven, MI were selected as sites for the container and field trials, which included Berryhill Family of Nurseries (BFN, formerly Zelenka Nursery), Spring Meadow Nursery, Inc., and Northland Farms Nursery, LLC. At BFN, containerized and field trials were carried out, while at Spring Meadow and Northland Farms, only containerized trials were performed. The trade and common names and manufacturers of the herbicides used are as follows: Tower (dimethenamid-p) + Pendulum (pendimethalin, BASF Corp.), FreeHand (dimethenamid-p + pendimethalin, BASF Corp.), Biathlon (oxyfluorfen + prodiamine, OHP, Inc.), F6875SC (sulfentrazone +prodiamine, FMC), Gallery (isoxaben, Dow Agro Sciences + Barricade (prodiamine, Syngenta), SureGuard 51 WDG (flumioxazin, Valent U.S.A) + Surflan (oryzalin, Dow Agro Sciences) and Indaziflam G (Bayer Corp.). Phytotoxicity evaluations were performed at 1 WA1T (week after first treatment), 2 WA1T, 4 WA1T, 1 WA2T (weeks after second treatment), 2 WA2T, and 4WA2T. Visual ratings were performed on a scale of 0-10 with 0 being no phytotoxicity, 10 being dead, and $\leq$3 commercially acceptable. All liquid treatments were applied with a CO_2 backpack sprayer with a spray volume of 20 gal/ac using nozzles delivering 0.15 gal/ min/ nozzle and the nozzle spacing at 12 inches. Field plots included 3X 3 ft. areas for liner beds in each replication, with 4 replications/ rate for each variety.

For the containerized portion at BFN, species selected included: daylily, (*Hemerocallis* 'Stella d'Oro'), elderberry (*Sambucus nigra* Blacklace™), barberry (*Berberis thunbergii* 'Crimson Pygmy'), purple coneflower (*Echinacea purpurea* 'Purple Magnus'), and euonymus (*Euonymus* f*ortunei* 'Emerald & Gold'). The species selected for the field trial at BFN included common lilac (*Syringa* 'Common Purple') and compact euonymus (*Euonymus alatus* 'Compacta'). For the containerized portion at Northland Farms, species selected included daylily (*Hemerocallis* 'Stella d'Oro'), elderberry (*Sambucus nigra* Blacklace™), barberry (*Berberis thunbergii* 'Crimson Pygmy'), purple coneflower (*Echinacea purpurea* 'Purple Magnus'), and euonymus (*Euonymus* f*ortunei* 'Emerald & Gold'). Species selected at Spring Meadow included rose (*Rosa* 'Home Run RED'), barberry (*Berberis thunbergii* Sunjoy® Gold Beret *'Talago'),* azalea *Azalea* Bloom-a-thon® Pink Double and viburnum (*Viburnum* Red Balloon™ 'Redell').

Herbicides selected for the containerized portion included: Indaziflam (Bayer Corp.) at 0.11, 0.22, and 0.44 lb. ai/ac on daylily; Tower + pendulum at 21 oz./ac + 2qt/ ac on daylily and viburnum; Gallery + Barricade at 1.0 lb. ai/ac + 0.66 lb. ai/ac on daylily, euonymus, elderberry and coneflower; FreeHand at 2.65, 5.3, and 10.6 lb. ai/ac on elderberry, viburnum, azalea and coneflower; Biathlon at 2.75 lb. ai/ac on azalea, coneflower, daylily and viburnum and F6875 at 0.375, 0.75, 1.5 lb. ai/ac on barberry, euonymus and daylily. The containerized trials were initiated on March 27, 2012 at all locations, with each location having at least 10 replications/ herbicide/ rate. Treatments were reapplied at 6 weeks after original treatments were applied. Pot sizes were one-gallon trade pots at BFN and Northland Farms and at Spring Meadow 4 inch pots were used.

Results and discussion.

Container trials: At BFN phytotoxicity occurred with *Berberis* 'Crimson pygmy' with F6875 1 and 2 WA1T at the 2X and 4X rate; however, the plants recovered from the injury by the end of the trial (Table 3 and Fig. 6).

Fig. 6. Damage from F6875 at 4X rate on *Berberis thunbergii* 'Crimson pygmy '2 WAT at BFN Nursery near Grand Haven, MI.

Injury also occurred on *Echinacea* 'Purple Magnus' with FreeHand at BFN and at Northland Farms. At Northland Farms the injury was just above commercially acceptable at the 4X rate 4WA2T (Table 3 and Fig. 7). At BFN the injury occurred after the second application at the 4X rate and at that time was just above commercially acceptable (Table 3). However, pictures taken during on August 12 of the BFN *Echinacea* indicated the stunting effect of the FreeHand had continued for the 3months after the trial ended with severe root stunting also occurring (Fig. 8). Damage also occurred to *Echinacea* with Gallery + Barricade at Northland Farms (Table 3) (Fig. 9). Although the plants were starting to grow out of the injury at 4WAT (Fig. 9 B) the second application increased the injury through to the end of the trial (Table 3). The products that caused no injury are included in Tables 3 and 6.

Fig. 7. (left) Leaf distortion from FreeHand at 600 lbs. / ac on *Echinacea* 'Purple Magnus' at Northland Farms at 4 WA2T. Picture by: Luke Case.

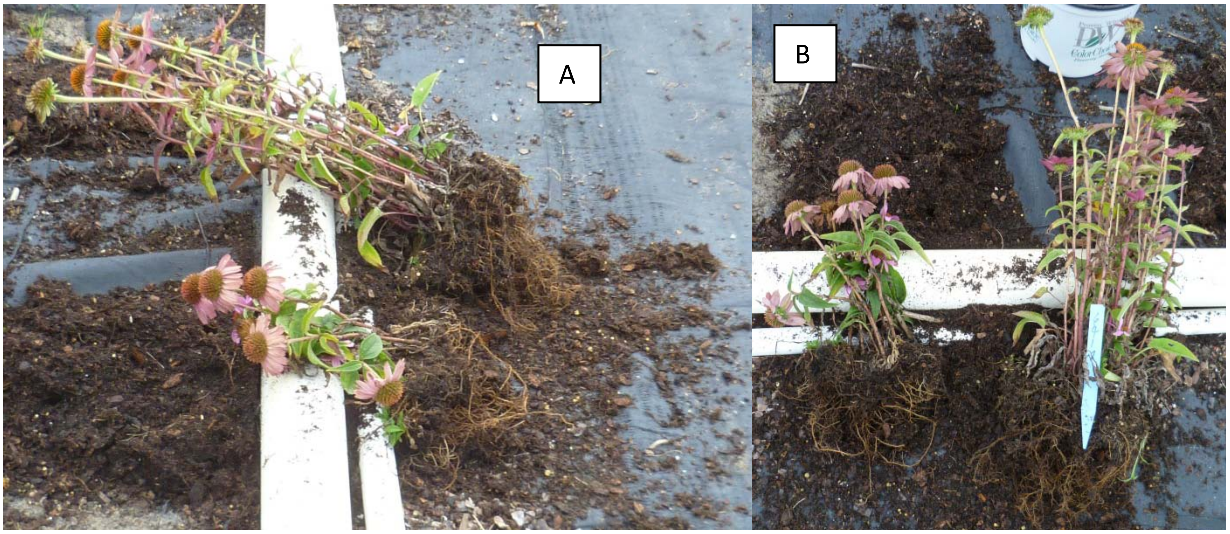


Fig. 8 (A and B). A. Side view of *Echinacea* 'Purple Magnus' at BFN, three months after the trial ended (August 12, 2012) showing severe root inhibition with FreeHand at the 4X rate (foreground) compared to the control (background). **B.** Front view of stunting caused by FreeHand at 4X rate (left) compared to the control (right). Pictures by: Hannah Mathers.

Fig. 9. (A and B). A. Damage from Gallery + Barricade at 1.0 lb. + 0.66 lb. ai/ac, respectively on *Echinacea* 'Purple Magnus' at Northland Farms at 2 WAT. **B.** Damage from Gallery + Barricade at 1.0 lb. + 0.66 lb. ai/ac, respectively on *Echinacea* 'Purple Magnus' at Northland Farms at 4 WAT. Picture A: Luke Case, Picture B: Hannah Mathers.

Hemerocallis was injured at BFN with Biathlon, Tower + Pendulum, Indaziflam at all rates and F6875 at all rates (Table 3). Hemerocallis was also injured at Northland Farms with Indaziflam at the 4X rate (Table 3). The injury from Biathlon, Tower + Pendulum and F6875 at 1 and 2X was transitory and no injury was present by the end of the trial (Table 3). However, the injury from indaziflam at all rates (Fig. 10) and F6875 at the 4X rate persisted (Table 3). The F6875 injury at the 4X rate was still apparent in August 2012 or 3 months after the trail ended (Fig. 11). The products that caused no injury are listed in Tables 3 and 6.

Fig. 10. Damage Indaziflam (left to right) control, 1X, 2X and 4X (800 lb. / ac) on *Hemerocallis* ‘Stella d’Oro’ at 4 WA2T at Northland Farms. Notice that the new leaves are yellow and drooping down. Picture by: H. Mathers

Fig. 11. (left) Damage on *Hemerocallis* ‘Stella d’Oro’ from F6875. Picture taken Aug. 12, 2012, three months after the trial ended. From front to back, control, 1X, 2X and 4X. Notice the severe stunting with the 4X rate. Picture by: Hannah Mathers.

Damage also occurred on azalea and viburnum at Spring Meadow from Tower + pendulum (Table 3). The damage on azalea (Fig. 12) was worse than on viburnum (Fig. 13). The products that caused no injury are included in Tables 3 and 6.

Fig. 12. (left) Tower + Pendulum at 21 oz. + 2 qtr. /ac, respectively, on *Azalea* ‘Bloom-a-thon Pink Double’ (right) vs. control (left) at Spring Meadow Nursery at 2 WAT.

Fig. 13. (left) Tower + Pendulum damage (left) compared to untreated (right) *Viburnum* x 'Red Balloon' at 21 oz. + 2 qtr. respectively at 2 WAT at Spring Meadow Nursery.

Table 3. Phytotoxicity from various herbicides on several ornamental species located at three nurseries near Grand Haven, MI

Sambucus 'Blacklace'

Treatment	Rate/ac	Location	1 WAT[z]	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
FreeHand	150 lb.	BFN	0.0	0.0	0.0	0.0	2.2 **	0.0
FreeHand	300 lb.	BFN	0.3	0.2	0.0	1.8 **	2.6 **	0.0
FreeHand	600 lb.	BFN	0.3	0.2	0.5	0.0	0.4	0.0
Untreated	--	BFN	0.2	0.3	0.0	0.0	0.0	0.0

Berberis 'Crimson pygmy'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
F6875	0.375 lb. ai	BFN	1.9 **	1.1 **	--	1.2	0.4	0.3
F6875	0.75 lb. ai	BFN	3.0 **	2.5 **	--	1.6 **	1.0 **	0.3
F6875	1.5 lb. ai	BFN	3.7 **	3.5 **	--	2.8 **	2.4 **	0.6
Untreated	--	BFN	0.0	0.0	--	0.5	0.2	0.2

Echinacea 'Purple Magnus'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Biathlon	100 lb.	BFN	1.4	2.0 **	1.0	1.8	2.5 **	2.9 **
FreeHand	150 lb.	BFN	0.8	0.7	0.2	1.1	1.1	3.1 **
FreeHand	300 lb.	BFN	0.4	0.2	0.6	1.2	2.3 **	2.0
FreeHand	600 lb.	BFN	1.3 *	0.5	0.5	3.3 **	3.3 **	3.2 **
Untreated	--	BFN	0.5	0.4	0.8	1.5	0.8	0.9

Euonymus 'Emerald and Gold'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Gallery + Barricade	1 lb. ai + 0.66 lb. ai	BFN	0.0	0.0	1.0	0.0	0.2	3.0 **
F6875	0.375 lb. ai	BFN	0.2	0.3	0.2	0.6 **	0.8	0.0
F6875	0.75 lb. ai	BFN	0.0	0.2	0.6	0.2	0.3	0.0
F6875	1.5 lb. ai	BFN	0.4	0.1	0.5	1.5 **	1.6 **	0.3
Untreated	--	BFN	0.2	0.1	0.8	0.0	0.0	0.1

Hemerocallis 'Stella d'Oro'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Biathlon	100 lb.	BFN	1.9 **	3.9 **	3.8 **	0.5	0.8 **	1.9 **
Tower + Pendulum	21 fl. oz. + 2 qtr.	BFN	5.4 **	5.0 **	3.9 **	0.5	1.5 **	0.3
Gallery + Barricade	1 lb. ai + 0.66 lb. ai	BFN	0.6	0.3	0.0	0.0	0.2	0.4
Indaziflam	200 lb.	BFN	0.8	3.3 **	3.1 **	0.0	0.1	1.5 **
Indaziflam	400 lb.	BFN	1.5 **	3.7 **	3.3 **	1.8 **	2.3 **	3.5 **
Indaziflam	800 lb.	BFN	1.5 **	3.7 **	3.8 **	3.0 **	3.7 **	4.0 **
F6875	0.375 lb. ai	BFN	5.5 **	4.9 **	3.8 **	1.4 **	1.7 **	2.5 **
F6875	0.75 lb. ai	BFN	5.9 **	5.2 **	3.7 **	2.6 **	2.9 **	2.9 **
F6875	1.5 lb. ai	BFN	7.1 **	5.6 **	5.3 **	3.9 **	5.1 **	5.7 **
Untreated	--	BFN	0.4	0.0	0.0	0.0	0.0	0.5

Sambucus 'Blacklace'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
FreeHand	150 lb.	Northland Farms	0.0	0.3	0.2	0.3	0.0	0.7
FreeHand	300 lb.	Northland Farms	0.0	0.1	0.3	0.7	2.8 **	0.4
FreeHand	600 lb.	Northland Farms	0.0	0.1	1.3 **	2.0 **	2.3 **	2.3 **
Gallery + Barricade	1 lb. ai + 0.66 lb. ai	Northland Farms	0.0	0.8 **	1.1 *	0.0	3.0 **	0.9
Untreated	--	Northland Farms	0.0	0.1	0.0	0.0	0.0	0.0

Echinacea 'Purple Magnus'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Gallery + Barricade	1 lb. ai + 0.66 lb. ai	Northland Farms	4.4 **	4.4 **	3.5 **	6.8 **	7.7 **	4.2 **
FreeHand	150 lb.	Northland Farms	0.5	0.5	1.0	1.2	2.3 **	2.0 **
FreeHand	300 lb.	Northland Farms	0.8 **	1.0	2.3 **	1.8 **	4.6 **	2.3 **
FreeHand	600 lb.	Northland Farms	0.3	1.0	2.4 **	1.6 **	2.4 **	3.2 **
Untreated	--	Northland Farms	0.0	0.2	0.1	0.1	0.0	0.0

Euonymus 'Emerald and Gold'

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
F6875	0.375 lb. ai	Northland Farms	0.4	0.3	0.3	0.0	0.0	0.0
F6875	0.75 lb. ai	Northland Farms	0.4	0.5	0.6	0.3	0.0	0.0
F6875	1.5 lb. ai	Northland Farms	1.1 **	1.6 **	1.3 **	1.5 **	0.0	0.0
Gallery + Barricade	1 lb. ai + 0.66 lb. ai	Northland Farms	0.2	0.2	0.5	0.2	0.0	0.0
Untreated	--	Northland Farms	0.2	0.2	0.1	0.0	0.0	0.0

Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Indaziflam	200 lb.	Northland Farms	0.2	3.2 **	2.7 **	1.6	1.0	1.4
Indaziflam	400 lb.	Northland Farms	0.0	3.4 **	2.2 **	2.5 **	2.7 **	2.8 **
Indaziflam	800 lb.	Northland Farms	0.5	4.3 **	2.8 **	3.7 **	4.4 **	5.0 **
Gallery + Barricade	1 lb. ai + 0.66 lb. ai	Northland Farms	0.5	1.1	0.2	0.4	0.8	0.0
Untreated	--	Northland Farms	0.4	0.3	0.2	0.3	0.0	0.0
Berberis thunbergii SUNJOY Gold Beret ('Talago')								
Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
FreeHand	150 lb.	Spring Meadow	0.0	0.8	1.3	0.7	1.3	2.8 **
Untreated	--	Spring Meadow	0.0	1.5	1.9	1.0	0.8	0.0
Rosa x HOME RUN RED ('WEKcisbako')								
Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Indaziflam	200 lb.	Spring Meadow	0.7	3.1	2.4	0.9	0.0	0.2
Untreated	--	Spring Meadow	0.3	3.4	2.5	0.4	0.0	0.2
Viburnum x RED BALLOON ('Redell')								
Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Biathlon	100 lb.	Spring Meadow	0.0	0.3	0.0	0.0	0.0	0.0
Tower + Pendulum	21 fl. oz. + 2 qtr.	Spring Meadow	2.8 **	3.7 **	3.7 **	3.6 **	3.8 **	2.9 **
FreeHand	150 lb.	Spring Meadow	0.3	0.0	0.0	0.2	0.0	0.0
Untreated	--	Spring Meadow	0.0	0.2	0.0	0.4	0.0	0.5
Azalea 'BLOOM-A-THON Pink Double'								
Treatment	Rate/ac	Location	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Biathlon	100 lb.	Spring Meadow	0.1	0.0	0.0	0.0	0.0	0.0
Tower + Pendulum	21 fl. oz. + 2 qtr.	Spring Meadow	0.0	3.7 **	3.9 **	4.1 **	4.1 **	4.9 **
FreeHand	150 lb.	Spring Meadow	0.0	0.3	0.0	0.1	0.0	0.0
Untreated	--	Spring Meadow	0.3	0.0	0.0	0.0	0.0	0.0

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

y = Phytotoxicity visual ratings based on a 0-10 scale with 0 being no phytotoxicity and 10 death with $\leq$3 commercially acceptable

x = Treatment means followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)

Field trials. Due to frost events and cool, wet weather in the early part of the season, we were unable to start the filed evaluations until May, 2013. Due to the late start we were only able to evaluate the field trials until 4 WAT. No second applications were performed. Even with the short evaluation time, commercially acceptable weed control was only evident with two products 4WAT, Tower + Pendulum and SureGuard + Surflan (Table 4). The similar control of Tower + Pendulum to SureGuard + Surflan is indicates its utility as a replacement product to this industry standard, SureGuard.

Table 4. Treatment efficacy (weed control) in the field at BFN nursery in Michigan, May – July, 2013.

Treatment	Rate/ac	Location	1 WAT[z]		2 WAT		4 WAT	
Biathlon	100 lb.	BFN	7.8[y]	ab	8.4	bc	5.9	c
Tower + Pendulum	21 fl. oz. + 2 qtr.	BFN	9.5	a	9.7	ab	8.2	ab
Indaziflam	200 lb.	BFN	6.8	bc	8.3	c	5.6	c
Indaziflam	400 lb.	BFN	8.0	a	9.0	abc	6.8	abc
Indaziflam	800 lb.	BFN	6.8	bc	8.3	c	6.9	abc
SureGuard + Surflan	12 oz. + 2 qtr.	BFN	9.8	a	9.8	a	8.7	a
F6875	0.375 lb. ai	BFN	8.0	a	8.2	c	6.1	bc
Untreated	--	BFN	5.8	c	6.0	d	3.4	d

z = WAT: weeks after first treatment
y = Efficacy visual ratings based on a 0-10 scale with 10 being complete control, 0 no control and ≤7 commercially acceptable.
Treatment means followed by similar letters mean they are not significantly different from each other, based on lsmeans ($\alpha = 0.05$)

Due to frost events early in spring, above commercially acceptable injury persisted on the *Syringa* ‘Common purple’ for the duration of the trial as evidenced by the control (Table 5) in BFN fields. However, the *Euonymus* ‘Compacta’ did not have above commercially acceptable injury from frosts (Table 5). Usually products that have high efficacy also have high phytotoxicity. The *Syringa* in this trial supports this generality (Table 5). Even with the high phytotoxicity in the controls the damage caused to the BFN *Syringa* from over-the-top sprays of Tower + Pendulum and SureGuard + Surflan stand out as above commercially acceptable injury (Table 5). On the *Euonymus* the SureGuard + Surflan also caused very high phytotoxicity (7.4) (Table 5) (Fig. 13). Fig. 13 shows almost total kill from the application of SureGuard + Surflan on some *Euonymus* compared to a 4X rate of Indaziflam. The F6875 also caused above commercially acceptable injury 4WAT (3.5) on *Euonymus* (Table 5). F6875 also caused injury on *Syringa* in the field; however, taking into account the high phytotoxicity of the control, we could not confirm the level of injury from the F6875 to *Syringa*. There was no injury from Tower + Pendulum on *Euonymus*. In past SCBGs applications of Tower + Pendulum have caused no injury to *Syringa*, and it may have been possible that the existing injury to the *Syringa* was a causal factor the injury we found in this SCGB. Treatments that caused no injury in field trials are listed in Tables 5 and 6.

Fig. 13. Indaziflam at 800 lbs./ac (foreground) (1st stake-three plants following) , causing no phytotoxicity compared to SureGuard + Surflan at 12 oz. + 2 qtr./ac, respectively (background) (2nd stake – three plants following) on *Euonymus alatus* ‘Compacta’ at BFN Nursery, Grand Haven, MI, Spring 2013. Picture by: Luke Case.

Table 5. Phytotoxicity from various herbicides on several ornamental species located at Berry Family Nursery, Grand Haven, MI.

Syringa 'Common purple'

Treatment	Rate/ac	Location	1 WAT[z]		2 WAT		4 WAT	
Tower + Pendulum	21 fl. oz. + 2 qtr.	BFN	4.3[y]		4.8		7.5	**
Indaziflam	200 lb.	BFN	3.5		3.4		6.1	
Indaziflam	400 lb.	BFN	3.8		3.2		5.4	
Indaziflam	800 lb.	BFN	4.1		4.3		5.0	
SureGuard + Surflan	12 oz. + 2 qtr.	BFN	9.7	**	8.7	**	8.4	**
F6875	0.375 lb. ai	BFN	6.5	**	4.7	**	5.0	
Untreated	--	BFN	3.3		2.9		4.6	

Euonymus alatus 'Compacta'

Treatment	Rate/ac	Location	1 WAT		2 WAT		4 WAT	
Biathlon	100 lb.	BFN	1.2		0.3		1.8	
Tower + Pendulum	21 fl. oz. + 2 qtr.	BFN	1.5		1.5		1.7	
Indaziflam	200 lb.	BFN	0.9		1.2		2.5	
Indaziflam	400 lb.	BFN	1.7		0.9		2.3	
Indaziflam	800 lb.	BFN	1.9		1.7		2.6	
SureGuard + Surflan	12 oz. + 2 qtr.	BFN	9.5	**	9.3	**	7.4	**
F6875	0.375 lb. ai	BFN	2.7		2.2	*	3.5	**
Untreated	--	BFN	1.2		0.3		1.5	

z = WAT: weeks after first treatment
y = Phytotoxicity visual ratings based on a 0-10 scale with 0 being no phytotoxicity and 10 death with $\leq$3 commercially acceptable.
Treatment means followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)

Table 6. Summary of all herbicides and crops that experienced **no phytotoxicity** at the three MI sites in 2012.

Herbicide	**No phytotoxicity**	**Comments**
Indaziflam	*Rosa* 'Home Run Red'	
	Euonymus 'Compacta'	Field
Biathlon	*Viburnum 'Red Balloon'*	1X
	Euonymus 'Compacta'	1X field
	Azalea 'Pink Double'	1X
	Hemerocallis 'Stella d oro'	1 application
FreeHand	*Viburnum 'Red Balloon'*	1X
	Sambucus 'Black Lace'	(Caution: Make sure it does not hang up at base)
	Azalea 'Pink Double'	1X
	Berberis Sunjoy	1X
Tower + pendulum	*Euonymus* 'Compacta'	Field
Gallery + Barricade	*Hemerocallis* 'Stella d oro'	
	Sambucus 'Black Lace'	
	Euonymus 'Emerald & Gold'	
F6875SC	*Euonymus 'Emerald & Gold'*	

Accomplishing Objectives 3: Further preliminary studies were conducted regarding objective 3 to identify specific weed control approaches for highly specific weed issues in MI nurseries such as mugwort (Artemisia vulgaris L) and Yellow nutsedge (Cyperus esculentus):

Preliminary Field Trial Results. At Northland Farm in a yellow nutsedge trial, Tower + Pendulum provided the best control in the field with an above commercially acceptable control rating 4WAT (Table 7).

Table 7. Northland Farms, Yellow nutsedge trial.

Treatment	Rate/ac	Taxus		Sedge Control	
Biathlon	100 lbs	0.2[z]		3.0[x]	bc
Tower + Pendulum	21 oz + 2 qt	0.9	**	7.3	a
FreeHand	200 lbs	0.0		5.3	ab
Indaziflam	200 lbs	0.0		4.0	abc
Untreated	--	0.0		0.0	c

z = Ratings are based on a 0-10 scale with 0 being no phytotoxicity and 10 death, with ≤3 commercially acceptable. Ratings are averaged over 3 dates of evaluation.

Treatment means followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively).

x = Efficacy ratings are based on a 0-10 scale with 0 being no weed control and 10 perfect weed control with ≥7 commercially acceptable. Ratings are averaged over all evaluations.

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

At BFN a preliminary postemergence trial in a heavy infestation of *mugwort (Artemisia vulgaris L)* (Fig. 14) four products showed promise for continued trials in 2013, Lontrel® (Clorpyralid) (Fig. 15E), Certainty (Sulfosulfluron, Monsanto Corp.) (Fig. 15B), Riverdale® Corsair™(Chlorsulfuron, NuFarms America Inc., IL) (Fig. 15C) and SedgeHammer (Halosulfuron-methyl, Gowan Co., AZ) (Fig. 15D) versus the control (Fig. 15 A) (Table 8). These four products also provided minimal phytotoxicity (Table 8) at 4 WAT.

Fig. 14. Mugwort or false chrysanthemum (*Artemisia vulgaris*.) is a non-native perennial aster. Mugwort foliage appears similar to common ragweed (*Ambrosia artemisiifolia*) and ornamental chrysanthemums (*Chrysanthemum* spp.). Unlike those weeds, the lower surfaces of mugwort leaves are covered with a dense, silver-white pubescence. Mature *A. vulgaris* stems, which can grow 2 m (6 ft.) tall, yield rankly aromatic flower heads. It disperses in nurseries and landscape plantings primarily by rhizomes transported on contaminated cultivation equipment and nursery crops. Once established, mugwort rhizomes gradually expand outward, excluding other plants and

forming a dense, monotypic stand. It has named one of the 10 most problematic weeds in nurseries of the eastern U.S.

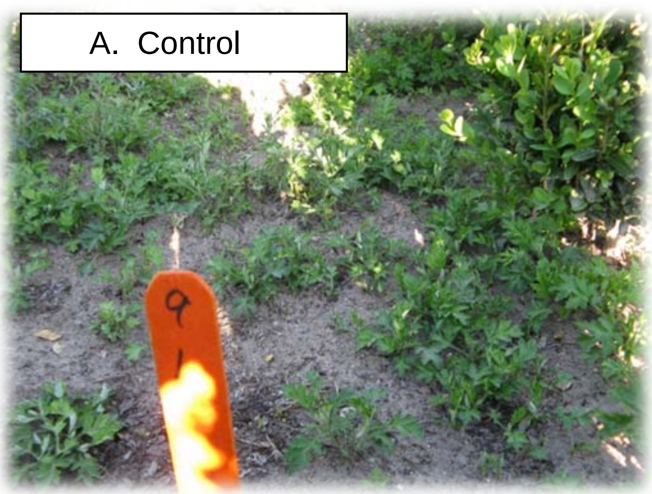
Table 8. Berry Family Nurseries, Mugwort trial.

Treatment	Rate/ac	Buxus		Efficacy	
Basagran	2 pt.	0.1[z]		1.5[x]	cd
V-10233	7.5 oz	3.8	**	5.3	b
Pennant Magnum	2 pt.	0.3		0.8	d
Lontrel	1 pt.	1.9	**	8.0	a
Certainty	0.06 lb. ai	2.3	**	7.5	a
F6875	0.375 lb. ai	2.9	**	3.8	bc
Corsair	5.5 oz.	1.8	**	8.3	a
SedgeHammer	0.125 lb. ai	1.2	*	7.8	a
Untreated	--	0.0		0.0	d

z = Ratings are based on a 0-10 scale with 0 being no phytotoxicity and 10 death, with ≤3 commercially acceptable. Ratings are averaged over 3 dates of evaluation.

Treatment means followed by *, ** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively).

x = Efficacy ratings are based on a 0-10 scale with 0 being no weed control and 10 perfect weed control with ≥7 commercially acceptable. Ratings are averaged over all evaluations.
Efficacy ratings in the same column followed by the same letter are not significantly different based on lsmeans (α = 0.05).



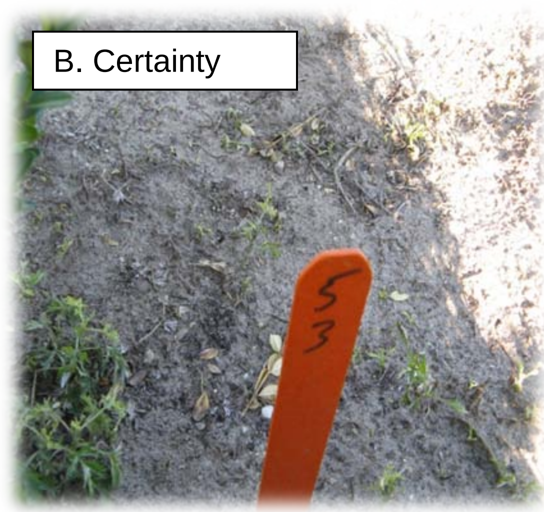


Fig. 15 (A, B, C, D and E). Mugwort *(Artemisia vulgaris L)* control with four products versus the control (A), in 2012 field trials at BFN, Lontrel® (Clorpyralid) (Fig. 15E), Certainty (Sulfosulfluron, Monsanto Corp.) (Fig. 15B), Riverdale® Corsair™(Chlorsulfuron, NuFarms America Inc., IL) (Fig. 15C) and SedgeHammer (Halosulfuron-methyl, Gowan Co., AZ) (Fig. 15D).

Beneficiaries. Beneficiaries from these trials were obviously the nursery managers and staff that were involved in the trials at the three sites in MI. However, in 2012, 16 extension/ research presentations were also given with results from these trails. Seven of these were out-of-Ohio and benefited 504 attendees in MI and IN. Nine were in-Ohio presentations and benefited 2069 attendees from landscape, lawn care, nursery, arboriculture and garden center backgrounds. All of the out-of-state presentations were invited and were for industry organized events. This indicates the value and demand for this information to industry members. All of the in-state presentations were also invited with 65% organized by university, extension or government agencies indicated the high demand for the information from agencies that promote current information to their audiences. One technical report and four contributed articles to technical reports were completed in association with this project. Three papers in proceeding and 9 trade articles were published using information obtained from this project. It is estimated that between the 16 presentations that were given and the 9 trade articles published we reached over 5000 people in the MI ornamental industry.

Lessons Learned. We started the trials very early in the spring to be representative of normal industry preemergence herbicide timing; however, we encountered numerous frost events with somewhat impeded our ability to diagnosis injury at some sites. In the future we will start the trials later in the spring to ensure frost events have past.