Michigan Department of Agriculture

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Final Performance Report

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Project Title: STATE-WIDE WEED CONTROL INITIATIVE FOR MICHIGAN NURSERY AND LANDSCAPE INDUSTRIES

Project Summary:
Project Purpose and Objectives:

1. Maximize preemergence herbicide efficacy by evaluating specific herbicide/weed interactions in different regions of Michigan, factors affecting herbicide degradation (irrigation; substrate components; herbicide rates), timing of application and ornamental plant tolerance.
2. Investigate strategies for controlling weeds with non-chemical cultural practices, such as bio-herbicide mulch combinations and bio-rational approaches to reduce overall costs and amounts of herbicides applied.
3. Characterize the diversity and abundance of weedy plants present in the propagule banks at different nurseries and adjacent wild areas in Michigan.

Project Approach and Goals and Outcomes Achieved:

Addressing Objective 1:

A. Phytotoxicity and efficacy of several products to control liverwort

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

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

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

Results and discussion.

Phytotoxicity.

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

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

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

Efficacy.

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

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

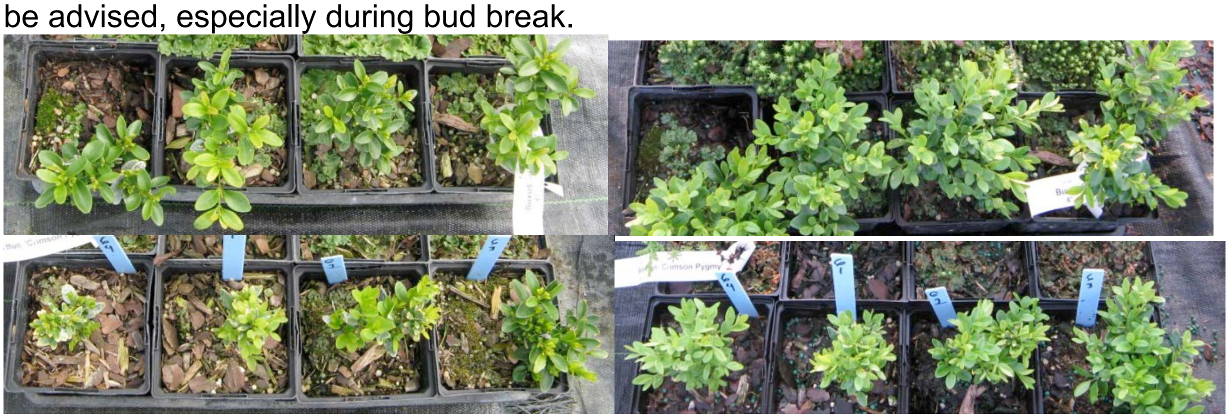

Fig. 2. Tower will delay bud break if applied at bud break. On the left are pictures of *Buxus* at 3 WA1T, with the untreated on top and those treated with Tower on the bottom. Tower treated *Buxus* are behind in growth. On the right are plants at 4 WA2T, with the untreated *Buxus* in the top picture.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

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

Syringa meyeri 'Paliban'

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

Hydrangea amorences 'Invincibelle '

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

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

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

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

Buxus microphylla 'Green velvet'

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

Berberis thunbergii 'Crimson Pygmy'

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

Ilex merservea 'China Girl'

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

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

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

Table 2, cont.
Thuja 'Techny'

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

z = WA1T: weeks after first treatment; WA2T: weeks after second treatment
y = visual ratings in the same column followed by ** are significantly different from the control based on Dunnett's t test (_ = 0.05), and ratings followed by * are different at the _ = 0.10 level

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

Euonymus x 'White Album'

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

Viburnum dentatum 'Double pink'

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

Juniperus horizontalis 'Hughes Gold'

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

Chaenomeles x ' Double Take Pink Storm'

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

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

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

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

Spring Meadow Nursery

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

Lincoln Nursery

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

Zelenka Nursery

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

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

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

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

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

Fig. 5. Tower on *Syringa meyeril* 'Paliban' at Spring Meadow Nursery.

Addressing Objective 1:

B. Phytotoxicity of selected herbicides to ornamental plants at three Michigan nurseries

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

Materials and methods. Phytotoxicity trials were set up on April 29, 2010 and evaluated at three nurseries in Michigan: Lincoln Nurseries, Inc., near Grand Rapids (Fig.6a), Spring Meadow Nursery, Inc., near Grand Haven (Fig. 6b), and Zelenka Nursery, LLC, also near Grand Haven n(Fig.6c). Nine to six species were selected by the individual nurseries from the IR-4 priority 2010 list for a total of 22 container trials and one field test at Zelenka. The nine species at Lincoln were *Berberis thunbergii* 'Crimson pygmy', *Chamaecyparis* 'Golden spangel', *Clematis* 'Midnight showers', *Coreopsis* 'Crème brule', *Cornus* 'Baileyi', *Echinacea purpurea* 'White satin', *Hemerocallis* 'Strawberry candy', *Hydrangea macrophylla* 'All summer beauty', and *Potentilla fruticosa* 'Pink beauty' were selected. The eight species at Spring Meadow were *Berberis thunbergii* 'Gold pillar', *Buddelia* 'Adonis blue', *Ceanothus xpal.* 'Marie bleu', *Chamaecyparis* 'Soft serve', *Cornus sanguinea* 'Arctic sun', *Euonymus alatus* 'Fireball', *Potentilla* 'Goldfinger', and *Viburnum dentatum* 'Blue muffin'. The six species at Zelenka were *Berberis thunbergii* 'Aurea', *Buddleia davidii* 'Black night', *Coreopsis* 'Moonbeam', *Echinacea purpurea*, and *Hydrangea macrophylla* 'Mini penny' for containerized material, and *Buxus x*'Green mountain' for field phytotoxicity. Herbicides (not every herbicide was used on all species) were evaluated at their 1X, 2X and 4X label rates, respectively and included, oxyfluorfen + prodiamine (Biathalon, OHP, Mainland, PA) at 2.75, 5.5 and 11.0 lb ai/ac; dimethenamid-p +

pendimethalin (FreeHand, BASF Corp., Research Triangle Park, NC) at 2.65, 5.3 and 10.6 lb ai/ac; sulfosulfuron (Certainty, Monsanto Co., St. Louis, MO) at 0.059, 0.117 and 0.234 lb ai/ac; dimethenamid-p (Tower, BASF Corp.) at 0.97, 1.94 and 3.88 lb ai/ac; sulfentrazone + prodiamine (F6875, FMC Corp., Fresno, CA), two formulations, granular and liquid, at 0.375, 0.75 and 1.5 lb ai/ac; and mesotrione (Callisto, Syngenta Corp., Wilmington, DE) at 0.187, 0.25 and 0.37 lb ai/ac. Halosulfuron-methyl (SedgeHammer, Gowan, Yuma, AZ) was applied only in the field at rates of 1.3, 2.6 and 5.2 oz/ac.

On April 29, 2010, weather conditions were generally overcast with temperatures ranging from about 46 °F at time of start to 61 °F at the end of the day. The liquid formulations of Tower, Certainty, and F6875 4SC were sprayed with a CO_2 backpack sprayer using 8003 vs. nozzles in a spray volume of 30 gallons per acre. All other herbicides were granular formulations and spread by shaker jars. The second application of each herbicide was applied on June 24, 2010. The weather was warm, approximately 75-88 °F during the course of applications with some dew present in the morning at the first site, Lincoln. Immediately after each application, ½ acre-inch of irrigation was applied. Phytotoxicity evaluations were performed at 1 WA1T (week after first treatment), 2 WA1T, 4 WA1T, 1 WA2T (week after second treatment), 2 WA2T, and 4 WA2T. Visual ratings were performed on a scale of 0-10 with 0 being no phytotoxicity, 10 being dead, and ≤3 commercially acceptable. Growth of nursery stock was also assessed by measuring heights (from the ground to the tallest extended leaf) for *Hemerocallis* 'Strawberry candy' and a growth index (GI) [GI = height + width at widest point + width 90° to first width/ 3] (Keever, 1994) on the first and last evaluations. These two GI's were used to calculate a delta or change in GI (Δ GI) [ΔGI = last GI – first GI). The higher the ΔGI value the greater the growth of the plant.

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

Results and discussion. Unless otherwise specified, refer to Table 5 for all herbicides and species discussed below.

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

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

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

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

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

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

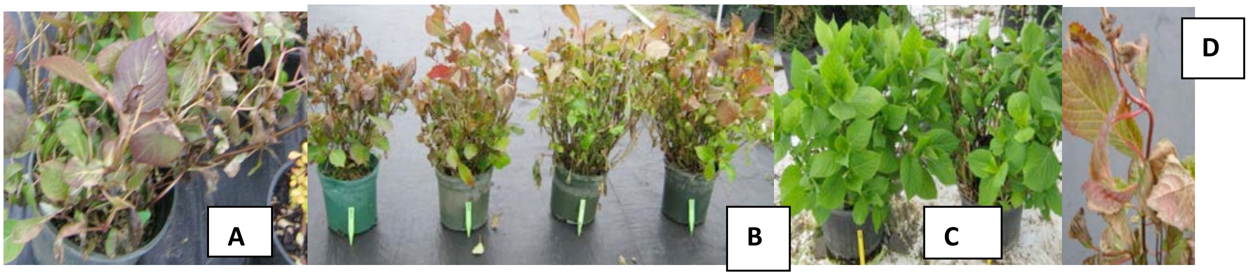

Fig. 9. A and D *Hydrangea macrophylla* 'Mini penny' two weeks after one application of sulfentrazone + prodiamine (F6875, FMC Corp., Fresno, CA) as a liquid, at 0.375, 0.75, and 1.5 lb ai/ac (1x, 2x and 3x, respectively) at Zelenka nursery. Note the twisted foliage and twigs. **B** From left to right: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

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

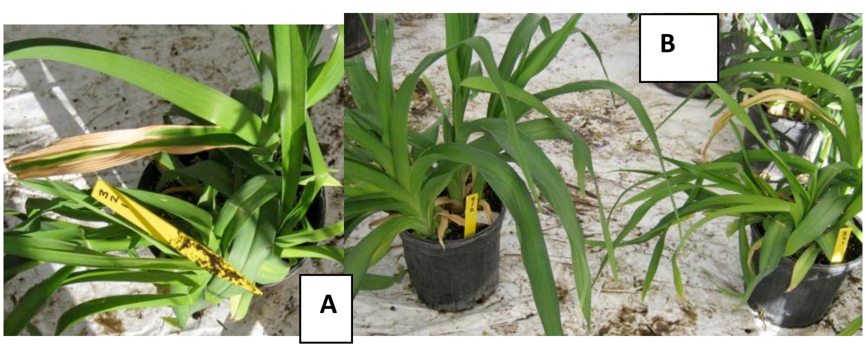

Fig. 10. A *Hemerocallis* 'Strawberry candy' at Lincoln Nursery two weeks after one application of dimethenamid-p (Tower, BASF Corp.) at 3.88 lb ai/ac; (4X). Note the stunting of the leaves and yellowing. **B** From left to right: the control and 4X. The first number on the tag is the treatment rate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

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

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

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

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

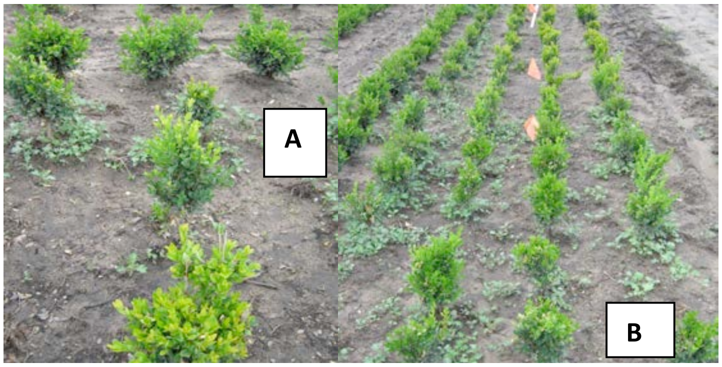

Fig. 13. A Following Halosulfuron-methyl (SedgeHammer, Gowan, Yuma, AZ) applications in the field at 1.3, 2.6 and 5.2 oz/ac, *Buxus x*'Green mountain' showed distinct yellowing and stunting by the second application. Note the two plants in the sprayed rows in the foreground with the two control rows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

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

Berberis 'Crimson pygmy' — Lincoln

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

Berberis 'Gold pillar' — Spring Meadow

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

Berberis 'Barberry golden' — Zelenka

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

Buddleia 'Adonis blue' — Spring Meadow

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

Buddleia 'Black night' — Zelenka

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

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

y = Growth indices

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

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

Table 5., Continued

Ceonothus xpal. 'Marie Bleu' — Spring Meadow

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

Chamaecypari s 'Golden spangel' — Lincoln

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

Chamaecyparis 'Soft serve' — Spring Meadow

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

Clematis 'Midnght showers — Lincoln

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

Coreopsis 'Crème brule' — Lincoln

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

Coreopsis 'Moonbeam' — Zelenka

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

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

y = Growth indices

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

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

Table 5., Continued

Cornus 'Baileyi' — Lincoln

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

Cornus sanguinea 'Arctic sun' — Spring Meadow

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

Echinacea purpurea 'White satin' — Lincoln

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

Echinacea purpurea — Zelenka

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

Euonymus alatus 'Fireball' — Spring Meadow

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

Hemerocallis 'Strawberry candy' — Lincoln

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

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

y = Growth indices

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

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

Table 5., Continued

Hydrangea macrophylla 'All summer beauty' Lincoln

Treatment	1 WA1T [z]	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI [y]
F6875 4SC 0.375 lb ai/ac	3.9 [x] ** [w]	5.8 **	2.7 **	0.5	0.0 ns	0.0 ns	ns
F6875 4SC 0.75 lb ai/ac	3.4 **	6.2 **	3.0 **	0.8	0.3 ns	0.0 ns	ns
F6875 4SC 1.5 lb ai/ac	4.2 **	6.9 **	3.8 **	1.6 **	0.0 ns	0.0 ns	ns
Untreated	0.6	1.5	0.6	0.2	0.0	0.0	

Hydrangea macrophylla 'Mini penny' Zelenka

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
F6875 4SC 0.375 lb ai/ac	3.1 **	6.6 **	4.2	0.6	4.5	2.0 *	-3.8 ns
F6875 4SC 0.75 lb ai/ac	3.7 **	7.1 **	4.7 **	1.4 **	6.0 **	2.5 **	-4.4 ns
F6875 4SC 1.5 lb ai/ac	4.6 **	8.3 **	5.5 **	2.1 **	5.3	3.2 **	0.1 ns
Untreated	1.3	3.9	3.7	0.4	3.2	0.3	-5.7

Potentilla fruticosa 'Pink beauty' Lincoln

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Biathalon 2.75 lb ai/ac	0.0 ns	0.2	0.2 ns	0.1 ns	0.0 ns	0.0 ns	ns
Biathalon 5.5 lb ai/ac	0.0 ns	0.5	0.6 ns	0.4 ns	0.0 ns	0.0 ns	ns
Biathalon 11 lb ai/ac	0.0 ns	1.0 *	0.2 ns	0.1 ns	0.0 ns	0.0 ns	ns
Untreated	0.0	0.0	0.2	0.1	0.0	0.0	

Potentilla fruticosa 'Goldfinger' Spring Meadow

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Biathalon 2.75 lb ai/ac	0.0	0.0 ns	0.0 ns	0.0 ns	0.0 ns	0.0 ns	ns
Biathalon 5.5 lb ai/ac	0.4	0.0 ns	0.0 ns	0.0 ns	0.0 ns	0.0 ns	ns
Biathalon 11 lb ai/ac	1.0 **	0.3 ns	0.0 ns	0.0 ns	0.0 ns	0.0 ns	ns
Untreated	0.0	0.0	0.0	0.0	0.0	0.0	

Viburnum dentatum 'Blue muffin' Spring Meadow

Treatment	1 WA1T	2 WA1T	4 WA1T	1 WA2T	2 WA2T	4 WA2T	GI
Certainty 0.059 lb ai/ac	2.8 **	5.8 **	4.5 **	3.6 **	4.0	5.5	6.8 *
Certainty 0.117 lb ai/ac	4.5 **	6.1 **	5.0 **	5.1 **	6.0	7.5 **	0.0 **
Certainty 0.234 lb ai/ac	4.5 **	7.1 **	5.8 **	7.8 **	8.8 **	9.7 **	-12.0 **
Untreated	0.0	0.0	0.0	0.0	5.4	4.8	12.0

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

y = Growth indices

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

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

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

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

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

y = Growth indices

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

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

Conclusions

Biathalon, FreeHand, the granular form of F6875 and Tower merit further evaluation in MI nurseries in the field and containers. SedgeHammer also merits further field testing due to its ability to suppress some of Michigan's particularly difficult weeds.

Addressing Objective 2:

A. Bio-herbicide mulch combinations and bio-rationale approaches to ornamental weed control

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

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

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

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

Fig. 14. Herbicide treated mulch efficacy trial at Sheridan Nursery. Outdoor geotextile covered growing area. Conventional treatments are towards the top of the picture and bio-herbicide mulch

combinations in foreground. The phytotoxicity trial with the *Euonymus fortunei* 'Emerald Gaiety' is in the background on the right. Picture taken by H. Mathers 90 days after treatment (DAT).

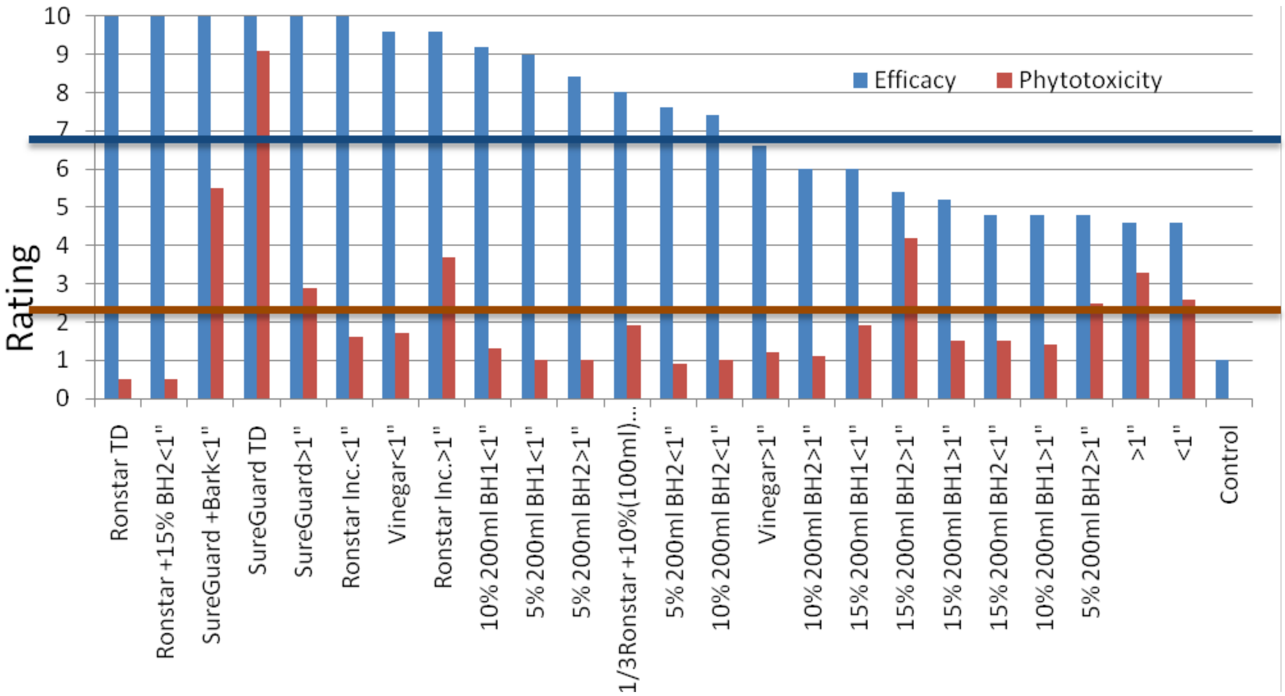

Fig. 15. Efficacy and phytotoxicity combined over three species, *Euonymus fortunei* 'Emerald Gaiety' (Winter Creeper Euonymus), *Sambucus canadensis* (American Elderberry) and *Pinus mugo* (Mugo Pine) at Sheridan Nursery. SureGuard and Ronstar were used with >1' and, 1" pine bark or alone. Two bio-herbicides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

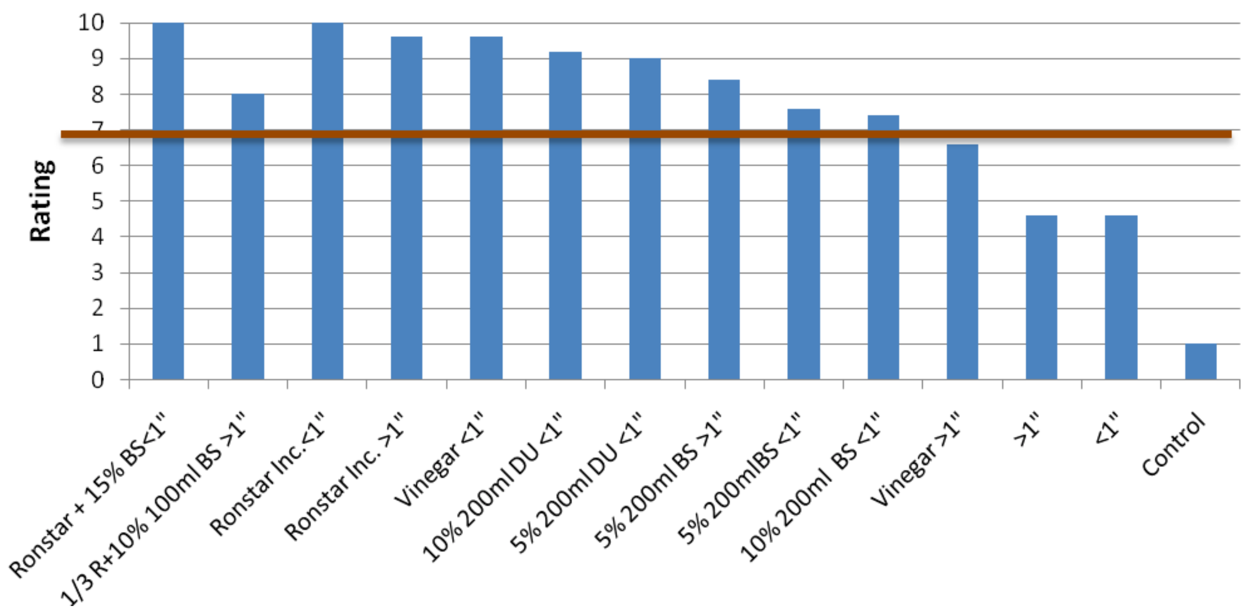

Fig. 16. Efficacy of three conventional Ronstar applications compared with bio-herbicides treatments (BH2 or BS) and (BH1 or DU) were applied to >1" and <1" pine bark from Gro-Bark Ltd., Caledon, ON, at Sheridan Nursery, Halton Hills, ON, 90 days after treatment (DAT). Two sizes of were used. The BH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

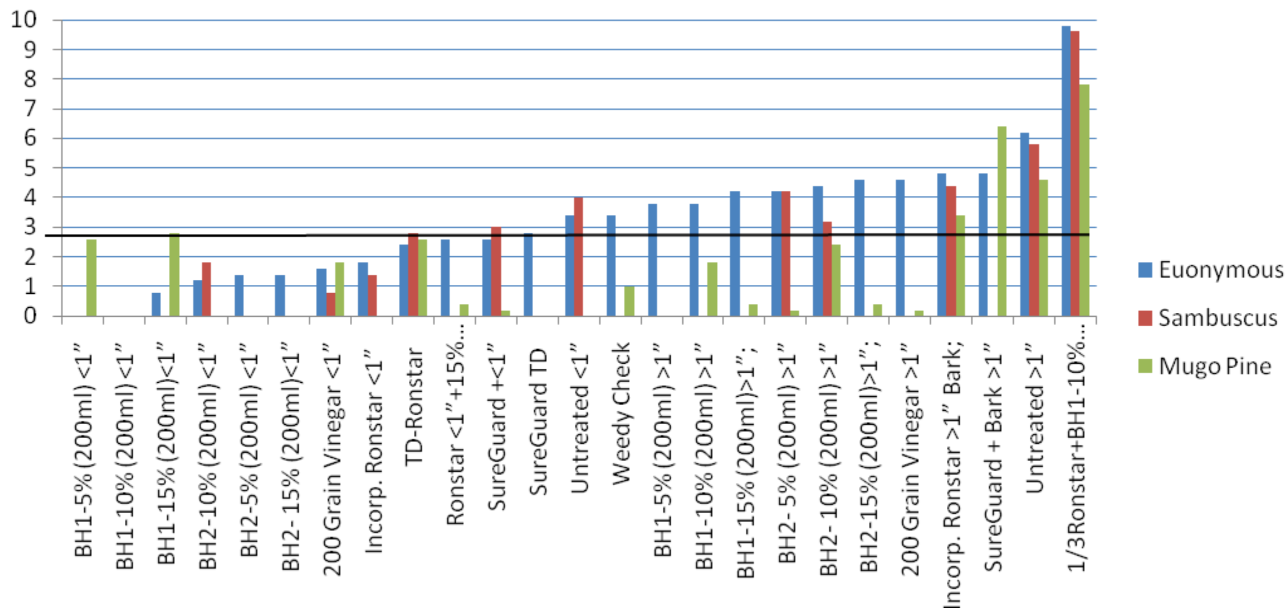

Fig. 17. Phytotoxicity by species and treatment for *Euonymus fortunei* 'Emerald Gaiety' (Winter Creeper Euonymus), *Sambucus canadensis* (American Elderberry) and *Pinus mugo* (Mugo Pine) at Sheridan Nursery, Halton Hills, ON 90 days after treatment. SureGuard and Ronstar were used with >1" and <1" pine bark from Gro-Bark Ltd., Caledon, ON. Two bio-herbicides [BH1 (DU) and BH2 (BS)] made from two plant extracts (which will remain anonymous for the purpose of potential patenting) were applied at three concentrations (5%, 10% or 15%) and one 200 grain vinegar was also applied. Phytotoxicity visual ratings of 0 (no injury) to 10 (complete kill) were used with $\leq$ 3 being commercially acceptable.

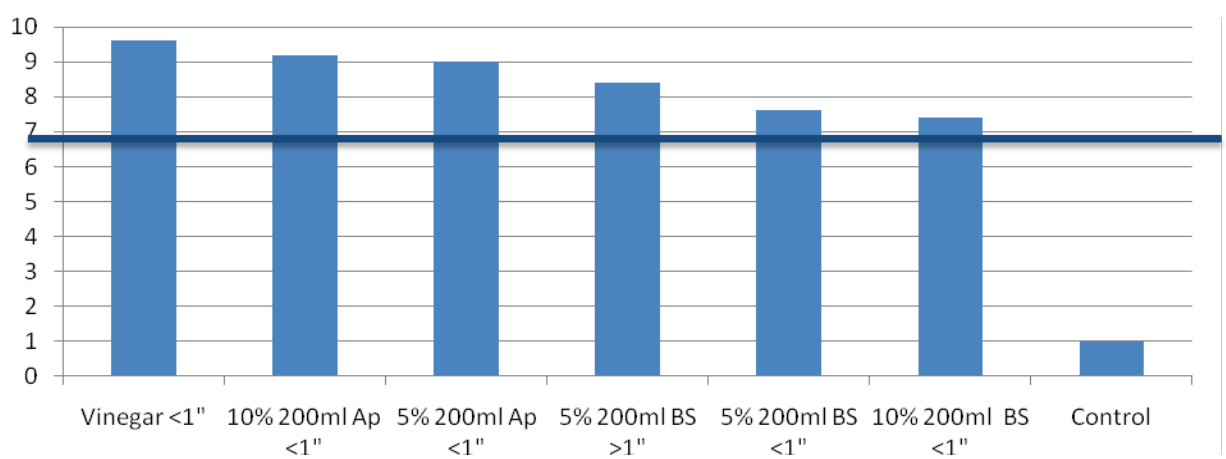

Fig. 18. The six most efficacious treatments applied at Sheridan Nursery, Halton Hills, ON 90 days after treatment compared to the control, no herbicide or bark. Two sizes of Pine bark >1" and <1",

were used. The Bio-herbicide treatments (BH2 or BS) and (BH1 or DU) were applied at three concentrations (5%, 10% or 15%) to the two bark sizes and one 200 grain vinegar was also applied. Efficacy ratings of weed control from 0 (no control) to 10 (complete control) were used with $\geq$7 being commercially acceptable.

Conclusions:

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

Addressing Objective 2:

Bio-herbicide mulch combinations and bio-rationale approaches to ornamental weed control 2nd Year

Objectives:

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

Materials and Methods:

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

No weed seeding was conducted. Efficacy and phytotoxicity were rated as described in the 2009 experiment. There were 28 treatments evaluated. BH1 at 15, 10 and 5%, 10%, pelargonic acid (Scythe™) at 10% v/v, (Gowan Co., LLC, Yuma, AZ) and Munger Horticultural Vinegar Plus (20% acetic acid (Engage Agro, Guelph, ON) were applied to each of the three barks for a total of 15 treatments. Scythe was also applied directly to the soil around the plants. Two other vinegars 200

A B C

Grain Vinegar (similar to that used in the 2009 trial from the Ohio State University, Food Science Department) and WeedPharm™ (20% acetic acid) at 10% v/v (Pharm Solutions Inc., Port Townsend, WA) were applied to the soil and to each mulch for eight additional treatments. The final four treatments consisted of the three barks alone and a control (no mulch, no chemical).

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

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

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

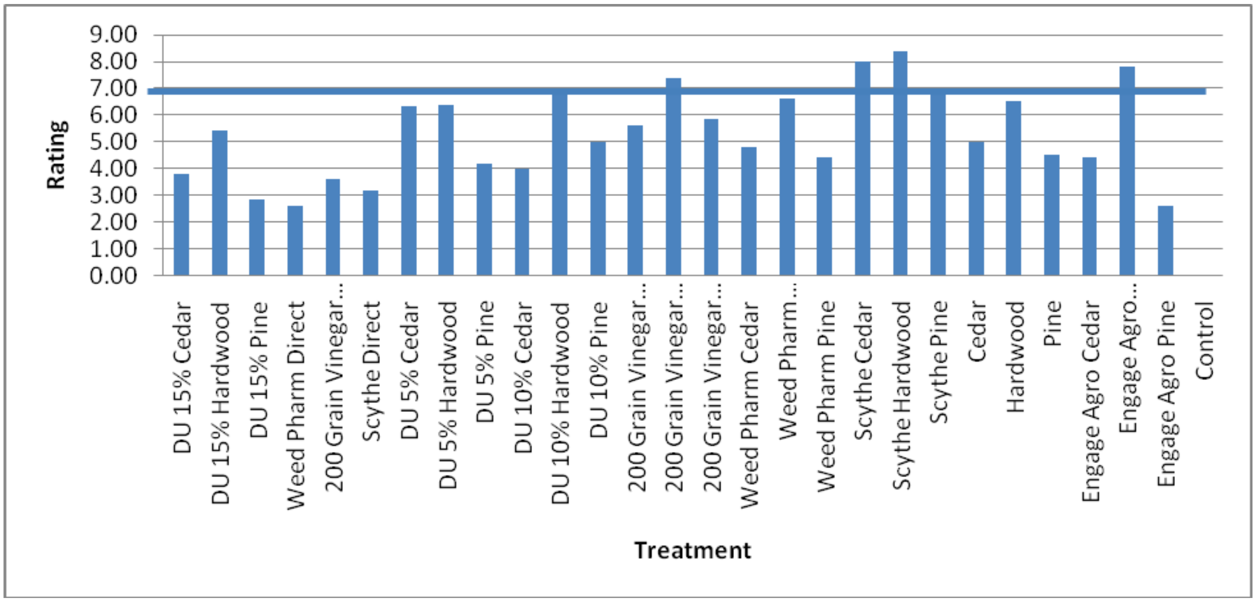

Fig. 20. Efficacy evaluations of the three bark types (Pine, Hardwood and Cedar bark) from Gro-Bark Ltd., Caledon, ON at 50 days after treatment (DAT) and bio-herbicide treatment (BH1 or DU) applied at three concentrations (5%, 10% or 15%) to the three barks. Efficacy ratings of weed control ranged from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

Conclusions:

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

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

A B

Addressing Objective 3:

A. Characterize the propagule-bank at Michigan nurseries.

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

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

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

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

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

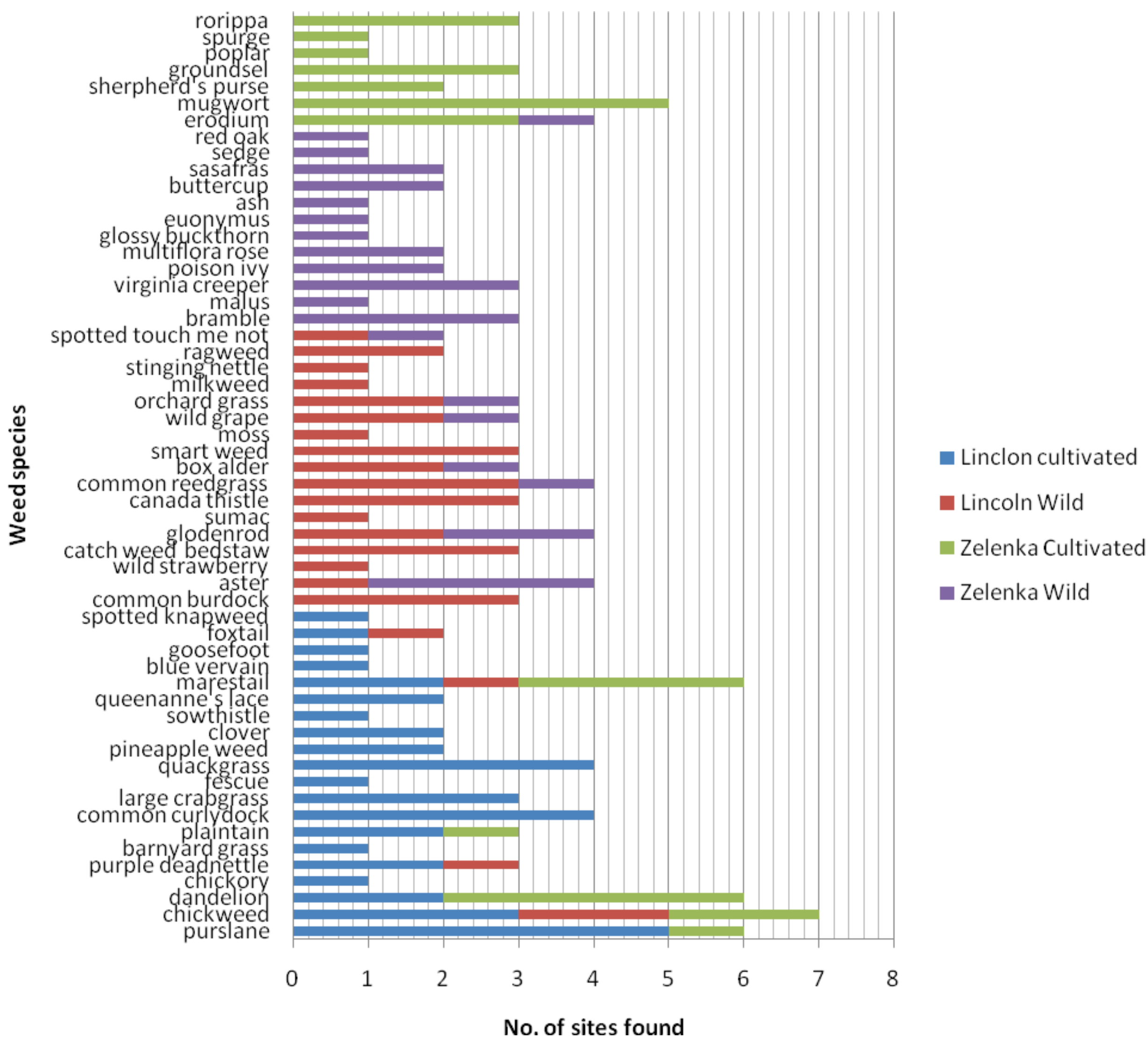

Fig. 24. Weed species identified at field nursery sites in MI, Lincoln Nurseries (Grand Rapids, MI), Zelenka Nursery (Grand Haven, MI), and natural adjacent areas. The species composition of invasive and noxious weed species on the site were sampled during early fall (after most seedlings have emerged)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

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

Fig. 25A

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

Fig. 25B

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

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

A

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

Red Stem Filaree (Erodium cicutarium)

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

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

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

Horseweed/ Marestail (*Conyza canadensis*)

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

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

Contracting of this project with:

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Technical Assistance: Mr. Luke Case (MSc), Department of Horticulture and Crop Science, Ohio State University, Howlett Hall, 2001 Fyffe Rd, Columbus, OH 43210-1096, Tel. 614-292-0209; Fax 614-292-3505; *case.49@osu.edu* and
Mr. James Beaver (MSc), Mathers Environmental Science Services, 839 Riva Ridge Blvd., Gahanna, OH, 43230, Tel. 614-371-8744; *jabeav@gmail.com*

Beneficiaries and Lessons Learned:

Overall Final Report Summary:

In this research we have investigated liverwort in the division Bryophyta. As very primitive plants that have no leaves, roots, stems or vascular tissue and reproduce vegetatively and/or by spores, their control is very different from vascular plants. A large variety of products were tested.

Those that performed well in this study and that merit further testing are Scythe, SureGuard, TerraCyte and Weed Pharm with comparison to other horticultural vinegars. We also conducted phytotoxicity trials that were set up on April 29, 2010 and evaluated at three nurseries in Michigan: Lincoln Nurseries, Inc., near Grand Rapids, Spring Meadow Nursery, Inc., near Grand Haven and Zelenka Nursery, LLC, also near Grand Haven. Six to nine species were selected by the individual nurseries from the IR-4 priority 2010 list for a total of 22 container trials and one field test at Zelenka. Of the nine herbicides evaluated in this research Biathalon, FreeHand, the granular form of F6875 and Tower all merited further evaluation in MI nurseries in field and containers. SedgeHammer was also found to merit further field testing due to its ability to deal with some of Michigan's particularly difficult weeds discussed on pages 33-35.

Two experiments with alternative and bio-rationale approaches to nursery weed control were also evaluated in this project using novel previously untested bio-herbicide mulch combinations and herbicide treated mulch. Possible patenting of some of the bio-herbicides evaluated in this research is being pursued. Thus, details regarding these products are not given; however, their general performance without specifying their names is provided. In the first experiment, a 200 grain Vinegar on < 1" pine bark was very efficacious and provided the same level of weed control as the conventional herbicide Ronstar with less than half the phytotoxicity at 90 DAT. The BH1 plant extract or DU 200ml at 10 and 5% <1" was statistically as efficacious as the Vinegar <1" and the Ronstar; however, the phytotoxicity with BH1 was almost half that of even vinegar and 3.5 X less than the Ronstar. The potential of vinegar and BH1 as bio-herbicides combined with mulch shown in this first study indicated that further testing with horticultural vinegars compared to 200 grade vinegar and the BH1 extract, with different kinds of mulches, was warranted. Also, the results warranted testing in a field setting to determine the suitability in landscape or nursery field operations. In the second study with three vinegar formulations, the Munger Horticultural Vinegar Plus provided the best results. Further evaluations of the Munger HVP and of Scythe on various barks especially hardwood should be conducted. The BH1 plant extract or DU 200ml at 10% due to its high efficacy and low phytotoxicity also warrants further examination with different carriers and perhaps surfactants. More testing with other alleopathic plant extracts should also be performed.

The last study we conducted as part of this report evaluated the propagule banks at four sites: two field nursery sites in MI, Lincoln Nurseries and Zelenka Nursery, and two adjacent natural areas. The number and species composition of seeds and other propagules of potentially invasive and noxious weed species in the soil propagule bank were sampled during early fall after most seedlings had emerged using methods described by Cardina and Sparrow (1996) at each site. Randomly chosen ten 1-meter^2 plots at each site five in active nursery fields and five in adjacent wild areas bordering the nursery were taken in Sept. 2010. Weed diversity was much higher at Lincoln Nursery than at Zelenka in their cultivated areas, possible indicating greater herbicide usage at Zelenka Nursery. In addition to the loss of weed diversity at Zelenka, three very herbicide resistant weeds, mugwort (*Artemisia vulgaris* L), creeping yellow field cress (*Rorippa sylvestris)* and Red Stem Filaree (*Erodium cicutarium)* were found at Zelenka. The six species found in greatest frequency at both sites were: mugwort, found at 100% of Zelenka nursery cultivated sites; Erodium, found at three Zelenka cultivated sites and one wild site; Marestail, found at 2 Lincoln cultivated, one Lincoln wild, and three Zelenka cultivated sites; Dandelion, found at 2 Lincoln cultivated and four Zelenka cultivated sites; Chickweed, found at 3 Lincoln cultivated, two Lincoln wild, and two Zelenka cultivated sites; and Purslane found at 5 Lincoln cultivated and one Zelenka cultivated sites.

We have found that the standard programs used at some MI nurseries are actually increasing weed populations of difficult weed species by releasing them from competition from other weeds. Continued research is needed to evaluate a variety of preemergence herbicides alone, or in combination, that might control these three problematic weed species without causing phytotoxicity to frequently grown MI nursery crops.

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Additional Information:
Final Report Dollars Requested: $58, 211.69
Expenses

Date	Activity	Hotel	Salary	Mileage	Meals	Total
Mar. 31, 2010 covered Obj. 1A to 03/25	Interim Report	$443.31	$14,200.00	$1,955.00	$190.00	**$16,788.31**
Summer 2010	Advance to MESS					**$ 3,000.00**
April 1, 2010	2 WAT of 2nd application evaluation **Obj. 1A**	N/A	$ 1,640.00	320.00 X 2 X 0.50 = *$320.00* to Grand Rapids pd. 3rd party	20.00	
April 15, 2010	4 WAT of 2nd application evaluation	2 rooms = $147.70 pd. MESS Summer Advance	$ 2,640.00	340.00 X 2 X 0.50 = *$340.00* to Grand Rapids and Grand Haven, MI	30.00 pd. MESS Summer Advance	
April 29, 2010	Trial initiation, including growth index (GI) eval. **Obj. 1B**	2 rooms = $147.70 pd. MESS Summer Advance	$ 3,640.00	340.00 X 2 X 0.50 = *$340.00* to Grand Rapids and Grand Haven, MI	20.00	
May 6, 2010	1 WAT evaluation	N/A	$ 1,640.00	*$340.00* Pd. MESS Summer Advance	25.00	
May 13, 2010	2 WAT evaluation	1 room = $74.00 pd. MESS Summer Advance	$ 1,640.00	340.00 X 2 X 0.50 = *$340.00* to Grand Rapids and Grand Haven, MI	25.00 pd. MESS Summer Advance	
May 27, 2010	4 WAT Evaluation +	3rd party pd.	$ 2,000.00	Pd.3rd party	Pd. 3rd party	

	GI					
June 24, 2010	2nd application trial initiation, including growth index (GI) eval. **Obj. 1B**	2 rooms = 147.70 pd. MESS Summer Advance	$ 3,000.00	Pd. 3rd party	40.00 pd. MESS Summer Advance	
July 1, 2010	1 WA2T evaluation	NA	$ 1,492.10 ($147.90 pd. MESS Summer Advance)	340.00 X 2 X 0.50 = *$340.00* to Grand Rapids and Grand Haven, MI	N/A	
July 8, 2010	2 WA2T evaluation	N/A	$ 1,640.00	340.00 X 2 X 0.50 = *$340.00* to Grand Rapids and Grand Haven, MI	$20.00	
July 22, 2010	4 WA2T Evaluation + GI	3rd party pd.	$ 3,640.00	*$340.00* to Pd. MESS Summer Advance	40.00 pd. MESS Summer Advance	
July 23, 2010	Presentation for grower discussions **Obj. 1A and B**	3rd party pd.	$ 1,640.00	$11.69	N/A	
Dec. 10, 2009	Data analyses, summary and design of 2010 experiment **Obj. 2A and B**	2 rooms $150.00 X 2 = $600.00 Pd. MESS Summer Advance $600.00	$ 2,640.00	$350.00 x 2 x 0.50 = $350.00 to Vineland, ON and Georgetown, ON	40.00	
June 8, 2010	Trial initiation **Obj. 2B**	Pd. MESS Summer Advance $600.00	$ 3,080.00	$320.00 X 2 X0.50 = $320.00 pd. MESS Summer Advance	40.00	
July 13, 2010	1st Evaluation (35 DAT) **Obj. 2B**	2 rooms = $300.00	$ 2,640.00	$320.00 X 2 X0.50 = $320.00	22.90	
July 28, 2010	2nd Evaluation (50 DAT) **Obj.**	2 rooms 150.00 X 1	$ 3,640.00	$320.00 X 2 X0.50 =	10.00	

	2B	= $300.00		$320.00		
Sept. 9, 2010	Fall preemergence herbicide applications and seed bank evaluations **Obj. 3**	3rd party pd.	$ 3,192.10	*$340.00* to Grand Rapids and Grand Haven, MI	40.00	
Sept. 11	Potting of soil samples, evaluations and counting collected at two nurseries and wild areas	N/A	$ 2,500.00	N/A	N/A	
Data analyses and final reporting of all objectives		N/A	$ 9,200.00	N/A	N/A	
Sub Total since 03/10		$ 600.00	$51,652.10	$ 2,721.69	$ 237.90	**$55,211.69**
Sub Total Interim Report		$ 443.31	$14,200.00	$ 1,955.00	$ 190.00	**$16,788.31**
Sub Total MESS Summer Advance		$ 1,717.10	$ 147.90	$ 1,000.00	$ 135.00	**$ 3,000.00**
Grand Total		$ 2,760.41	$66,000.00	$ 5,676.69	$ 562.90	**$75,000.00**

MNLA
MICHIGAN NURSERY AND LANDSCAPE ASSOCIATION
- since 1922 -

REQUEST FOR FUNDS

Requisition by: AGR
Date of Request: 8/5/10
Date Required: ASAP
Amount Requested: $3,000.00

Make check payable to: Mathews Environmental Science Services
Address: 839 River Ridge Blvd.
Gahanna, OH 43230

Purpose of Payment: Advance on Research through Specialty Crop Block Grant program (to be paid in November). to MNLA

INTERNAL USE

☒ Approved ☐ Disapproved

Charge to this account:

Authorization: AGR
Executive Director

Additional Information: