WEED CONTROL IN SPECIALIZED AND TRADITIONAL MICHIGAN NURSERIES

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Activities Performed:

The 2012-13 project had three objectives dealing with three issues in the industry:

- **A.** Loss of Methyl Bromide soil fumigant
- **B.** Liner bed weed control with pre- and post-emergence herbicides for difficult weeds ex. *Rorippa sylvestris*
- **C.** Liverwort control

Note: For overall accomplishments see pp. 37-38. Each objective will be addressed separately according to activities, results, accomplishments, recommendations, problems and delays in the sections below.

A) Loss of Methyl Bromide:

Background:

Forests are increasingly important, for mitigating global environmental challenges. The first step in forest establishment is the production of tree seedlings by forest tree nurseries. These nurseries provide healthy starting material for reforestation. Direct yield losses, in terms of seedlings/hectare, may not be large on average with improper pest control, intensive seedling production relies on the ability of nursery managers to meet quality and yield goals as well as certification that plants are essentially pest-free.

Methyl Bromide (MeBr) has been used extensively as the soil fumigant of choice to manage fungal pathogens (e.g., *Fusarium*, *Alternaria*, *Phytophthora*, *Pythium, Rhizoctonia*, *Cylindrocladium* spp., *Cylindrocarpon*, and *Macrophomina*), nematodes (e.g., *Circonemoides*, *Helicotylenchus*), and yellow and purple nutsedges (species of *Cyperus*) in forest and herbaceous seedling nurseries in MI and the rest of the US. In 1994, the Clean Air Act mandated 100% phase-out of MeBr by 2001. MeBr was being phased out internationally because it depletes stratospheric ozone, which protects life on Earth from the harmful effects of the sun's ultraviolet radiation. In 1998, the phase-out schedule was revised. The U.S. Congress amended the Clean Air Act to synchronize it with the Montreal Protocol. The 1998 phase-out planned for developed countries reduced production and import of methyl bromide by the following percentages of the 1991 baseline amounts: 25% in 1999, 50% in 2001, 70% in 2003 and 100% in 2005. By 2015, MeBr will be gone.

Activities Performed:

From our pre-project start surveys, we learned that forest and herbaceous seedling growers currently use no herbicides and their MeBr applications cost approximately $1700.00/ ac. Weekly hand weeding costs over $600.00/ ac on average over the growing season. Therefore, their total cost of weed control before this project was $2300.00/ ac.

Walters Gardens is a 385 acre nursery. The preemergence herbicides found to be effective in this project cost less than $35.00/ ac. We targeted to cut their weed control program cost by 30%. Using the herbicides we found effective accomplished this target. Much more work is needed in this area due to the total phase out of MeBr by 2015, the lack of alternative fumigants and this being the first study of preemergence herbicide use in these industries.

Trials with supplemental preemergence herbicides were conducted on three growth stages of deciduous, coniferous or herbaceous seedlings. The three growth stages are listed below in order of highest to lowest potential to cause injury and death:

1) Before the seed emerged in seedling beds
2) Two to six weeks after the seedlings had emerged
3) Transplant beds, two weeks after two year old seedlings were transplanted from seedbeds to the transplant beds.

Stage 1& 2 trials were conducted at Walters Gardens, Inc., at their 400 80th Ave, Zeeland, MI location. The soils are a Gladwin Series sandy loam with low fertility and available water capacity. Gladwin Series soils are moderately permeable. Applications were made on the morning of May 22, 2013. There was a light rain, cloudy skies and the temperature was 63°F. For Stage 1 and 2 trials, nine treatments were applied with four replications of 3 ft. X 3 ft. sections of beds and one ft. buffers between each (Fig. 1 A). The nine treatments and replicates were randomized within each bed/ species. Chemical treatments included trifluralin (Treflan 4 EC) (Helena Chemical Company, Collierville, TN, 38017) applied at (1/2 rate) 1qt and (1/4 rate) 1 pt. per acre; prodiamine (Barricade 4FL) (Syngenta Crop Protection, LLC, Greensboro, North Carolina, 27419) applied at (1/2 rate) 10 oz./ac; Barricade 4FL (1/4 rate) (5 oz./ac) plus Treflan 4EC (1/4 rate) (1pt/ac); oxyfluorfen + prodiamine (Biathlon) (OHP, Inc., Mainland, PA, 19451) applied at (1/4 rate) 50 lb./ac; pendimethalin (Pendulum 2G) (BASF Corporation, Research Triangle Park, NC 27709) applied at (1/2 rate) 100lb./ac and oxadiazon + pendimethalin (Jewel) (Scotts-Sierra Crop Protection Company, Marysville, OH 43041) applied at (1/2 rate) 50 lb./ac. The remaining two treatments to total nine were an untreated weeded check and an untreated weedy check.

The three species used in Stage 1 trials at Walters Gardens were Beard tongue, *Penstemon barbatus* 'Coccineus'; Swamp milkweed, *Asclepias incarnata* ‘Cinderella,’ and Rhubarb, *Rhubarb* ‘Victoria.’ These species had been seeded on May 20, 2013

only two days before we treated the beds with the herbicides listed above. The beds were weed free at time of application with no seed germination occurring (Fig. 1 A and B). The three species used in Stage 2 trials at Walters Gardens were Oriental poppy, *Papaver orientalis* 'Queen Alexander'; Columbine, *Aquilegia* 'Dorothy Rose'; and, Perennial larkspur and *Delphinium* x *cultorum* 'Round Table Mix'. These species had been seeded on April 29, 2013 approximately 3 weeks prior to treatment. *Papaver* 'Queen Alexander' was just emerging at the time of application on May 22, 2013. *Aquilegia* 'Dorothy Rose' was germinated but barely emerged from the ground. *Delphinium* ' Round Table Mix' was the most advanced of the three stage 2 species used at Walters with cotyledons emerged but no true leaves (Fig 2 A and B). Weeds were already emerging in these stage 2 fields with a heavy infestation of white clover (*Trifolium repens*) at the north end of the field.

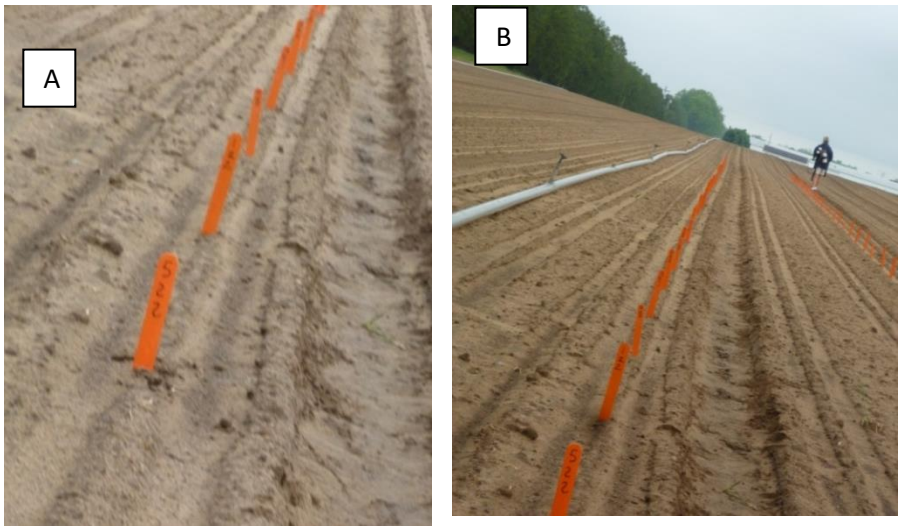


Fig. 1. A and B. (Left) Stage 1 trials at Walters Gardens, Zeeland, MI on Gladwin Series soils were conducted on Beard tongue, Swamp milkweed and Rhubarb **(A).** These species had been seeded on May 20, 2013 two days before treatments were applied (**B)**.

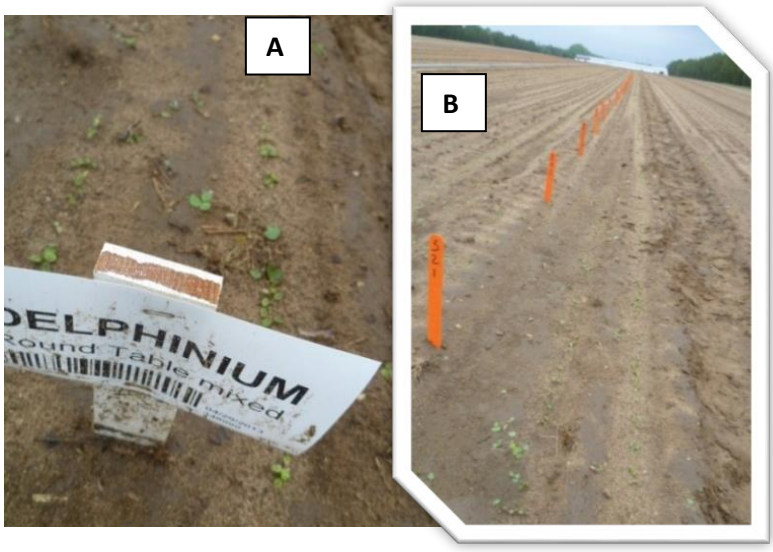


Fig. 2. A and B. (Left) The Stage 2 species at Walters Gardens, Zeeland, MI were Oriental poppy, Columbine and Delphinium. Delphinium was the most advanced of the stage 2 species with cotyledons emerged but no true leaves **(A).** Stage 2 species had been seeded on April 29, 2013 approximately 3 weeks before applications on May 22, 2013 and were barely emerging from the soil **(B)**. Some weeds had also emerged by application time.

Stage 2 and 3 trials were conducted at New Life Nursery, 3720 64th St. Holland, MI on deciduous and coniferous seedlings. Applications were applied in the early afternoon of May 22, 2013. There was a moderate rain, cloudy skies and the temperature was 55°F. Stage 2 trials consisted of the same nine treatments applied at Walters Gardens, with four replications of 3 ft. X 3 ft. sections of beds and one ft. buffers between each. The nine treatments and replicates were randomized within each bed/ species. For Stage 3 trials, 12 treatments were conducted: dimethenamid-P + pendimethalin (FreeHand 1.75G) (BASF Corporation, Research Triangle Park, NC 27709) applied at (normal rate) 150 lb./ac; indaziflam (Marengo G) (OHP, Inc., Mainland, PA, 19451) applied at (½ rate) 50 lb./ac and (normal) 100lb./ac; oxyfluorfen + prodiamine (Biathlon) (OHP, Inc., Mainland, PA, 19451) applied at (3/4 rate) 150 lb./ac and (1/3 rate) 75 lb./ac; pendimethalin (Pendulum 2G) (BASF Corporation, Research Triangle Park, NC 27709) applied at (1/2 rate) 100lb./ac; oxadiazon + pendimethalin (Jewel) (Scotts-Sierra Crop Protection Company, Marysville, OH 43041) applied at (normal rate) 100 lb./ac; Barricade 4FL (1/4 rate) 5 oz/ac plus Treflan 4EC (1/2 rate) 1qt/ac; dimethenamid-P (Tower) + pendimethalin (Pendulum Aqua Cap) (BASF Corporation, Research Triangle Park, NC 27709) applied at (normal rates) 1 qt/ac + 1 qt/ac; and, isoxaben (Gallery) (Dow Agro Sciences, LLC, Indianapolis, IN 46268) applied at (1/3 rate) 0.65 lb.ac + Barricade 4FL (½ rate) 10 oz./ac. The remaining two treatments to total 12 were an untreated weeded check and an untreated weedy check.

The Stage 2 trials at New Life were conducted on Common lilac, *Syringa vulgaris;* Black walnut, *Juglans nigra;* and, Bur oak, *Quercus macrocarpa*. Soils at New Life are Saugatuck series sands. They are very deep and somewhat poorly drained soils with cemented subsoil. Saugatuck Series soils were formed in sandy glaciofluvial deposits on lake plains, till plains, and outwash plains (Fig. 3 and 4). The lilac field had been fumigated prior to fall planting with MeBr at 400 lb./ac. Post planting, a thin layer of pine mulch was applied to the lilac field to decrease wind erosion of the sandy soils. The walnut and the bur oak were also fumigated with MeBr at 400 lb./ac prior to fall planting. Lilac had emerged approximately ¼ inch above the ground at time of application on May 22, 2013. Cotyledons were presented and some seedlings had their first true leaves just expanding (Fig. 3 A and B). Applications to the oak and walnuts were conducted on June 19, 2013 due to rain on May 22, 2013 and thus they were more advanced in growth having been emerged for approximately 3 weeks. The Stage 3 trials were conducted using Norway Spruce, *Picea abies* that were being grown as 2+1 transplants (2 years in the seedbed) and transplanted two weeks before on May 8, 2013. They were approximately six inches tall at time of application (Fig. 4). The spruce fields had not received MeBr prior to planting nor mulch post planting. Data was analyzed using SAS® GLM. Phytotoxicity effects of treatments were compared to the controls using Dunnett's t-test ($\alpha = 0.10$ and 0.05). Efficacy treatments were compared

to each other using least significant difference (ls means). Evaluations were conducted every two weeks after application for 3 months or 12 WAT, unless otherwise stated.

Fig. 3. A and B. (Left) New Life Nursery, Holland, MI, lilac seeded fall of 2012 just beginning to emerge at time of herbicide applications, May 22, 2013 **(A).** (Below) Note the fine layer of mulch applied post planting **(B)** on top of Sagatuck Series soils.

Fig. 4. (Left) Norway spruce fields at Walters Gardens, Holland, MI. Two year old seedbed spruce (approximately six inches tall) was transplanted into beds on May 8, 2013, two weeks prior to herbicide applications on May 22, 2013.

Results, Accomplishments, Conclusions and Recommendations:

Stage 1 trials at Walter's Gardens have never been tried anywhere before. Placing a preemergence herbicide, which inhibits germination, over seedbeds before any plants have emerged is problematic at best. However, all herbicides have selectivity and some selectivity was found in these trials (Table 1). With no information available regarding herbaceous perennial seed susceptibility to herbicides, the species chosen for this trial were those with the largest market share for Walters Gardens. The results indicated that for most perennial species tested and treatments used, severe injury and death occurred (Table 1). However, the Treflan 1 pt rate (Fig. 5A), the Barricade 10 oz. rate and the Biathlon 50 lb./ac rate (Fig. 5B) on milkweed (*Asclepias*) provided near commercially acceptable phytotoxicity at most evaluation dates including 12 WAT. If Barricade had not been reapplied at 8 WAT to milkweed, it would have caused very low phytotoxicity and been more than commercially acceptable. The Barricade was reapplied at 8 WAT in the hopes of picking up additional weed control. The results for Rhubarb, which was also a Stage 1 plant used at Walters Gardens, are not presented. Following treatment application none of the Rhubarb emerged in any of the treatment plots. The results at 2 WAT show high values indicative of high phytotoxicity (Table 1); however, at this stage few plants had emerged and thus were scored as non- or barely existent. The *Penstemon*, another Stage 1 plant, had high phytotoxicity ratings especially in the weedy check 2 WAT (Fig. 6) to 10 WAT (Table 1). We believe that much of the *Penstemon* seed was non-viable. Therefore treatment impacts were difficult to interpret for this species. Treflan at 1 qt./ac (2 WAT) had low germination; however, in the control, germination was no better (Fig. 6) with ratings of 9.5 and 9.8, respectively (Table 1). We recommend that Treflan, Barricade and Biathlon be tried again at even lower rates and not reapplied for *Penstemon* and *Asclepias*. Further studies with more species are also warranted. These three treatments do seem to show promise on Stage 1 plants.

We had hypothesized that Stage 1 treatments would cause more phytotoxicity than Stage 2 treatments at Walters Gardens. This was not the case. Treatment impacts were equal to or more severe on Stage 2 plants (Table 2) than on Stage 1 plants (Table 1). The results for the poppy are not presented. As with the Stage 1 Rhubarb, all treatments on Stage 2 *Papaver* caused death, at all evaluation dates (Fig. 7 A and B). Again, however, the Barricade 10 oz./ac rate seemed to show promise with low phytotoxicity at 6 WAT on *Delphinium* (Fig. 8) and *Aquilegia* (Fig. 9 A and B). Even with reapplication of Barricade at 8 WAT on *Aquilegia* 'Dorothy Rose,' phytotoxicity was below commercial acceptable levels and not different than the control (Table 2) (Fig. 9 B and C). The *Delphinium* x *cultorum* 'Round Table Mix' would have also had commercially acceptable phytotoxicity with Barricade 10 oz./ac if it had not been

reapplied at 8 WAT (Table 2). The *Delphinium* x *cultorum* 'Round Table Mix' also seemed to show some promises with Pendulum 2G at 100 lb./ac (Fig. 10 A). The Pendulum 2G ratings at 12 WAT of 6.5 was statistically equivalent to the two controls (Fig. 10 B and C) and the photos (Fig. 10 A, B and C). Unlike with Stage 1 trials, Biathlon 50 lb./ac was very phytotoxic to Stage 2 plants. Biathlon contains oxyfluorfen which has some postemergence potential on very small seedlings. Because the Stage 2 trials were on very small seedlings, any product containing herbicides other than mitosis inhibitors MoA (i.e., Jewel and Biathlon) caused severe injury to total kill.

We recommended in future trials using a larger buffer zone between treatments. In the sandy soils at Walters Gardens, there was more leaching than usual in our trials. Some of the treatments leached into adjacent plots (Fig. 11). This was demonstrated by the high phytotoxicity ratings of the untreated plots (Table 1 and 2). We also recommend for future trials that the perennial seed be planted deeper. This recommendation is based on observations of the rows closest to the tractor tire. The rows immediately adjacent to the tractor tire were unaffected by the herbicides; however, the rows next to these were damaged (Fig. 5 A) or dead (Fig. 8). The tractor tire created a berm and thus the seed was planted deeper in the adjacent row. In row crops, such as corn, the Pendimethalin (Prowl) label specifies the seeding depth needs to be at least 1.5" deep. At Walters Gardens, fields were weeded almost every week as normal practice; therefore, all treatments had very high efficacy ratings (Table 3).

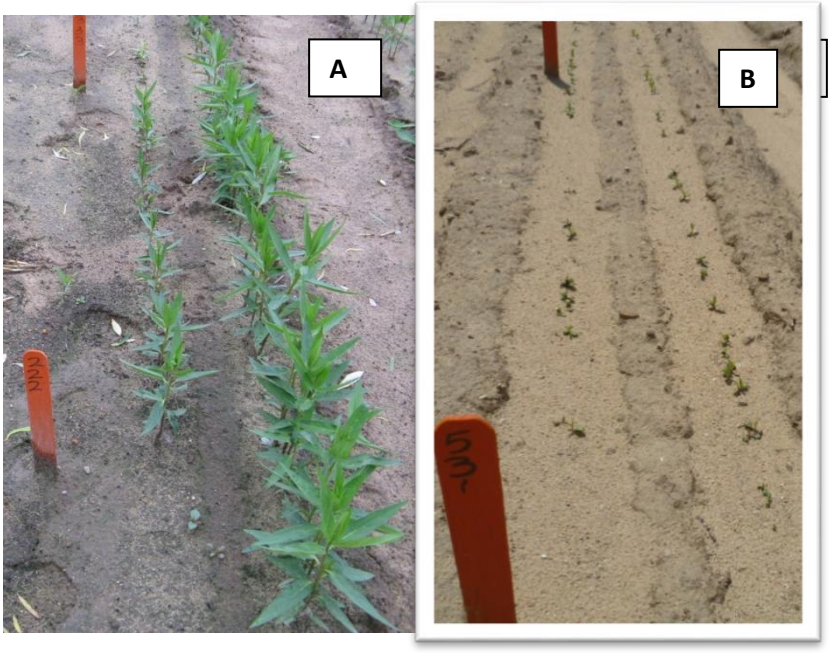
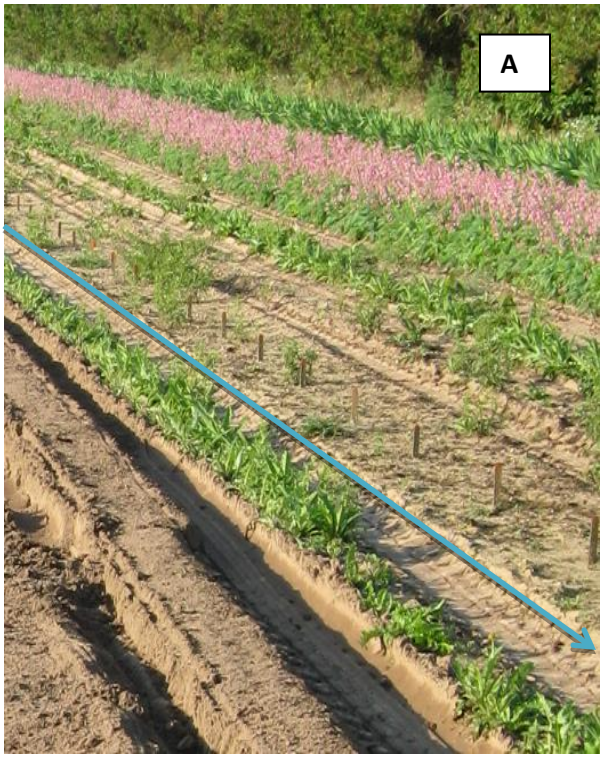


Fig. 5. A and B. (Left) Stage 1 *Asclepias incarnata* 'Cinderella' at Walters Gardens, Zeeland, MI at 6 WAT with Treflan 1 pt/ac (rating 2.5) (**A**). Biathlon 50 lb./ac at 2 WAT (**B**) showing little injury.

Fig. 6. (Above) Stage 1 *Penstemon coccineas* at 2 WAT at Walters Gardens, Zeeland, MI . The stake in the foreground marks the beginning of the Treflan 1 qt./ac plot. The stake in the background marks the beginning of the untreated weedy check 2 WAT (phytotoxicity ratings 9.5 and 9.8, respectively).



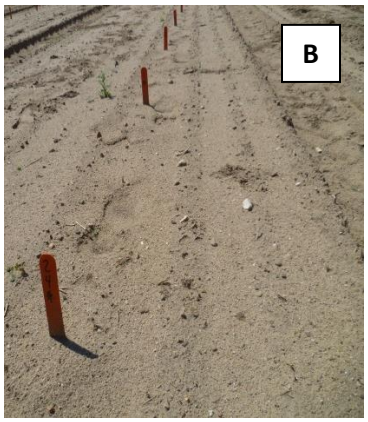


Fig. 7. A and B. (Left) Stage 2 *Papaver orientalis* 'Queen Alexander' at Walters Gardens, Zeeland, OH The second row from the left of the photo **(A)** just to the right of the blue line was the treated row at 6 WAT. Note the stakes that start the various treatment plots and the death in most of these **(A).** At 2 WAT also no germination occurring in any treated plot **(B)** (above).

Fig. 8. (Left) Stage 2 *Delphinium* 'Round Table Mix' at Walters Gardens 6 WAT. Stake in foreground marks the [illegible] of the Barricade 10 [illegible] (rating 4.0). Note the row adjacent to the tire track is fine; however the row to the left of that is almost all dead. The tire track is denoted by a black line.

Fig. 9. A, B and C. (Above) Stage 2 *Aquilegia* 'Dorothy Rose' at Walters Gardens, Zeeland, MI 2 WAT with Barricade 10 oz./ac (**A**), at 12 WAT with Barricade 10 oz./ac (rating 1.8) (**B**) compared to the Control at 12 WAT (rating 1.8) (**C**).

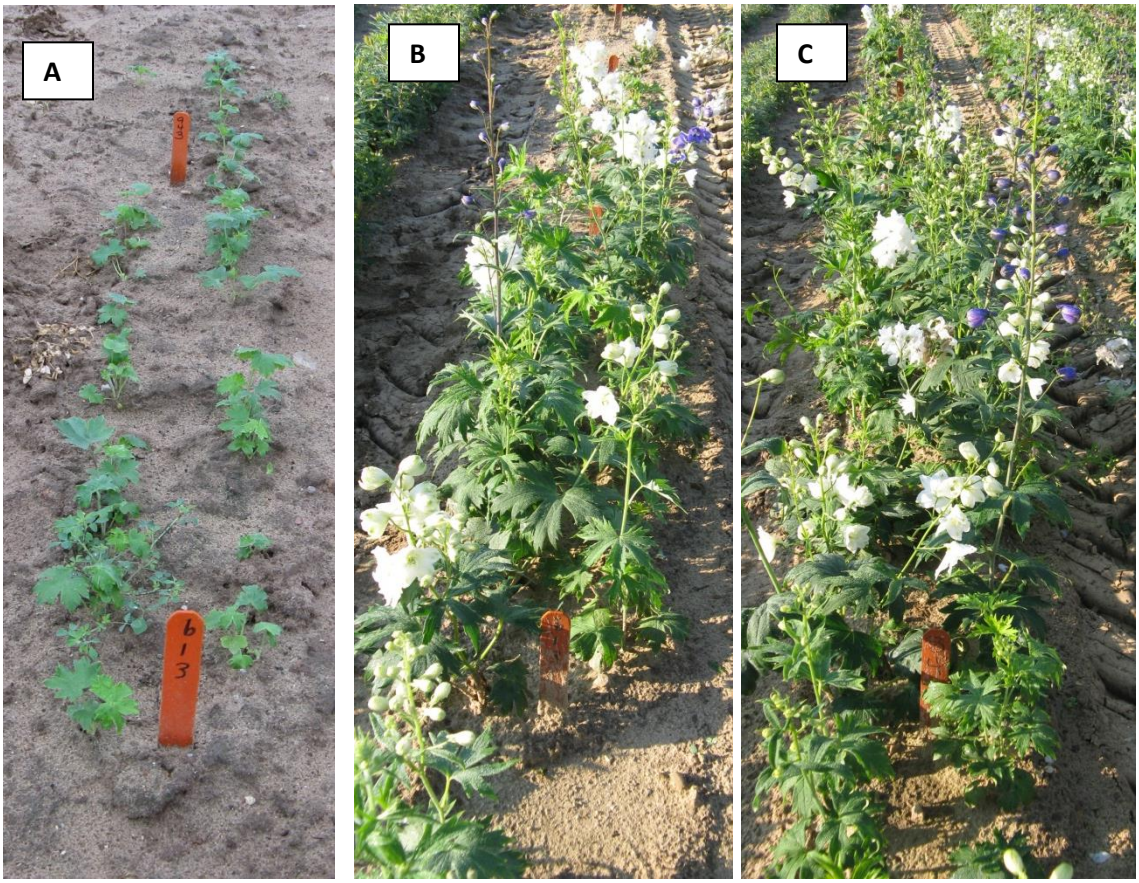


Fig. 10. A, B and C. (Above) Stage 2 *Delphinium* 'Round Table Mix' at Walters Gardens. Stake in foreground marks the beginning of the Pendulum 2G at 100 lb./ac (rating of 5) and stake in background the weedy check (rating 4.5) at 6 WAT **(A).** *Delphinium* 'Round Table Mix' at Walters Gardens 12 WAT with Pendulum 2G at 100 lb./ac (rating 6.5) **(B)** compared to untreated weeded control **(C)** (rating 3.5).

Fig. 11. (Left) Stage 1 Swamp milkweed, *Asclepias incarnata* 'Cinderella, at Walters Gardens 6 WAT. Stake in foreground is start of the untreated check (rating 2.5) and the stake in start of the background is the start of Jewel at 50 lb./ac (rating 9.8). Note the herbicide leaching that has occurred from the Jewel plot into the buffer between the plots (causing death) and into the control plot (especially along the right row nearest the tire tract, denoted by a black line).

Table 1. Stage 1, phytotoxicity of several ornamental herbicides on selected herbaceous perennials at Walters Gardens Zeeland, MI.

Penstemon coccineas

Treatment	Rate/ac	2 WAT[z]	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
Treflan	1 qt	9.5 [y x]	8.0	7.5 *	7.8 **	7.5	8.0 **
Treflan	1 pt	9.8	7.5	6.8	6.5	6.5	6.5 *
Barricade 4FL	10 oz	9.3	7.3	7.8 *	8.8 **	5.8	8.5 **
Barricade 4FL + Treflan	5 oz + 1 pt	9.8	8.5	9.0 **	8.5 **	8.5 *	8.8 **
Biathlon	50 lb	10.0	10.0 **	9.8 **	9.8 **	9.8 **	9.8 **
Pendulum 2G	100 lb	9.5	9.5 **	9.0 **	8.5 **	8.3 *	8.0 **
Jewel	50 lb	10.0	10.0 **	10.0 **	10.0 **	10.0 **	10.0 **
Untreated weeded	--	9.3	5.8	4.0	4.0	3.8	3.3
Untreated	--	9.8	7.3	6.0	5.3	5.0	2.8

Asclepias incarnata

Treatment	Rate/ac	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
Treflan	1 qt	9.3 **	4.0	4.8	5.0 *	4.5	5.3
Treflan	1 pt	8.3	4.0	2.5	2.0	2.5	2.8
Barricade 4FL	10 oz	8.3	3.5	4.0	3.0✓ [w]	3.3	**4.3**
Barricade 4FL + Treflan	5 oz + 1 pt	8.3	4.3	5.0	5.0	4.8	**6.5** **
Biathlon	50 lb	9.5 **	4.0	4.3	4.4	3.0	3.5
Pendulum 2G	100 lb	8.0	7.0 **	9.0 **	9.8 **	9.5 **	9.3 **
Jewel	50 lb	10.0 **	9.5 **	9.8 **	9.5 **	9.8 **	9.5 **
Untreated weeded	--	6.3	1.0	1.3	1.0	1.0	1.3
Untreated	--	7.8	0.5	2.5	2.5	1.8	3.0

z = weeks after treatment (WAT)

y = 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 untreated weeded control based on Dunnett's t-test (α = 0.10 and 0.05, respectively

w = ✓ indicates treatment was reapplied on this date

Table 2. Stage 2, phytotoxicity of several ornamental herbicides on selected herbaceous perennials at Walters Gardens, Zeeland, MI.

Aquilegia 'Dorothy Rose'

Treatment	Rate/ac	2 WAT[z]	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
Treflan	1 qt	8.2[yx]	9.0 **	8.3 **	8.0 **	8.3 **	8.5 **
Treflan	1 pt	7.8	7.8 **	4.8 *	5.3 **	6.8 **	5.5 **
Barricade 4FL	10 oz	8.0	1.3	1.0	1.2✓[w]	2.3	1.8
Barricade 4FL + Treflan	5 oz + 1 pt	8.5	8.0 **	5.5 **	5.5 **	5.8 **	5.3 **
Biathlon	50 lb	9.8 **	9.8 **	7.0 **	9.8 **	9.8 **	9.8 **
Pendulum 2G	100 lb	8.3	5.5 **	6.0 **	7.0 **	7.0 **	6.8 **
Jewel	50 lb	9.5 **	6.3 **	4.8 *	5.3 **	7.0 **	5.5 **
Untreated weeded	--	7.8	0.0	0.3	0.3	0.3	0.0
Untreated	--	8.8 *	2.3	2.3	1.8	2.3	1.8

Delphinium 'Round Table Mix'

Treatment	Rate/ac	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
Treflan	1 qt	8.3	8.0 **	7.8 **	8.5 **	8.3 **	8.0 **
Treflan	1 pt	7.5	5.3	4.3	4.3	5.3	6.0
Barricade 4FL	10 oz	7.8	7.0 **	4.0	6.3✓	5.5	6.3
Barricade 4FL + Treflan	5 oz + 1 pt	8.3	7.0 **	6.0	7.3 **	7.5 **	7.0 *
Biathlon	50 lb	10.0 **	10.0 **	10.0 **	10.0 **	10.0 **	10.0 **
Pendulum 2G	100 lb	7.8	5.0	5.0	5.8	6.0 *	6.5
Jewel	50 lb	9.8 **	8.8 **	7.5 **	8.0 **	8.8 **	8.5 **
Untreated weeded	--	7.3	3.3	2.8	2.8	2.8	3.5
Untreated	--	8.0	5.0	4.5	4.5	3.8	4.5

z = weeks after treatment (WAT)
y = 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 untreated weeded control based on Dunnett's t-test (α = 0.10 and 0.05, respectively
w = ✓ indicates treatment was reapplied on this date

Table 3. Efficacy of several ornamental herbicides in liner beds at Walters Gardens, Zeeland, MI and New Life Nursery, Holland, MI

		Walters Gardens[z]				New Life[y]			
Treatment	Rate/ac	4 WAT[x]		6 WAT		4 WAT		6 WAT	
Treflan	1 qt	9.6[wv]	abc	9.2	abc	8.3	b	7.8	bc
Treflan	1 pt	9.6	abc	9.2	abc	7.5	b	7.6	cd
Barricade 4FL	10 oz	9.3	c	8.8	cd	8.0	b	7.6	cd
Barricade 4FL + Treflan	5 oz + 1 pt	9.6	abc	9.1	abcd	7.8	b	7.3	cd
Biathlon	50 lb	9.8	a	9.4	ab	8.5	b	8.4	ab
Pendulum 2G	100 lb	9.8	a	9.5	a	8.3	b	7.3	cd
Jewel	50 lb	9.7	ab	9.6	a	9.8	a	8.9	a
Untreated weeded	--	9.3	c	8.6	d	6.3	c	7.0	d
Untreated	--	9.4	bc	8.9	bcd	6.0	c	6.1	e

z = treatment means were averaged over liner beds of *Papaver, Aquilegia, Delphinium, Penstemon, Asclepias and Rhubarb* varieties

y = treatment means were taken from a *Syringa* liner bed

x = weeks after treatment

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

v = treatment means followed by the same letter in the same column are not significantly different, based on ls means ($\alpha = 0.05$)

The Stage 2 trials at New Life on woody plant seedlings had very different results than on the herbaceous seedlings at Walters Gardens. At 12 WAT, all treatments were providing low phytotoxicity on the *Juglans* and the *Quercus* (Table 4). The damage on these species had been either passing on the *Quercus* as with Treflan 1 qt./ac and Biathlon 50 lb./ac (Fig. 12 A and B, respectively) or non-existent with the *Juglans* (Table 4).

Averaged across all dates of evaluation, there were four treatments that provided commercially acceptable phytotoxicity with the Lilacs, Treflan 1pt./ ac, Treflan 1qt./ ac, Barricade 10 oz./ ac and Pendulum 2G (data not shown). At 8 WAT the Barricade and the Pendulum picked up phytotoxicity and exceeded commercially acceptable (Table 4). The best treatments for reduced phytotoxicity at New Life Nursery for Lilac were Treflan 1pt./ac and Treflan 1 qt./ac. (Fig. 13 A and Fig. 14 B, respectively). Jewel at 50 lb./ac was the most phytotoxic (Fig. 13 and 14 D).

The un-weeded control at New Life had significantly lower efficacy than Treflan 1pt./ ac, Treflan 1qt./ ac, Barricade 10 oz./ ac and Pendulum 2G (Fig. 14 A, B and C and Table 3). At New Life, managers were also concerned about weeds, so we ended the efficacy trial at 6 WAT, due to weeding (Table 3). Also, the people weeding picked out the plot markers at 8 WAT in the lilac and thus ended the trial. We recommend that trials on woody plant seedlings be continued with Treflan, Barricade and Pendulum 2G at lower rates in further studies and on more species. The low phytotoxicity levels

demonstrated with these products are of tremendous value to the forest seedling industry.

Table 4. Phytotoxicity of several ornamental herbicides in Stage 2 (emerged two to six weeks) seedling beds of *Syringa vulgaris*, *Juglans nigra,* and *Quercus macrocarpa*

Syringa vulgaris

Treatment	Rate	2 WAT[z]	4 WAT	6 WAT	8 WAT
Treflan	1 qt	2.0[yx]	1.0	0.8	2.0
Treflan	1 pt	2.8	1.0	0.8	1.0
Barricade 4FL	10 oz	3.5	0.5	1.5	3.5 **
Barricade 4FL + Treflan	5 oz + 1 pt	4.0	3.0 **	1.8 *	4.0 **
Biathlon	50 lb	5.0 *	2.0 **	2.0 **	3.5 **
Pendulum 2G	100 lb	3.8	2.0 **	1.0	4.3 **
Jewel	50 lb	8.3 **	5.3 **	5.5 **	6.3 **
Untreated weeded	--	2.0	0.0	0.0	0.0
Untreated	--	1.5	0.0	0.0	1.0

Juglans nigra

Treatment	Rate	2 WAT	4 WAT	6 WAT	8 WAT
Treflan	1 qt	1.0	0.0	1.0	0.5
Treflan	1 pt	0.8	0.3	0.8	1.3
Barricade 4FL	10 oz	0.5	0.5	0.3	0.5
Barricade 4FL + Treflan	5 oz + 1 pt	0.8	0.3	0.5	0.3
Biathlon	50 lb	0.3	0.0	0.3	0.3
Pendulum 2G	100 lb	0.0	0.3	0.5	1.0
Jewel	50 lb	0.3	0.3	0.3	0.5
Untreated weeded	--	0.3	0.3	1.5	0.8
Untreated	--	0.8	0.0	1.3	1.3

Quercus macrocarpa

Treatment	Rate	2 WAT	4 WAT	6 WAT	8 WAT
Treflan	1 qt	2.8	0.8	1.8	2.8
Treflan	1 pt	1.5	0.3	0.5	0.0
Barricade 4FL	10 oz	1.3	0.3	0.5	0.0
Barricade 4FL + Treflan	5 oz + 1 pt	2.3	0.5	0.5	0.8
Biathlon	50 lb	2.0	0.5	2.0	1.0
Pendulum 2G	100 lb	0.3	0.0	0.8	0.0
Jewel	50 lb	1.3	0.5	1.5	0.3
Untreated weeded	--	0.0	0.0	0.0	0.0
Untreated	--	0.3	0.5	0.0	0.0

z = weeks after treatment (WAT)

y = 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 untreated weeded control based on Dunnett's t-test (α = 0.10 and 0.05, respectively

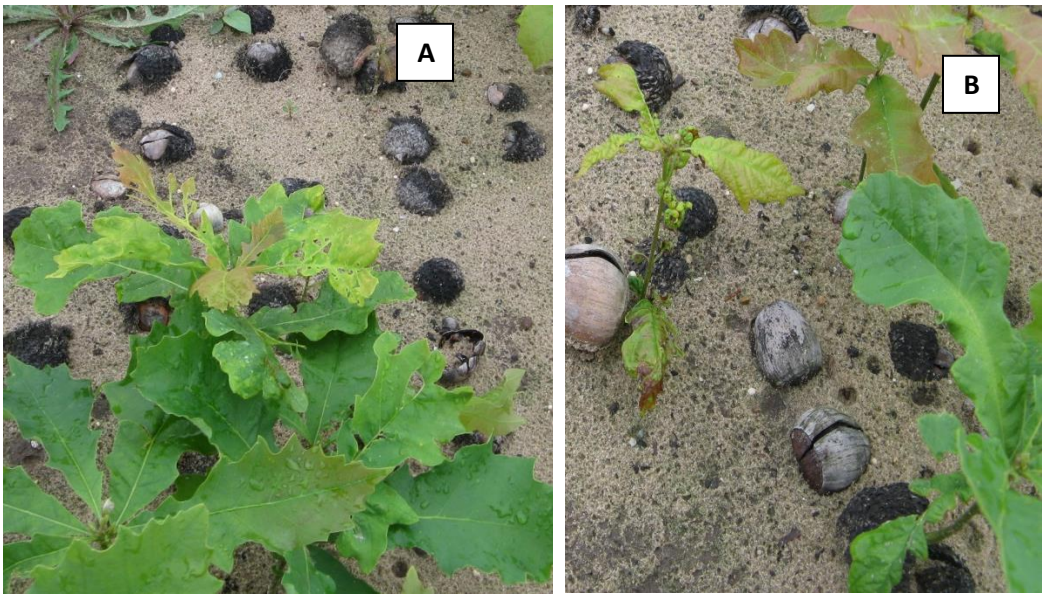


Fig. 12. A and B. Damage on Stage 2 Oaks at New Life Nursery, Holland, MI from Treflan 1 qt./ ac (**A**) and Biathlon 50 lb./ac (**B**) 2 WAT. By 8 WAT, all the oaks had grown out of any phytotoxicity.

Fig. 13. A, B, C and D. Stage 2 *Syringa vulgaris* seedlings at New Life Nursery, Holland, MI 2 WAT with Treflan 1 qt./ac (**A**), Barricade 10 oz./ac (**B**) versus the weeded control (**C**) and the most phytotoxic treatment Jewel 50 lb./ac (**D**).

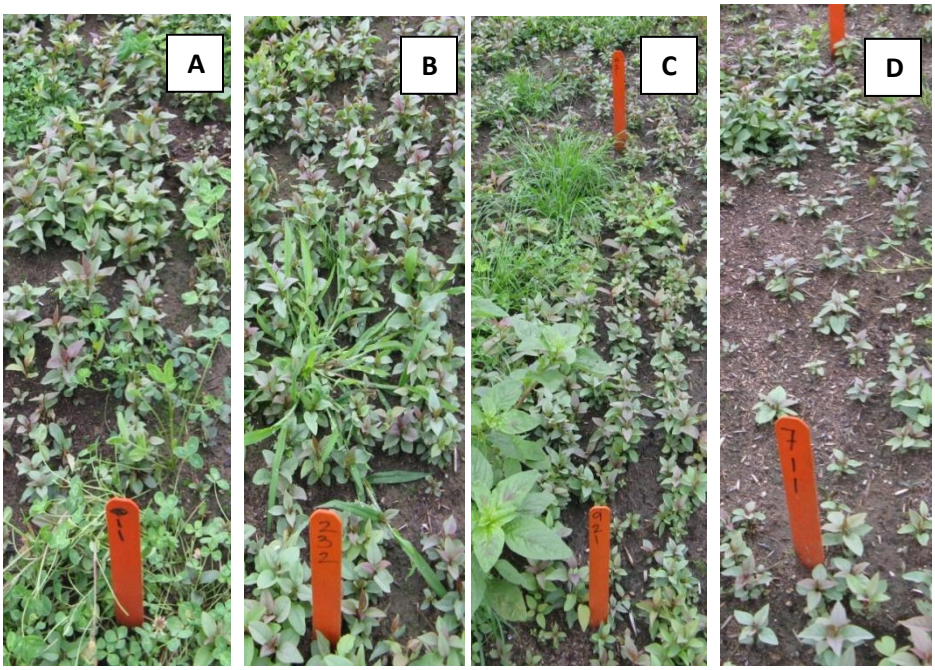


Fig. 14. A, B, C and D. Stage 2 *Syringa vulgaris* seedlings at New Life Nursery, Holland, MI 6 WAT with Treflan 1 qt./ac (**A**), Treflan 1 pt./ac (**B**) versus the un-weeded control (**C**) and the most phytotoxic treatment Jewel 50 lb./ac (**D**). Note more weeds in **B** versus **A** but far less than in **C**.

Table 5. Phytotoxicity of several ornamental herbicides on Stage 3 *Picea abies* seedlings at New Life Nursery, Holland, MI.

Treatment	Rate	2 WAT[z]	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
FreeHand	150 lb	0.8[yx]	0.0	0.8	1.8	1.8	1.5
Marengo	50 lb	0.0	0.0	0.8	0.8	1.3	1.3
Biathlon	150 lb	1.5	0.0	0.3	0.3	0.3	0.3
Pendulum 2G	100 lb	0.8	1.5 **	1.8	2.8 **	3.0 **	2.3 *
Biathlon	75 lb	2.5	0.0	0.5	0.8	0.5	0.3
Marengo	100 lb	1.0	1.0	1.5	3.0 **	2.8 **	2.8 **
Jewel	100 lb	0.5	0.0	0.5	1.0	0.0	0.0
Barricade + Treflan	5 oz + 1 qt	2.0	0.8	1.3	2.5✓w *	2.0	2.8 **
Tower + Pendulum	1 qt + 1 qt	0.8	0.3	0.3	0.8✓	1.3	1.8
Gallery + Barricade	0.65 lb +10 oz	1.0	0.5	1.5	1.8✓	1.5	1.3
Untreated	--	0.5	0.0	0.3	0.0	0.0	0.0
Untreated weeded	--	0.5	0.0	0.3	0.8	0.0	0.3

z = weeks after treatment

y = 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 untreated weeded control based on Dunnett's t-test (α = 0.10 and 0.05, respectively.

w = ✓ indicates treatment was reapplied on this date

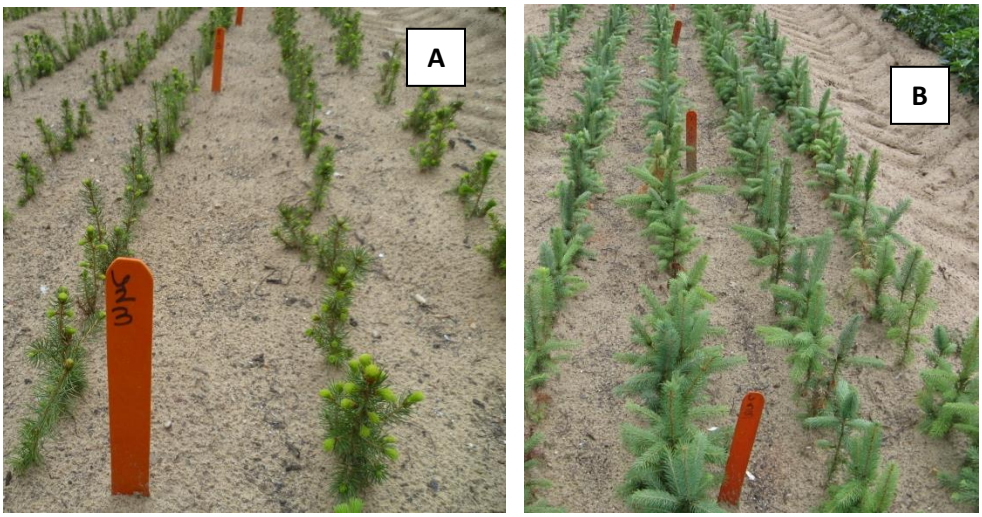


Fig. 15. A and B. Stage 3 *Picea abies* seedlings at New Life Nursery, Holland, MI 2 WAT with Marengo G 100 lb./ac (**A**) and at 6 WAT (**B**). At 2 WAT, there was no phytotoxicity, but at 6 WAT, there was phytotoxicity greater than the control but still commercially acceptable (2.8 rating).

Fig. 16. A and B. Stage 3 *Picea abies* seedlings at New Life Nursery, Holland, MI 2 WAT with Barricade + Treflan (5 oz./ac + 1 qt./ac **(A)** (above) showing no injury and at 6 WAT **(B)** (left). By 6 WAT, there was phytotoxicity greater than the control but still commercially acceptable (2.8 rating).

Problems and Delays:

Our objective in addressing the issue of Methyl Bromide (MeBr) loss in this 12-25-B-1468 project was to test two MeBr alternative fumigants, Chloropicrin and Basamid with supplemental low-rates of preemergence herbicides for weed control in forest and herbaceous seedling nurseries in MI. However, before beginning the studies, in the spring of 2013, additional regulations were placed on the use of Chloropicrin in 2012 that made the use of this product impossible. Chloropicrin is a powerful tear gas; it is one of the most toxic to insects of the fumigants. Chloropicrin is a highly hazardous material and can be handled and used only by those who are specially trained. The additional restrictions placed on Chloropicrin in 2012 also made this MeBr alternative extremely restrictive for seedling growers to consider. The industry had no desire to test Basamid (e.g. metam-sodium and dazomet) due to inconsistent pest management performance in previous studies. Since 2005, forest nurseries and other seedling growers have made nominations for critical use of MeBr in those nurseries where registered alternatives are not effective or sufficiently tested to enable commercial use. The use of MeBr is considered critical where alternatives are not suitable because of regulatory, economic, or technical constraints. Instead of supplementing the use of low rates of preemergence herbicides with Basamid or Chloropicrin (as planned) the herbicides in this project were tested as supplements to MeBr applications. All except *Picea abies* fields at New Life in this study were treated with MeBr either in the fall or spring before planting.

B) Liner Bed Pre- and Post- Emergence Herbicides for Controlling Creeping Yellow Field Cress (*Rorippa sylvestris*):

Background. Creeping yellow cress also known as Kik and yellow cress, is a major nuisance weed in nurseries. *Rorippa* is a member of the mustard family and forms dense stands. Creeping yellow cress has roots that spread widely and can be propagated by small pieces of the roots. Stands of creeping yellow cress cover the ground and choke the life out of any plants around. *Rorippa sylvestris* is the most rapidly dispersing invasive weed in MI and most efforts to control its spread have been ineffective.

Activities Performed:

Two trials were conducted in Berry Family Nurseries, Grand Haven, MI fields, one as a preemergence study, and the other a postemergence study. Evaluations for the pre- and post- emergence trials consisted of visual ratings of weed control and phytotoxicity to crop species. Visual ratings of weed control were based on a 0-10 scale with 0 being no control and 10 perfect control with ≥7 commercially acceptable. Visual

ratings of phytotoxicity were based on a scale of 0-10 with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable. Data was analyzed using SAS® GLM. Phytotoxicity effects of treatments were compared to the controls using Dunnett's t-test (α = 0.10 and 0.05). Efficacy treatments were compared to each other using least significance difference (ls means).

The preemergence trial was started on April 4, 2013 in a liner bed of Common purple lilacs (*Syringa vulgaris*) that had not yet broken dormancy and were approximately 6" (15 cm) tall. Weather at time of application was sunny, approximately 40 °F with no dew present. Six herbicides and one herbicide + mulch were compared to an untreated control. Herbicides included Corsair (chlorsulfuron, Nufarm Americas, Inc.) at 5.3 oz/ac, Certainty (sulfosulfuron, Monsanto Corp.) at 1 oz/ac, SedgeHammer (halosulfuron, Gowan Co.) at 2 oz/ac, Lontrel (clopyralid, Dow Agro Sciences) at 1 pt/ac, V-10336 (no trade name yet, flumioxazin + pyroxasulfone, Valent U.S.A.) at 15 oz/ac, and Diuron 80 (diuron, Drexel, Inc.) at 3 lb./ac. For the herbicide + mulch treatment, Casoron CS (dichlobenil, Chemtura Corp.) at 3 gal/ac was applied just prior to application of 2 inches of pine nugget mulch. The herbicides were applied with a CO_2 backpack sprayer delivering 25 gal/ac. The creeping yellow cress was just beginning to green below the soil surface (Fig 17). Plots were approximately 3' x 3' with approximately 1-2' between plots.

Fig 17. Creeping yellow cress at time of application at Berry Family Nursery on April 4, 2013.

The postemergence trial treatments were also conducted on Common purple lilacs (*Syringa vulgaris*); however, unlike the preemergence trial, the lilacs had broken dormancy at the time of application and were approximately 7" (17.5 cm) tall. Applications were made on May 16, 2013. Weather was approximately 65 °F, 5 mph wind, sunny. Herbicides included: Corsair (chlorsulfuron, Nufarm Americas, Inc.) at 5.3 oz/ac, Certainty (sulfosulfuron, Monsanto Corp.) at 1 oz/ac, SedgeHammer

(halosulfuron, Gowan Co.) at 2 oz/ac, Lontrel (clopyralid, Dow Agro Sciences) at 1 pt/ac, V-10336 (no trade name yet, flumioxazin + pyroxasulfone, Valent U.S.A.) at 15 oz/ac, Diuron 80 (diuron, Drexel, Inc.) at 3 lb/ac, Classic (chlorimuron, Dupont Crop Protection) at 2/3 oz/ac, and Marengo SC at 9 oz/ac. All treatments included the addition of nonionic surfactant at 0.25% v/v. Herbicides were applied with a CO_2 backpack sprayer delivering 25 gal/ac.

Results, Accomplishments, Conclusions and Recommendations:

Preemergence trial. In the weeks following the preemergence applications, there was considerable rainfall in Grand Haven, MI. Rainfall in 2013 set a new record for April, measuring 11.10", 7.75" more than usual, and 8.12" more than last year (2.98"). 11.10" total rainfall broke the previous April record of 8.29" set in 1909. April 2013 is now the third wettest month on record after June 1892 (13.22") and September 1986 (11.85") in Grand Haven. In April 2013, 18 days received measurable precipitation, five days more than average. This abnormally high rainfall caused leaching of the treatments into adjacent plots. Some of the control plots demonstrated higher phytotoxicity than normal (Fig. 18, Table 6).

Fig. 18. (Left) Untreated control showing phytotoxicity due to herbicide leaching from adjacent treatments in Lilacs at Berry Family Nurseries, Grand Haven, MI

Corsair, Certainty, and SedgeHammer provided perfect efficacy through 8 WAT. Corsair provided the highest efficacy at 11 WAT and was the only treatment that was significantly better than the untreated controls (Table 6). Lontrel provided little to no preemergence efficacy for creeping yellow cress. This is not surprising, as Lontrel is not labeled as a preemergence herbicide. V-10336 provided excellent control through 5 WAT; however, by 6 WAT, efficacy decreased to a rating of 5.5, only slightly better than untreated (Table 6).

Phytotoxicity varied among the treatments (Table 5). Corsair, although extremely efficacious, was also extremely phytotoxic. BY 11 WAT, all the lilacs were dead in the Corsair plots (Table 5). V-10336 at 15 oz/ac was also very phytotoxic to lilac by 11

WAT (Table 5). V-10336 became more phytotoxic as the trial progressed (Table 5), even though it was applied during dormancy. Casoron also became increasingly phytotoxic over time and significantly so by 11 WAT (Table 5). We recommend Certainty and SedgeHammer be used in further studies for preemergence control of *Rorippa* in lilacs and other species as both showed promise in efficacy and reduced phytotoxicity.

Table 5. Phytotoxicity to *Syringa vulgaris* from selected preemergence applications at Berry Family Nurseries, Grand Haven, MI.

Phytotoxicity

Treatment	Rate/ac	4 WAT[z]	5 WAT	6 WAT	8 WAT	11 WAT
Corsair	5.3 oz	7.5[yx]	8.3 **	9.0 **	9.3 **	10.0 **
Certainty	1 oz	4.5	4.5	5.5	6.5	5.0
SedgeHammer	2 oz	5.3	5.3	6.3 *	6.0	4.8
Lontrel	1 pt	3.3	3.5	4.8	4.5	4.3
V-10336	15 oz	3.8	4.3	5.0	7.3	7.0 **
Diuron	3 lb	2.0	3.0	4.5	5.8	5.8
Casoron + PN	3 gal	3.5	4.8	5.3	6.3	8.0 **
Untreated	--	2.3	1.5	2.5	3.5	2.5

Table 6. Efficacy in *Syringa vulgaris* fields for *Rorippa sylvestris* (creeping yellow cress) from selected preemergence applications at Berry Family Nurseries, Grand Haven, MI.

Creeping yellow field cress control

Treatment	Rate/ac	4 WAT	5 WAT	6 WAT	8 WAT	11 WAT
Corsair	5.3 oz	9.0[wv] a	9.3 a	10.0 a	10.0 a	9.8 a
Certainty	1 oz	10.0 a	9.5 a	10.0 a	10.0 a	8.8 ab
SedgeHammer	2 oz	10.0 a	9.8 a	10.0 a	9.8 a	8.5 abc
Lontrel	1 pt	2.8 c	3.3 d	6.8 bcd	7.0 bc	6.8 bc
V-10336	15 oz	9.5 a	7.5 ab	5.5 cd	2.5 d	5.8 c
Diuron	3 lb	4.3 bc	6.3 bc	7.5 bc	7.8 ab	8.3 abc
Casoron + PN	3 gal	6.3 b	8.0 a	7.8 ab	7.0 bc	9.0 ab
Untreated	--	3.5 c	4.0 cd	5.0 d	4.8 cd	6.0 bc

z = weeks after treatment

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

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

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

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

Postemergence trial. Although April had record rainfall, May 2013 had normal rainfall. All the rains of April did bring “lots of flowers” and weeds for this postemergence trial. Unfortunately, all of the treatments caused greater phytotoxicity than the control (Table 7). Lontrel, however, was the only treatment where the injury was near commercially acceptable (Table 7, Fig. 19). More work and trials need to be conducted to determine the best option for control of creeping yellow field cress in field situations.

Fig. 19. (Left). Injury on lilac at 11 WAT from Lontrel applied postemergence on May 16, 2013 at Berry Family Nurseries, Grand haven, MI. Note stunting and leaf distortion typical of Lontrel injury.

Excellent efficacy was achieved with six of the eight treatments; Marengo SC and Lontrel were the only two treatments not providing acceptable control at 5 WAT (Table 8). Marengo was significantly better than the control at 2 WAT, but not 5 WAT (Table 8). Lontrel, although not commercially acceptable, provided better control than Marengo and the untreated plots and was similar to Diuron at 5 WAT (Table 8) Corsair, just like in the preemergence trial, provided the best control of *Rorippa* through 5 WAT (Fig. 20).

We recommend Lontrel be further studied for control of *Rorippa* as it was the only product to provide near acceptable phytotoxicity and some level of weed control. Although Lontrel’s efficacy was not as high as some of the other products, it seems to be the only one with promise. We recommend there be much more work and trials conducted to determine the best option for control of *Rorippa* in various liner bed species in MI due to the rapid dispersion of this weed.

Table 7. Phytotoxicity to *Syringa vulgaris* from selected postemergence herbicide applications at Berry Family Nurseries, Grand Haven, MI.

Treatment	Rate/ac	Phytotoxicity 2 WAT[z]		5 WAT	
Corsair	5.3 oz	6.0[yx]	**	9.8	**
Certainty	1 oz	4.8	**	6.3	**
SedgeHammer	2 oz	6.0	**	7.3	**
Classic	2/3 oz	6.5	**	8.8	**
Lontrel	1 pt	3.8	**	3.3	**
V-10336	15 oz	9.0	**	7.8	**
Diuron	3 lb	7.5	**	7.5	**
Marengo SC	9 oz	4.3	**	6.0	**
Untreated	--	1.0		0.8	

Table 8. Efficacy in *Syringa vulgaris* fields for *Rorippa sylvestris* (creeping yellow cress) from selected preemergence applications at Berry Family Nurseries, Grand Haven, MI.

Treatment	Rate/ac	Creeping yellow field cress control 2 WAT		5 WAT	
Corsair	5.3 oz	9.0[wv]	a	9.8	a
Certainty	1 oz	9.0	a	9.5	a
SedgeHammer	2 oz	8.8	ab	9.0	a
Classic	2/3 oz	9.0	a	9.5	a
Lontrel	1 pt	6.0	c	6.5	b
V-10336	15 oz	9.0	a	9.0	a
Diuron	3 lb	6.5	bc	7.8	ab
Marengo SC	9 oz	6.8	abc	5.5	bc
Untreated	--	3.0	d	2.3	c

z = weeks after treatment
y = Phytotoxicity ratings based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable
x = Treatment ratings followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)
w = Control ratings are based on a 0-10 scale with 0 being no control and 10 perfect control with ≥7 commercially acceptable
v = Treatment ratings followed by the same letter in the same column are not significantly different based on lsmeans (α = 0.05)

Fig. 20. (Left) Control of creeping yellow cress at Berry Family Nurseries, Grand Haven, MI at 11 WAT of Corsair postemergence on May 16, 2013. Although weed control is perfect, injury to the crop is also complete death (rating 9.8).

Targets: From our pre- project start surveys we found that liner bed growers in MI were using the following herbicides, Rout, Barricade, Snapshot, SureGuard, Pendulum, Round up, Goal, Tower, Lontrel and 2, 4-D. On average, they were spending $250.00/ac to hand weed problem areas with difficult weeds such as *Rorippa.* We had targeted to reduce their weed program cost by 30%. We accomplished this goal. The acceptable use of Lontrel in this study provided 35% control, thus reducing hand weeding costs by 35%.

Problems and Delays:

Between 5 and 6 WAT, in the preemergence study, Berry Family Nursery employees mistakenly went through the plots and applied glyphosate (Round up) as a directed spray onto the creeping yellow cress. This, plus the high rains of April, caused high phytotoxicity ratings in the untreated plots of the efficacy study (Table 6). However, differences could still be distinguished between treatments. Working at nursery sites is a great way to reach the industry with these trials; however, worker error always seems to be a problem.

In the original proposal, we were going to evaluate preemergence efficacy trials for mugwort (*Artemisia vulgaris* L), creeping yellow field cress (*Rorippa sylvestris)*, Red Stem Filaree (*Erodium cicutarium),* Wild Garlic *(Allium vineale)* and marestail *(Conyza canadensis).* In this project, we only did the *Rorippa*; however, we also did a postemergence trial. We used a broader range of pre- and post- emergence products than originally planned and it was the post- trial that accomplished our target.

C) Liverwort Control:

Background: Michigan propagation nurseries have severe issues with liverwort infestations in their nursery containers. Crop phytotoxicity occurs with current controls; alternative non-phytotoxic controls are critical. In previous Specialty Crop Block Grants (SCBGs) we have identified potential bio-rationale products for utilization in these MI nurseries; however, these nurseries also grow many new and unusual plants. Further evaluation of potential products on a range of new plant species and evaluation of new products suggested by IR-4 is required to keep these high value nurseries economically viable.

Activities Performed:

Trials were initiated in late February, 2013 at two Michigan nurseries to determine liverwort efficacy and ornamental phytotoxicity from selected herbicide treatments. Seven treatments were evaluated at Spring Meadow Nursery, Grand Haven, MI: SureGuard (flumioxazin, Valent U.S.A.) at 3 and 4 oz/ac, baking soda (for this treatment, Arm and Hammer, Church and Dwight Co, Inc.) at 2.24 g/ft^2, MilStop (Potassium bicarbonate, BioWorks, Inc.) at 2.24 g/ft^2, WeedPharm (Pharm Solutions, Inc.) at 10% v/v, Marengo SC (indaziflam, Bayer Crop Science) at 9 oz/ac, and the untreated control. Liquid applications were applied with a CO_2 backpack type sprayer set to deliver 50 gal/ac with 8004 VS Teejet nozzles. Protocol required 100 gal/ac, so two passes were made to deliver the required volume. Species selected for phytotoxicity trials at Spring Meadow included *Hydrangea paniculata* 'Limelight', *Hibiscus* 'Satin blue', *Forsythia* 'Show off Sugar Baby', *Viburnum dentatum* 'Blue Muffin', and *Physocarpus* 'Summer Wine'. Reagent grade potassium bicarbonate (Sigma-Aldrich) at 2.24 g/ft^2 was also trialed at Spring Meadow, on one species, *Hydrangea paniculata* 'Limelight.' All species at Spring Meadow were just coming out of dormancy, i.e. bud swell. The *Physocarpus,* however, was more advanced with small leaves on the majority of plants. Four treatments were evaluated at Northland Farms Nursery, West Olive, MI: SureGuard at 4 oz/ac, MilStop at 2.24 g/ft^2, Marengo SC at 9 oz/ac and the untreated control. Species selected for phytotoxicity evaluations at Northland Farms included *Syringa* 'Miss Kim', *Cotoneaster apiculata*, *Euonymus* 'Blondie', *Syringa meyeri* 'Paliban', *Salvia* 'East Fryland', *Pachysandra* 'Green carpet', and *Vitis labrusca*. *Syringa* and *Vitis* were dormant; *Cotoneaster, Pachysandra,* and *Euonymus* were at bud swell; and *Salvia* was actively growing with rosettes of leaves approximately 3-4" in diameter at time of application.

Applications were applied on February 28, 2013 at both sites. Spring Meadow is a propagation nursery, so the environment was highly regulated. Northland Farms does

propagation but is not exclusively a propagation nursery. The first applications at Spring Meadow was made in a vented- roof greenhouse that was 60 °F with high humidity. At Northland Farms the first applications were made in a covered polyhouse at 45 °F and high humidity. SureGuard at 4 oz/ac and the WeedPharm at 10% v/v were reapplied on May 2, 2013 [8 WA1T (weeks after first treatment)] at Spring Meadow only in accordance with IR-4 protocols. Evaluations consisted of visual ratings of efficacy and phytotoxicity. Visual ratings of liverwort efficacy were based on a 0-10 scale with 0 being no control, 10 perfect control and ≥7 commercially acceptable. Visual ratings of phytotoxicity were based on a scale of 0-10 with 0 being no phytotoxicity, 10 death and ≤3 commercially acceptable.

Phytotoxicity. At Spring Meadow, SureGuard at 3 oz/ac caused some temporary injury but by 12 WAT all species were commercially acceptable (Table 9). The SureGuard at 4 oz/ac, on four of five species evaluated, caused greater phytotoxicity than commercially acceptable at 12 WAT (Table 9). However, the SureGuard 4 oz.ac injury occurred after the first application and persisted as delayed growth compared to the control. All five species had commercially acceptable injury at 8 WAT before reapplication. The second application, at 4 oz/ac SureGuard, caused significantly more injury than the controls (Fig. 21 A and B) (Table 9). SureGuard injury on actively growing plants is well documented and our results concur. *Physocarpus*, which was leafed out at the first application, also indicates SureGuard needs to be applied dormant or just at bud-break to prevent injury (Table 9). The first application of Marengo also caused significant delays in bud break with *Hibiscus, Forsythia,* and *Viburnum.* However the impact was more severe and longer term on *Hydrangea* (Fig. 22), up to 8 WAT with *Hydrangea* (Table 9) and through to 12 WAT with *Physocarpus* (Table 9). Marengo also impacted the roots of *Hibiscus* causing a significant reduction in root development at 6 WAT (Fig. 23) and was gone by 9 WAT (Table 9). WeedPharm was not injurious when applied at bud swell. WeedPharm applied to active growth ex. *Physocarpus* initially, or as a second application (Fig. 24), to other species did cause significant injury (Table 9). MilStop and baking soda were not injurious on any species. Potassium bicarbonate reagent, which was applied once at a later date on *Hydrangea,* caused significant leaf burn and injury. However, by 9 WAT the injury had decreased to commercially acceptable (Table 9).

Phytotoxicity at Northland Farms used only the 4 oz/ac rate of SureGuard and as at Spring Meadow it caused some delay in bud break and injury (Table 10). However, only *Pachysandra* by 8 WAT, had injury that was greater than commercially acceptable (Table10, Fig. 25). Bud break occurred much later at Northland Farms as the plants were in unheated polyhouses. All treatments at Northland were applied later and were not evaluated as long (Table 10). SureGuard 4 oz/ac on *Salvia* did cause initial burn

and stunting (Fig. 26) that decreased to commercially acceptable by 8 WAT (Table 10). The Marengo also delayed bud break and growth, but not to the extent of the SureGuard. *Cotoneaster* had the most injury from Marengo (Table 10 and Fig. 27).

Efficacy. At Spring Meadow, all treatments provided some level of control; however, baking soda, MilStop, and K-bicarbonate all failed to provide commercially acceptable control at any date (Table 11). The MilStop was applied at ½ the rate of 2012 trials when it was exceptional in its control. SureGuard 3 oz (Fig. 28) and 4 oz/ac, and WeedPharm provided excellent control of liverwort throughout the experiment (Table 11). However, if the Weed Pharm had not been reapplied at 8 WAT, its control would not have been commercially acceptable. At 6 WAT WeedPharm efficacy was decreasing (Fig. 29) and was significantly worse than the other two treatments listed above and the control. Even though the 4 oz/ac rate was reapplied at 8 WAT, the 3 oz/ac rate clearly suggested it was sufficient for liverwort control out to 10 WAT combined across species (Table 11). The duration of control from 3 oz/ac rate did seem dependent on the level of infestation at time of application. Some species that had very high initial infestations of liverwort were waning in control at 6 WAT (Fig. 28) and 8 WAT(data not shown). Marengo surprisingly provided excellent control of liverwort throughout the trial, although death of the liverwort was slow (Table 11). The MilStop did provide some efficacy, but not commercially acceptable. Also the MilStop control was achieved quickly after application and decreased over time.

At Northland Farms, the environment was much different than at Spring Meadow and efficacy was not as high with SureGuard at 4 oz/ac, MilStop, or Marengo compared to Spring Meadow (Tables 12 and 11, respectively). Also there was less liverwort present at Northland Farms, which is evident with the control ratings (Tables 12) versus (Table 11). MilStop and Marengo (Fig. 27) did achieve significantly efficacy than the untreated controls (Table 12). Perhaps the lack of efficacy at Northland was due to the cooler environment at this location.

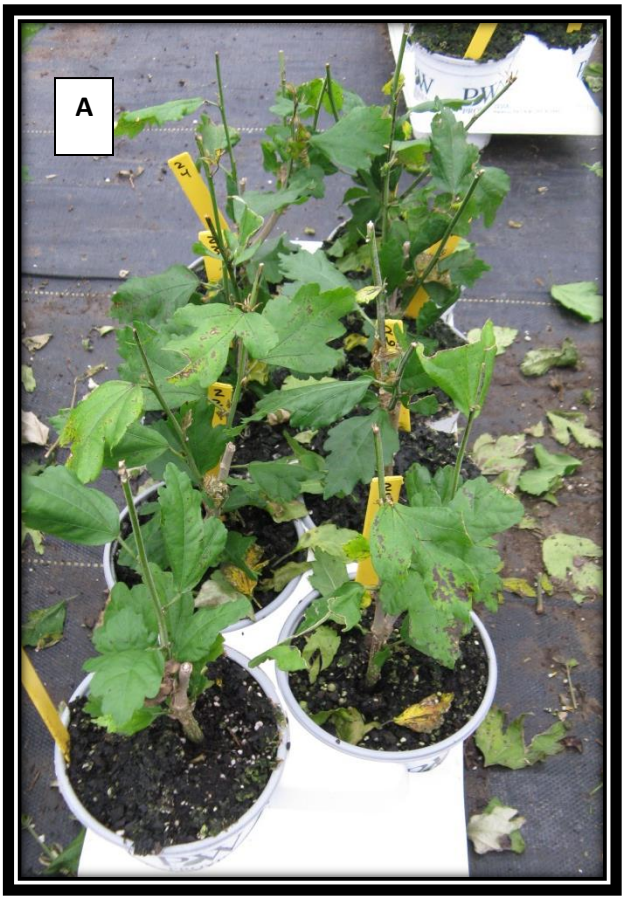


Fig. 21 A and B. (Left) SureGuard 4 oz/ac on Hibiscus at Spring Meadow Nursery 9 WAT with greater than commercially acceptable injury (phytotoxicity 3.9 rating). The first application was Feb. 28, 2013 the second application was at 8 WAT or one week before photo **(A)**. (Below) Hibiscus control at 9 WAT (rating 0) (**B**).

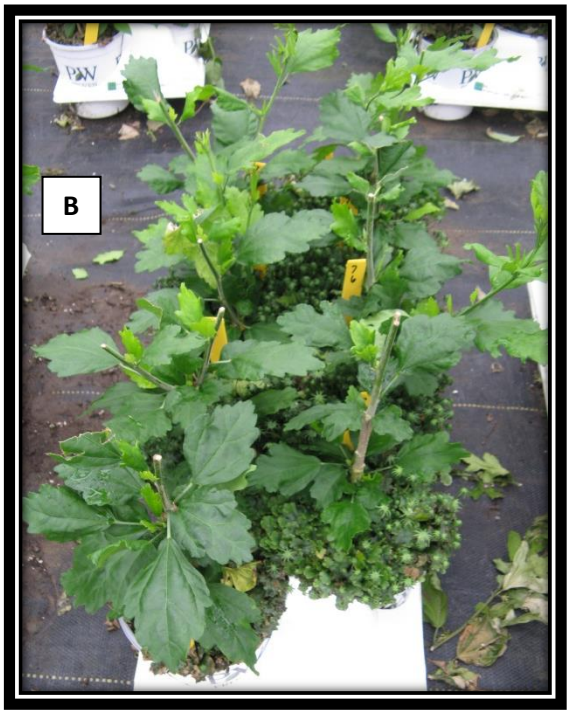


Fig. 22. (Left) Injury on *Hydrangea paniculata* caused by Marengo SC at 3 WAT (phytotoxicity rating 6). Many of the buds failed to emerge and the plants were retarded versus the control plants.

Fig. 23. (Left). *Hibiscus* 'Satin blue' at Spring Meadow Nursery, Grand Haven, MI, 6 WAT with (Left to right) Marengo 3SC (phytotoxicity 2.2 rating), Control (O rating), and SureGuard 3 oz/ac (0.9 rating). Note reduction in root growth in the Marengo #SC versus the SureGuard 3 oz/ac.

Fig. 24. (Right) *Hibiscus* 'Satin blue' at Spring Meadow Nursery, Grand Haven, MI, 9 WA1T or 1WA2T WeedPharm (3.1 phytotoxicity rating). Note loss of terminal growth.

Fig. 25. (Left) Pachysandra 'Green Carpet' at Northland Farms, West Olive, MI Control (left) at 8 WAT (phytotoxicity rating 0) versus treated with SureGuard 4 0z/ac (right) (rating 3.8).

Fig. 26. (Above) *Salvia* ‘East Fryland’ at Northland Farms, West Olive, MI at 4 WAT with SureGuard 4 oz/ac (left) (phytotoxicity rating 3.5) versus control (right) (rating 0).

Fig. 27. (Above) *Cotoneaster apiculata* at Northland Farms, West Olive, MI applied with Marengo 3 SC (left) (phytotoxicity rating 1) versus Control at 4WAT (rating 0).

Fig. 28. (Above) *Physocarpus* 'Summer Wine' at Spring Meadow Nursery, Grand Haven, MI, 6 WAT with SureGuard 3 oz/ac (efficacy 9.6 rating).

Fig. 29. (Above) *Hydrangea paniculata 'Limelight'* at Spring Meadow Nursery, Grand Haven, MI, 6 WAT with WeedPharm (Left) (efficacy rating 7.9) compared to control (right) (efficacy rating 0). Note the liverwort is starting to reemerge following the first application of WeedPharm shown with red lines.

Table 9. Phytotoxicity on ornamentals at Spring Meadow Nursery, Grand Haven, MI with selected products.

Hydrangea paniculata 'Limelight'

Treatment	Rate	1 WAT[z]	2 WAT	4 WAT	6 WAT	8 WAT	9 WAT	10 WAT	12 WAT
SureGuard	3 oz/ac	0.3[yx]	0.0	0.0	0.6	0.0	1.0	0.0	0.0
SureGuard	4 oz/ac	0.1	0.2	0.0	0.0	0.0✓	5.6 **	4.9 **	2.7 **
Baking Soda	2.2 g/ft^2	0.0	0.1	0.4	1.0	0.0	0.6	0.0	0.5
Milstop	2.2 g/ft2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WeedPharm	10% v/v	0.0	0.1	1.8	0.6	0.0	3.4 **	3.6 **	2.5 **
Marengo	9 oz/ac	3.3 **	6.0 **	7.0 **	4.0 **	4.4✓ **	1.2	0.9	1.3 **
Untreated	--	0.0	0.2	0.0	0.0	0.0	1.7	1.2	0.0

Hibscus syriacus 'Blue Satin'

Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT	9 WAT	10 WAT	12 WAT
SureGuard	3 oz/ac	1.2 **	0.9 **	1.3 **	0.9 **	1.7 **	0.0	0.0	0.0
SureGuard	4 oz/ac	2.1 **	2.1 **	2.1 **	1.2 **	1.5✓ **	3.9 **	4.3 **	5.5 **
Baking Soda	2.2 g/ft^2	0.2	0.0	0.1	0.3	0.3	0.0	0.0	0.0
Milstop	2.2 g/ft2	0.0	0.0	0.0	0.3	0.5	0.0	0.0	0.0
WeedPharm	10% v/v	0.1	0.2	0.4	0.9	1.1✓ **	3.1 **	1.5 **	2.5 **
Marengo	9 oz/ac	2.2 **	3.0 **	3.4 **	2.2 **	2.3 **	0.0	0.0	0.0 **
Untreated	--	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0

Forsythia 'Show Off Sugar Baby'

Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT	9 WAT	10 WAT	12 WAT
SureGuard	3 oz/ac	2.7 *	2.0	2.3	3.3	3.0	2.0	3.0	3.0
SureGuard	4 oz/ac	3.1 **	2.1	1.9	2.3	2.0✓	5.0	5.6	5.2
Baking Soda	2.2 g/ft^2	2.0	2.7	2.0	2.8	2.0	2.0	2.0	3.0
Milstop	2.2 g/ft2	0.0	0.2	0.6	3.0	5.2	4.0	4.2	4.7
WeedPharm	10% v/v	0.0	0.5	0.4	0.3	0.0✓	4.2	4.2	3.9
Marengo	9 oz/ac	2.1	1.2	0.3	0.2	0.0	0.0	0.0	0.0
Untreated	--	0.0	1.0	1.4	2.3	1.4	2.2	2.0	2.0

Viburnum dentatum 'Blue Muffin'

Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT	9 WAT	10 WAT	12 WAT
SureGuard	3 oz/ac	1.1 **	0.8	0.0	0.1	0.0	0.0	0.1	0.0
SureGuard	4 oz/ac	2.1 **	2.5 **	1.5 *	0.8 **	0.4✓	2.8 **	3.9 **	3.3 **
Baking Soda	2.2 g/ft^2	0.0	0.3	0.0	0.1	0.3	0.1	0.0	0.0

Milstop	2.2 g/ft2	0.1		0.1		0.0		0.0		0.3		0.0		0.0	
WeedPharm	10% v/v	0.1		0.0		0.0		0.1		1.1✓	**	3.4	**	2.1	**	2.6	**
Marengo	9 oz/ac	1.7	**	2.8	**	2.0	**	1.5	**	1.2	**	0.2		0.3		0.2	
Untreated	--	0.0		0.3		0.3		0.0		0.0		0.0		0.2		0.1	

Physocarpus opulifolius 'Summer Wine'

Treatment	Rate	1 WAT		2 WAT		4 WAT		6 WAT		8 WAT		9 WAT		10 WAT		12 WAT	
SureGuard	3 oz/ac	3.8	**	4.0	**	3.1	**	2.0	**	1.5		1.3		1.0		0.8	
SureGuard	4 oz/ac	4.0	**	3.9	**	2.6	**	2.6	**	2.2✓	**	5.0	**	4.6	**	4.7	**
Baking Soda	2.2 g/ft^2	0.0		0.3		0.3		0.1		0.2		0.5		0.0		0.0	
Milstop	2.2 g/ft2	0.0		0.1		0.3		0.3		0.6		0.5		0.0		0.0	
WeedPharm	10% v/v	3.4	**	2.1	**	1.8	**	1.0		1.4✓		6.1	**	4.7	**	3.7	**
Marengo	9 oz/ac	6.3	**	6.7	**	7.2	**	5.3	**	4.5	**	5.5	**	3.9	**	3.6	**
Untreated	--	0.0		0.0		0.0		0.0		0.3		0.0		0.0		0.3	

Hydrangea paniculata 'Limelight'

Treatment	Rate	1 WAT		2 WAT		4 WAT		6 WAT		8 WAT		9 WAT		10 WAT		12 WAT	
K-bicarbonate	2.2 g/ft2	--		--		--		6.6	**	5.6	**	1.7	**	1.2	**	0.8	*
Untreated	--	--		--		--		0.0		0.0		0.0		0.0		0.0	

z = weeks after treatment

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

x = Phytotoxicity ratings followed by *,** are significantly different from control based on Dunnett's t-test (α = 0.10, 0.05, respectively).

Table 10. Phytotoxicity on ornamentals at Northland Farms, West Olive, MI with selected products.

Pachysandra 'Green Carpet'

Treatment	Rate	1 WAT^z	2 WAT	4 WAT	6 WAT	8 WAT
SureGuard	4 oz/ac	--^{yx}	--	4.0 **	4.0 **	3.8 **

Milstop	2.2 g/ft2	--	--	0.0	0.0	0.0
Marengo	9 oz/ac	--	--	0.0	0.3	1.5 **
Untreated	--	--	--	0.0	0.0	0.0

Syringa meyeri 'Paliban'

Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT
SureGuard	4 oz/ac	--	--	--	0.8	0.0
Milstop	2.2 g/ft2	--	--	--	0.0	0.0
Marengo	9 oz/ac	--	--	--	0.5	0.0
Untreated	--	--	--	--	0.0	0.0

Euonymus 'Blondie'

Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT
SureGuard	4 oz/ac	--	--	--	2.0 **	2.3 **
Milstop	2.2 g/ft2	--	--	--	0.0	0.0
Marengo	9 oz/ac	--	--	--	0.8	0.5
Untreated	--	--	--	--	0.0	0.0

Cotoneaster apiculata

Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT
SureGuard	4 oz/ac	--	1.5 **	0.0	0.8 **	1.5 **
Milstop	2.2 g/ft2	--	0.0	0.0	0.3	0.0
Marengo	9 oz/ac	--	2.8 **	1.0 **	1.0 **	1.0 **
Untreated	--	--	0.0	0.0	0.0	0.0

Syringa 'Miss Kim'

Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT
SureGuard	4 oz/ac	--	--	--	0.0	1.8 **
Milstop	2.2 g/ft2	--	--	--	0.0	0.0
Marengo	9 oz/ac	--	--	--	1.3	0.3
Untreated	--	--	--	--	0.0	0.0

Salvia 'East Fryland'

Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT
SureGuard	4 oz/ac	4.2 **	4.0 **	3.5 **	2.5 **	1.5 **
Untreated	--	0.0	0.0	0.0	0.0	0.0

z = weeks after treatment

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

x = Phytotoxicity ratings followed by *,** are significantly different from control based on Dunnett's t-test (α = 0.10, 0.05, respectively).

Table 11. Efficacy at Spring Meadow Nursery, Grand Haven, MI for liverwort with selected products.

Treatment	Rate	1 WAT[z]	2 WAT	4 WAT	6 WAT	8 WAT	9 WAT	10 WAT	12 WAT
SureGuard	3 oz/ac	7.4[wv] b	9.8 a	9.6 a	9.6 a	9.6 a	9.7 a	9.7 a	9.7 a
SureGuard	4 oz/ac	7.5 b	9.8 a	9.5 a	9.6 a	9.8✓ a	9.9 a	9.8 a	9.9 a
Baking Soda	2.2 g/ft^2	5.8 c	5.3 b	3.5 c	3.8 c	4.0 c	4.3 c	5.3 b	4.9 b
MilStop	2.2 g/ft2	4.4 d	3.7 c	2.3 d	2.5 d	2.3 d	3.6 d	4.4 bc	4.5 b
WeedPharm	10% v/v	9.8 a	9.5 a	8.6 b	7.9 b	7.5✓ b	8.6 b	9.0 a	9.0 a
Marengo	9 oz/ac	6.2 c	9.4 a	9.4 a	9.8 a	9.5 a	9.7 a	9.8 a	9.7 a
Untreated	--	0.0 e	0.0 d	0.0 e	0.0 e	0.0 e	1.1 e	3.7 c	3.4 c
Treatment	Rate	1 WAT	2 WAT	4 WAT	6 WAT	8 WAT	9 WAT	10 WAT	12 WAT
K-bicarbonate	2.2 g/ft2	--	--	--	5.2 a	3.1 a	2.5 b	2.6 b	3.6 b
Untreated	--	--	--	--	0.0 b	0.0 b	8.7 a	9.6 a	9.7 a

z = weeks after treatment

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

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

Table 12. Efficacy at Northland Farms, West Olive, MI for liverwort with selected products.

Treatment	Rate	1 WAT[z]		2 WAT		4 WAT		6 WAT		8 WAT	
SureGuard	4 oz/ac	7.5[wv]	bc	7.3	ab	7.9	a	7.3	b	6.2	bc
Milstop	2.2 g/ft2	8.7	a	8.6	a	9.0	a	8.4	a	7.4	ab
Marengo	9 oz/ac	6.6	cd	6.5	b	8.1	a	8.9	a	8.8	a
Untreated	--	5.5	d	4.2	c	4.8	b	5.7	c	5.0	c

z = weeks after treatment

w = Liverwort control ratings followed by the same letter in the same column are not significantly different, based on lsmeans ($\alpha = 0.05$)

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

SureGuard at either 3 or 4 oz is an excellent choice for liverwort control in dormant species. There was no significant difference between the 3 and 4 oz rates for control and phytotoxicity was less with the 3 oz/ac rate. We recommended the 3 oz/ ac rate be used as it is more economical. Marengo is also an excellent choice for liverwort control if applied dormant and provides residual control up to 8-10 weeks much like the SureGuard. WeedPharm also provided excellent control. WeedPharm has no residual control unlike SureGuard and Marengo and required reapplication which was phytotoxic to several species. The baking soda and MilStop did not provide the level of control that we had seen in previous SCBGs, this was probably due to the rate being too low and half of other years. Some of the containers did show excellent control, indicating rate is important for controlling liverwort with these products. More work needs to be done with SureGuard and Marengo on dormant plants, with follow up applications of baking soda once active growth occurs.

Problems and Delays

There was little liverwort present at Northland Farms making it difficult to find enough plants to do several treatments and species. Northland Farms is using some of the controls we have advocated in previous SCGBs and thus their liverwort pressure has decreased significantly.

Overall Project Summary:

The 2012-13 project had three objectives dealing with three issues in the industry:

- **A.** Loss of Methyl Bromide soil fumigant
- **B.** Liner bed weed control with pre- and post-emergence herbicides for difficult weeds ex. *Rorippa sylvestris*

C. Liverwort control

Addressing objective A, the preemergence herbicides that we found to be effective in this project cost less than $35.00/ ac. Products such as Treflan 1 p/act rate and Barricade 10 oz/ac could be used for herbaceous seedlings and Pendulum 2G in some crops. Treflan, Barricade and Pendulum 2G were also found to be acceptable for woody plant seedlings. We targeted to cut forest and herbaceous seedling growers weed control program cost by 30%. Using the herbicides listed above we have accomplished this target. More work is needed with preemergence herbicides in these industries due to the total phase out of MeBr by 2015. The lack of alternative soil fumigants and this being the first study of preemergence herbicide use in these industries also confirms the importance of this work.

Addressing objective B, in pre- project start surveys we found that liner bed growers in MI were using the following herbicides, Rout, Barricade, Snapshot, SureGuard, Pendulum, Round up, Goal, Tower, Lontrel and 2, 4-D. On average, they were spending $250.00/ac to hand weed problem areas with difficult weeds such as *Rorippa.* We had targeted to reduce their weed program cost by 30%. We accomplished this goal. The acceptable use of Lontrel in this study provided 35% control, thus reducing hand weeding costs by 35%.

Addressing objective C, SureGuard at either 3 or 4 oz/ ac was found to be an excellent choice for liverwort control in dormant species. There was no significant difference between the 3 and 4 oz rates for control and phytotoxicity was less with the 3 oz/ac rate. We recommended the 3 oz/ ac rate be used as it is more economical. Marengo was also an excellent choice for liverwort control if applied dormant and provides residual control up to 8-10 weeks much like the SureGuard. Work with these two herbicide applied dormant needs to continue in conjunction with supplemental baking soda or potassium bicarbonate application in the growing season.