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Final Performance Report

Reporting Period: December 20, 2017 to September 1, 2019

Submitted: September 24, 2019

Project Title: *Killing the Weedy Competitors: Gaining Herbaceous Perennial Market Share for Michigan*

Project Impact and Findings

The Michigan (MI) Nursery and Landscape Association (MNLA) that led and executed this project found that the MI's herbaceous perennial (HP) market was capable of significant expansion. However, expansion was dependent on finding new high efficacy and low phytotoxicity herbicides. As part of this grant, 166 treatments were applied, on 25 HP species, with 19 different herbicides, at three MI nurseries, meeting or significantly surpassing all project objectives. Many of the 25 HP species studied had few to no herbicides registered for their use in 12/2017. For 23 of the 25, by 08/2019, one to five new herbicides were found. 77% of survey respondents at the beginning of the study indicated never using new herbicides. However, a more diverse, sustainable system in MI HP crops was developed with eight new herbicides employed by project conclusion. Hosta and Daylily are the two largest acreage HP crops in MI. Previously herbicide rotations, out of a conventional program, were impossible as no alternatives were available. At the project completion, **two and five** herbicide/ herbicide combinations for Fall planted Hosta and Daylilies, respectively, applied spring; **one** new herbicide combination for rotation from the conventional program, applied after Mid-October planting; **two and four** new herbicide/ herbicide combinations for spring planted daylily and Hosta, respectively, were developed. Several new science-based tools (i.e. new herbicides/herbicide timings) were delivered to 2000 growers via three presentations, two workshops and five trade magazine articles, exceeding the 100 growers originally indicated 20 times. A 50% reduction in weeding time was worth $188 million (Mn) annually for one company, exceeding the listed five Mn for increased revenue 37.6 times.

Beneficiaries
Number of project beneficiaries: 2000

Activities Performed
A. Research activities:
Table 1 provides a summary of all the research trials conducted at Walters Gardens, Zeeland, MI (Tables 2-7); Lynn Mayer's Great Lakes Glads, Bronson, MI (Fig. 4); and, Ray Wiegand's Nursery, Lenox, MI (Tables 8-9) for 166 herbicide tests, on 25 species, with 19 herbicides during the course of this grant (pp. 21-47). The highlights of these studies are listed by species and herbicide(s) that were found to be optimum, based on their lowest phytotoxicity (≤ 3) preferred, and highest efficacy ≥ 7 (Table 1). These will be sent to the IR-4 program for potential herbicide registration.

Table 1. Summarizes all research trials conducted at Walters Gardens, Zeeland, MI (Tables 2-7); Lynn Mayer's Great Lakes Glads, Bronson, MI (Fig. 4); and, Ray Wiegand's Nursery, Lenox, MI (Tables 8-9) of the 166 herbicide tests conducted on 25 species with 19 herbicides and highlights by species (pp.21-47). The herbicide(s) that were found to be optimum, based on lowest phytotoxicity (≤ 3) preferred and highest efficacy ≥ 7 are listed. **Nothing** indicates there are no previous herbicides registered for the species. **Yes,** indicates the herbicide has been previously tested and found suitable for the species. **No,** indicates the herbicide has previously been untested on the species and is not a registered herbicide. At least one new herbicide, previously untested for each of 23 species tested was found. Two of the 25 species tested (*Amsonia* sp. and *Panicum virgatum* 'Shenandoah') had never had any products tested on them before, and the tests on the other 21 species had previously never been conducted, with the exception of three products (Pennant Magnum) on two species (*Coreopsis verticillata* and *Hemerocallis*), (Gallery SC) on (*Hemerocallis*), and (Tower 6EC) on (*Hemerocallis*) (Table 1). At least one new herbicide and up to five, for each species evaluated, was found in this study.

Species	# tmt. tests	Last Eval. (WAT)	Table No.	Best Treatment (Based on lowest phyto. and highest efficacy	Efficacy (0-10, 10 = perfect)	Phyto. (0-10, 0 = no injury)	Registration (Yes or No)
Field -- Walter Gardens 2018 Active Growth – (SureGuard applied over all in December 2017)							
Amsonia 'Blue Ice'	5	20	2A	Pennant Magnum	7.0	6.0	Nothing
Coreopsis verticillata 'Sassy Saffron'	5	20	2B	Pennant Magnum	8.7	2	Yes
				Pennant Magnum + Tower 6EC	10	2.3	Yes + No
				Tower 6EC	8.3	2.7	No
Sanguisorba minor 'Little Angel'	5	20	2C	Pennant Magnum	10	3.7	Nothing
Kniphofia thomsonii 'Gold Rush'	5	20	2D	Tower 6EC	10	2.3	No
				Tower 6EC + Dimension 2EW	7.7	3	No + No
				Pennant Magnum	7.0	1.7	No
Kniphofia pyromania 'Orange Blaze'	8	20	2E	Pennant Magnum	9	1.3	No
				Pennant Magnum + Tower 6EC	9	2	No + No
				FreeHand 1.75G	9.3	2.5	No
				Fortress	8	0.8	No

Species	# tmt. tests	Last Eval. (WAT)	Table No.	Best Treatment (Based on lowest phyto. and highest efficacy	Efficacy (0-10, 10 = perfect)	Phyto. (0-10, 0 = no injury)	Registration (Yes or No)
				Marengo G	8.3	0.3	No
Penstemon 'Prairie Dusk'	5	20	2F	Pennant Magnum	7	1.7	No
				Pennant Magnum + Tower 6EC	9.3	2.3	No + No
				Tower 6EC	8	2	No
Penstemon 'Midnight Masaquerade'	8	20	2G	FreeHand 1.75G	7	0	No
				Fortress	8.3	0	No
				Marengo G	9.7	0	No
Coreopsis verticillata 'Red Hot Vanilla'	5	11	3A	Gemini G	-	0	No
				Biathlon	-	0	No
				FreeHand 1.75G	-	0	No
Coreopsis verticillata 'Curry Up'	5	11	3B	Biathlon	-	0.3	No
				FreeHand 1.75G	-	0	No
				Fortress	-	0	No
Vernonia 'Southern Cross'	5	11	3C	Biathlon	-	1.1	No
Aster novae-angliae 'Purple Dome'	5	11	3D	Biathlon	-	1.6	No
				FreeHand 1.75G	-	1.0	No
Field -- Walter Gardens Fall Planted 2018							
Hosta 'Francee' –Dormant	8	17	4A	Dimension 2EW + Pennant Magnum	8.9	2.5	No + No
			4A	Marengo G	8.5	0	No (not after emerged)
Hemerocallis ' Stella D'oro' - Active	8	17	4B	Basagran T/O	10	0	
				¾ Tower + Basagran	10	1.0	
				Marengo SC	10	1.4	
				Fortress	10	0.8	
				Marengo G	10	0	No (not after emerged)

| Species	# tmt. tests	Last Eval. (WAT)	Table No.	Best Treatment (Based on lowest phyto. and highest efficacy	Efficacy (0-10, 10 = perfect)	Phyto. (0-10, 0 = no injury)	Registration (Yes or No)
Field -- Walter Gardens Fall Planted 2018 - Marengo vs Conventional Practice							
Hemerocallis ' Stella D'oro' - Active	6	17	5	Conventional Practice: Mid October 2018 – Gallery SC + Buccaneer Plus + Salvo + Pendulum 3.3 EC	8.8	1.7	Yes + No + No + No
Species	**# tmt. tests**	**Last Eval. (WAT)**	**Table No.**	**Best Treatment (Based on lowest phyto. and highest efficacy**	**Efficacy (0-10, 10 = perfect)**	**Phyto. (0-10, 0 = no injury)**	**Current Registration (Yes or No)**
	6	17	5	Mid October 2018 - Marengo SC (12 oz) + Buccaneer Plus + Salvo	9.8	3.0	No + No + No
Field -- Walter Gardens 2019 Spring Planted							
Hemerocallis 'Happy Returns' - Active	7	9	6	½ Tower 6EC + ½ Pennant Magnum	8.3	2.3	Yes + Yes
				Tower 6EC + ½ Dimension 2EW	8.0	1.5	Yes + No (directed only)
Hosta 'Captain Kirk'	7	9	7	½ Tower 6EC + ½ Pennant Magnum	9.8	1.5	No + No
				Tower + ½ Dimension 2EW	9.0	2.0	No + No (directed only)
				Tower + Pendulum Aqua Cap (ratios mixed to = FreeHand 150 lb./ac)	10	1.3	No + Yes
				Pennant Magnum + Pendulum Aqua Cap	9.8	2.3	No + Yes
Field Grown Peonies – Lynn Mayer's Spring 2018							
Paeonia lactiflora 'Alexander Fleming'	7	7	Fig. 4	Tower 6EC + Dimension 2EW	7.0	2.0	No + No

| Species	# tmt. tests	Last Eval. (WAT)	Table No.	Best Treatment (Based on lowest phyto. and highest efficacy	Efficacy (0-10, 10 = perfect)	Phyto. (0-10, 0 = no injury)	Registration (Yes or No)
	4	10	N/A	FreeHand 1.75G	--	0.0	No
	4	10	N/A	Tower 6EC	--	0.0	No
	4	10	N/A	Dimension 1X	--	1.5	No
Containers – Ray Wiegand 2018 & 2019							
Rudbeckia fulgida 'Little Goldstar'	8	16	8A	Tower 6EC 1X	8.9	2.4	No
Penstemon schmidel 'Red Riding Hood'	8	16	8B	Fortress 1X	9.5	1.0	No
				Tower 6EC 1X	9	1.3	No
Panicum virgatum 'Shenandoah'	8	16	8C	Fortress 1X	7.9	1.0	Nothing
				Tower 6EC + Dimension 2EW	10	0	
Iris sibirica 'Sparkling Rose'	8	16	8D	Fortress 1X	8.9	0.8	No
				Tower 6EC 1X	10	0.4	No
				Biathlon	7	1.8	No
				Marengo G	7.8	1.0	No
Asclepias incarnata	8	16	8E	Fortress 1X	9.5	0.6	No
				Tower 6EC 1X	8.4	0	No
				Biathlon	7.9	0	No
				Marengo G	9.5	0	No
				Tower 6EC + Dimension 2EW	10	0.8	No
Hemerocallis 'Going Banana's'	5	40	9A	FreeHand 1.75G	7.6	2.0	Yes
				Fortress	7.7	1.0	Yes
Sedum spurium 'Dragon Blood'	5	40	9B	FreeHand 1.75G	10	2.2	Yes
				Fortress	9.6	2.8	No
				Biathlon	9.2	2.8	No
Echinacea purpurea 'Pow Wow White'	5	40	9C	Injury with all	--	--	--
Total Tests + SureGuard	166						

B. Survey activities:

Fig. 1 A and B, Fig. 2, and Fig. 3 A and B, summarize survey activities conducted (pp.8-9). The survey questions (1-14)(listed below) represent the data used to create Fig. 1 A and B., Fig. 2, and Fig. 3 A and B. Number of respondents is on the X axis of all bar graphs below. Survey outcomes and indicators are provided pp.17 -18 and 19.

**Survey questions asked at 2 workshops 01/2018 and 01/2019:**

1) Before this program had you, heard of Biathlon?   Yes   No (Circle)
2) Before this program had you, heard of FreeHand 1.75G?   Yes   No (Circle)
3) Before this program had you heard of Fortress?   Yes   No (Circle)
4) Before this program had you heard of Marengo G?   Yes   No (Circle)
5) Before this program had you heard of Gemini G?   Yes   No (Circle)
6) Before this program had you heard of Marengo SC?   Yes   No (Circle)
7) Before this program had you heard of Tower 6EC?   Yes   No (Circle)
8) Before this program had you heard of Gallery SC?   Yes   No (Circle)
9) If you had never used the 8 products above – will you use them after this program? (List all that apply)
10) How important is weed control in your business. Answer based on time spent by self or other staff engaged in weed control activities including weeding hoeing, applying herbicides, etc.:
a) 0-25% of time
b) 26-50% of time
c) 50-75% of time
11) How much money do you think one thing you learned in this program will save you/your boss?
a) 1,000 to 3,000 ---- 20 responded A = 40,000
b) 4,000 to 8,000 ----- 9 responded B = 54,000
c) 9,000 to 12,000 ---- 3 responded C = 31,500
d) 13,000 to 26,000 --- 5 responded D = 97,500
e) More than $27,000 --- 3 responded E = 81,000
12) What tolerance (in percent cover) do you have for weeds in your nursery/landscape operation:
a) 10% or less
b) 20% or less
c) 30% or less
d) 40% or less
13) What level of injury would you accept from an herbicide, if it saved you in weed control costs?
a) 10% or less
b) 20% or less
c) 30% or less
d) 40% or less
14) How many herbicide applications does your nursery current conduct per year?
a) 1
b) 2
c) 3
15) Before this program did you rotate modes of action of herbicides?   Yes   No (Circle)
16) After this program will you rotate modes of action of herbicides?   Yes   No (Circle)
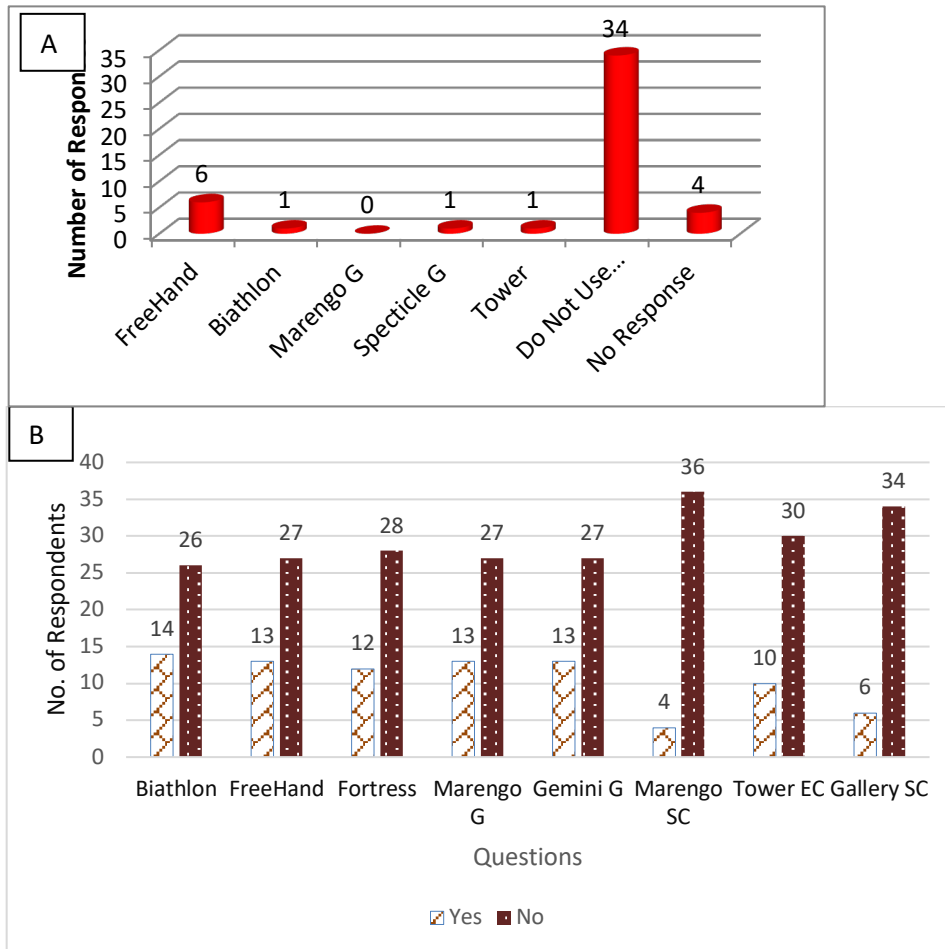
Fig. 1. A. and B. A. Indicates the survey responses gathered from our first workshop in January 2018 at the Michigan Nursery and Landscape Association (MNLA), Great Lakes Trade Exposition (GLTE) to Qu.#1-8 (listed above) and, **B.** the second MNLA GLTE workshop January 2019 to Qu.# 1-8. The two survey times were compared to indicate how we met Outcome 4, indicator 2a, 2b and 2c, and Outcome 5, indicator 2 and 6.
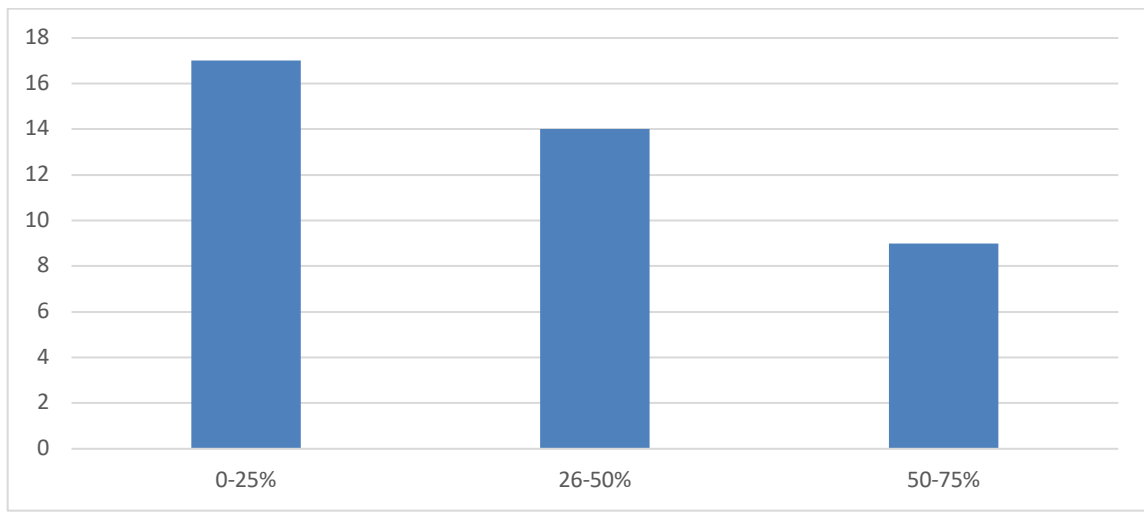
Fig. 2. Survey responses gathered from our second workshop on January 2019, to Qu. #10 (indicated above), how much time do you spend hand-weeding in your business? This question responses help indicate the meeting of Outcome 4, indicator 2a, 2b, 2c and 2d, Outcome 8, indicator 6 and 8.
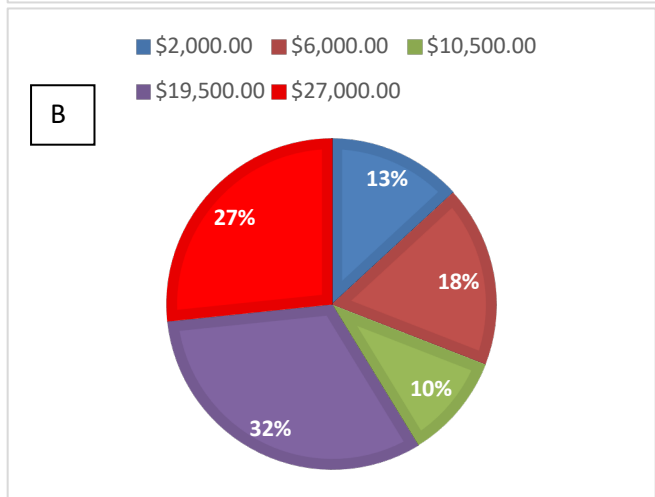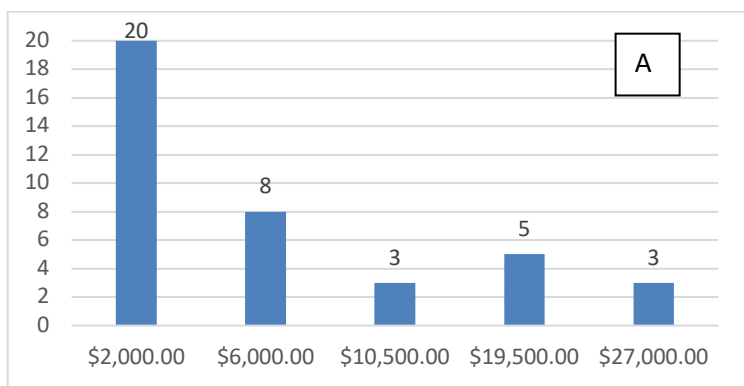
Fig. 3. A (left above) **and B.** (left lower) Survey responses gathered from our second workshop to indicate meeting Outcome 4 of increased efficiency and increased economic returns by replies to Qu. #11.

C. *Outreach activities:* Presentations (5) and Articles (5)

<u>Presentations</u>:

Mathers, H.M. 2019. Weed identification 3-hour hands-on session. Presented at Great Lakes Trade Exposition (GLTE) by the Michigan Nursery and Landscape Association to 60 industry members.(Attendance was limited to first come). Lansing, MI. (January 29).

Mathers, H.M. 2019. Current herbaceous perennial weed controls. Presented at Great Lakes Trade Exposition (GLTE) by the Michigan Nursery and Landscape Association to 65 industry members.(Winter storm reduced attendance). Lansing, MI. (January 28).

Mathers, H.M. 2018. Weed identification 3-hour hands-on session. Presented at Great Lakes Trade Exposition (GLTE) by the Michigan Nursery and Landscape Association to 40 industry members.(Attendance was limited to first come). Lansing, MI. (January 22).

Mathers, H.M. 2018. Killing the competition: The latest in weed control in herbaceous perennials. Presented at Great Lakes Trade Exposition (GLTE) by the Michigan Nursery and Landscape Association to 60 industry members. Lansing, MI. (January 23).

Mathers, H.M. 2018. A beginners' guide to herbicide modes of action. Presented at Great Lakes Trade Exposition (GLTE) by the Michigan Nursery and Landscape Association to 120 industry members. Lansing, MI. (January 23).

<u>Articles</u>:

Michigan Nursery and Landscape Association. The Michigan Landscape	Circulation: 8,200

Mathers, H.M. 2019. Evaluation of liquid over-the-top herbicide applications for field grown herbaceous perennials soon after planting. Michigan Landscape: 62(5):35-37.

Mathers, H.M. 2019. Evaluation of current herbicides for phytotoxicity and efficacy on five herbaceous perennials species in containers. Michigan Landscape: 62(2):54-55.

Mathers, H.M. 2018. Bindweed and its look a likes. Michigan Landscape: 61(5):31-36.

Mathers, H.M. 2018. The primitives. Part 2: Nostoc. Michigan Landscape: 61(2):34-38.

Mathers, H.M. 2018. The primitives. Part 1: Liverwort. Michigan Landscape: 61(1):34-38.

Objectives

Provide the approved project's objectives.

#	Objective	Completed? Yes	No*
1	Evaluate efficacy of four new ornamental herbicides and four herbicide combinations previously untested in HP crops on-site in MI nursery fields/containers from December 2017 to summer 2018 at three locations.	X	
2	Evaluate phytotoxicity of same four new ornamental herbicides and four herbicide combinations previously untested in HP crops, as used in objective 1, on-site in MI nursery fields/containers from December 2017 to summer 2018 at three locations.	X	
3	Discover much needed information for MI HP growers regarding the development of environmentally sound herbicide programs for field and container stock and determine overall (season-long) program efficacy and phytotoxicity.	X	
4	Determine the effectiveness of newly developed herbicides versus less environmentally sound, older herbicides at reducing and eradicating invasive species' proliferation in MI nursery fields/containers..	X	

Accomplishments

Accomplishment	Relevance to Objective, Outcome and/or Indicator
Dormant SureGuard application across the field on Dec. 20, 2017 was still showing efficacy 21 WAT and numerous soil disturbance events, including tilling, planter bed preparations and planting.	This is the first report of a SureGuard being used as a pre-plant, early winter application. This is an important finding in meeting objective 3 for herbaceous field growers and landscapers who are considering planting new perennial beds. This is also key to meeting objective four of determining an environmentally sound weed control program.
The eight new herbicides tested were [Fortress (formerly OHP 1701), Biathlon, Marengo G, Marengo SC, FreeHand 1.75G, Tower 6EC, Gallery SC and Gemini G]. The eight combination herbicides were [Tower 6EC + Dimension 2EW, Pennant Magnum + Tower 6EC, Tower 6EC + Basagran, Pennant Magnum + Dimension 2EW, Pennant Magnum +	We exceeded objectives one and two by of the grant as efficacy and phytotoxicity were evaluated for **eight (vs four**, as originally specified) new ornamental herbicides; **eight (vs four**, as originally specified) combination herbicides, and **three (vs 0**, originally specified) older herbicides. Therefore, 19 herbicides/

Pendulum Aqua Cap, Tower 6EC + Pendulum Aqua Cap, Marengo + Gly + 2,4-D and V-10233 (Fierce)]. The three older herbicides were Pennant Magnum, Basagran T/0 and SureGuard. The best herbicides found, based on lowest phytotoxicity (≤ 3, on a scale of 0-10, where 0 is no injury) preferred, and highest efficacy ≥ 7, on a scale of 0-10, where 10 is perfect weed control), in the 166 protocols, are summarized in Table 1.	herbicide combinations were tested (Table 10) vs the 8-original specified.
By the project completion we found **two** herbicide/ herbicide combinations for Fall planted Hosta, applied dormant (Dimension 2EW + Pennant Magnum and Marengo G) (Table 4A); **five** new herbicide/ herbicide combinations for fall planted Daylilies, applied spring, (Basagran T/0, ¾ Tower 6EC + Basagran T/O, Marengo SC, Fortress and Marengo G) (Table 4B); **one** new herbicide combination with slightly better efficacy vs the conventional program, applied to fall planted daylily after planting in mid-October (Marengo SC 12 oz + Buccaneer Plus + Salvo) (Table 5); **two** new herbicide/ herbicide combinations for spring planted daylily (½ Tower 6EC + ½ Pennant Magnum, and Tower EC + ½ Dimension 2 EW) (Table 6); and, **four** new herbicide/ herbicide combinations for spring planted Hosta (½ Tower 6EC + ½ Pennant Magnum, Tower EC + ½ Dimension 2EW, Tower 6EC + Pendulum Aqua Cap, and Pennant Magnum + Pendulum Aqua Cap).	We met objectives three by finding an environmental sound year-round program for Daylily and Hosta which are the two highest acreage, and largest selling HP crops in MI.
At least one new herbicide, previously untested for each of 23 species evaluated was found (Table 1) with low phytotoxicity	Objective four was met as all eight new herbicides tested were more environmental sound and provided

and high efficacy. Two of the 25 species tested (*Amsonia* sp. and *Panicum virgatum* 'Shenandoah') had never had any products tested on them before, and the tests on the other 21 species had previously never been conducted, with the exception of two species and three products (Pennant Magnum) on (*Coreopsis verticillata* and *Hemerocallis*), (Gallery SC and Tower 6EC) on (*Hemerocallis)* (Table 1). At least one new herbicide and up to five, was found for 23 species.	superior efficacy even on MI's toughest weeds.
Fortress a new herbicide in 2018 (dithiopyr 10.25 % + isoxaben 0.50%, by wt.) (OHP, Inc., Mainland, PA 19451) was used in 19 trials and found to be the best treatment in 9 of those or 47% of the time (Table 10). In addition to meeting the grant objectives by testing at a 1X rate, 150 lb./ac, we exceeded the objectives, by testing at a 2X rate, 300 lb./ac in three trials.	In conducting these 9 Fortress studies, outcome 4, 2a and 2d were partially met by the delivery of best management practices (BMP's). This is because, the Fortress results can be used by the manufacturer for label expansion. In Table 1, only the 1X rates of the herbicides are listed; however, if the 1X was suitable the 2X was also.
Tower 6EC was tested in 13 trials and was the best treatment 31% of the time (Table 10).	In addition to meeting the grant objectives one and two by testing Tower 6EC at a 1X rate, 26 oz/ac, we exceeded the objectives, by testing at a 2X rate, 52 oz/ac and ½X rates. In so doing, contributing to meeting outcome 4, 2a and 2d by delivery of BMPs.

Biathlon (oxyfluorfen + prodiamine) (OHP, Inc., Mainland, PA) and Marengo G (indaziflam) (Bayer), garnered their EPA registrations in 2013. Biathlon was tested in 12 trials and was the best treatment 58% of the time (Table 10).
 	
FreeHand 1.75G (dimethenamid-p + pendimethalin) (BASF Corporation, Research Triangle Park, NC) and Tower
	The evaluations of the four new granular products in containers listed in Table 9, show the same relative ranking as in Table 1. Fig. 15 shows the total mass of weeds collected from the study after 40 weeks, over species. Gemini was providing about the same efficacy as the control by mass (Fig. 15).
	        1st Freehand 1.75G (80%),
	        2nd Biathlon (58%)

6EC (dimethenamid-p) (BASF Corporation) were registered in 2011. FreeHand 1.75G was tested in 10 trials and was the best treatment 80% of the time (Table 10).	3rd Fortress 3rd (47%) 4th Gemini G (14%).
The tank mix application of **Pennant Magnum + Tower 6EC** applied May 16, 2018 had low phytotoxicity was the best treatment for 3 of 7 species evaluated at Walters Gardens, even though the chemical was applied to very tender newly planted materials and over-top of the SureGuard applied Dec. 20, 2017. The additional bonus of the material being liquid applications saves the grower time and eliminates the need for purchase of new equipment to apply granular products.	This is the first report of a Pennant Magnum + Tower 6EC being used as a tank mix for this crop and timing. This is an important finding in meeting objective 3 for herbaceous field growers and landscapers. This is also key to meeting objective four of determining an environmentally sound weed control program.
We continued with work with **Pennant Magnum** [Pennant Magnum (S-metolachlor 83.7%) (Class 15)- very long chain fatty acid (VLCFA) inhibitor) (Syngenta Crop Protection, LLC, Greensboro, NC, 27419)] **+ Tower 6EC** in 2019 testing it three more times and was the best treatment 56% of the time (Table 10).	Helping to meet objective 3 (1a) and 4 indicators 2b and 2c.
Tower 6EC + Dimension 2EW providing exceptional efficacy and little phytotoxicity in field grown peonies in a key finding. Current this peony grower uses little to no herbicides in their fields and their weed growth is limiting peony growths and increasing other insect and disease problems in the field. The use of Tower 6EC + Dimension 2EW as a **dormant** application is a critical finding to this grower.	There are very few registered products for weed control in peonies. To determine this control tank mix at the exception levels achieved objective 1, 2 and moves towards meeting objective 3 and 4.
Studies with **Tower 6EC + Dimension 2EW** were continued in 2019 to total 17	This tank mix was the highest-ranking liquid combination treatment in the trial

trials and was the best treatment 71% of the time (Table 10).	and plays an important role in achieving objective 1, 2, 3 and 4.
Continuing with the success of Pennant Magnum + Tower 6 EC in 2018, Pennant + Dimension 2EW and Pennant Magnum + Pendulum Aqua Cap were both tested twice and were best treatments once for each or 50% (Table 10). Pennant Magnum was tested alone 7 times and was the best treatment 86% of the time.	Achieving objective 1, 2, 3 and 4.
The July studies at Walters had Biathlon as the best treatment in all four species studied, FreeHand 1.75G in three species and Fortress and Gemini G in one each.	This shows Biathlon and FreeHand 1.75G have tremendous utility to use across a wide range of herbaceous materials and towards completing objective 3 and 4.
Ray Wiegand's Nursery currently uses no herbicides in their herbaceous container crops. Our finding of three low phytotoxicity products, **Tower 6EC 1X** (for 4 of 5 species), **Marengo G** (for 2 of 5 species), **Fortress** (for four of five species) **and Biathlon** (for two) with exceptional efficacy when applied **dormant** is a major outcome of this work. This gives this grower four herbicide product choices in three different modes of action when they had none before. This will save the grower not only in labor weeding the crop but crop losses due to weed infestations. In addition, one of the new products tested, Tower 6EC, is liquid formulation which makes for ease of application.	All the products we evaluated in this study have never been previously used in MI. The results are very promising and will be explored further in this research project. Several labels may be expanded in part from this research. These findings exceed the expectations of this grant and go above and beyond meeting objective 1 and 2 and towards 3 and 4.
Outcome 3, 4, 5 and 8	By finding one to five herbicide solutions for so many field and container herbaceous species, we enhanced the competitiveness of specialty crop and access for new growers; creating sustainable practices for increased

	yields and reduced inputs. This crop sector becomes more resilient and diverse by these findings and moves to improve the MI economy.

Challenges

Challenges and Developments	Corrective Action
Hand weeding of application areas by Waters Gardens.	Waters was more interested in the phytotoxicity portion of the trial as the problem with herbaceous perennial crops is not finding an herbicide that works but finding one that does not injure the crop severely.
Treatments applications at the head of the peony field where several misses occurred in the peony crop.	Luckily, we had eight replicates for each treatment, so the impact of the misses was minimized; however, the statistical precision was reduced.
Originally, we placed an emphasis on granular preemergence herbicides as these are usually recommended for herbaceous crops. However, in meetings with the three participating nurseries, in Dec. 2017 and February 2018, they indicated they were most interested in liquid formulations.	We learned that part of the lack of herbicide usage for these crops is due to lack of equipment for granular applications, especially, in the field. Therefore, both the container and field growers emphasized that we use more liquids in our studies, especially on dormant plants. Of the 9 best herbicides listed above, 6 are liquid formulations with optimum fit for existing herbaceous perennial programs (Table 10). The clear liquid program winners would be Pennant Magnum and Tower 6EC + Dimension 2EW (Tables 1 and 10).

Lessons Learned

Placement of tall bright colored posts marking the trial starting and ending locations in fields with secure, strong, bright colored tape tied from post to post are required to prevent cultivators, hand weeding and other unwanted operations from being conducted in the research plots. Numerous, highly visible flags and stakes are not sufficient. A physical barrier is required.

Continuation and Dissemination of Results

An article is planned for the winter (2019) issue of the Michigan Landscape magazine. Additionally, one talk is planned at the MNLA 2020 GLTE in January.

Outcome(s) and Indicator(s)/ Sub-Indicator(s)

Provide the results of the project outcome(s) and indicator(s) as approved in your State Plan and project proposal. The results of the outcome(s) and indicator(s) will be used to evaluate the performance of the SCBGP on a national level.

Survey responses were gathered in January 2018 at the MNLA Great Lakes Trade Exposition (GLTE) and a year later and indicate the surpassing of Outcome 4, indicator 2a, 2b and 2c; Outcome 5, indicator 2 and 6 (Fig. 1A and B). Outcomes 3 indicator (1a), and 5 indicators 8 were achieved via five articles contributed to Michigan Landscape magazine (section C of activities performed – above p. 11). Originally, these outcomes were to be meet with field days; however, we found workshops were a better way to collect the survey data required for the outcomes. We had 60 attendees with 44 respondents at the first workshop, and 40 attendees with 40 respondents at the second workshop. Originally, we had hoped to train 20 growers/ producers as first responders for outcome 5 indicator 6. We greatly exceeded this expectation by training 135 of which 84 we were able to tally into the results for Fig. 1 A and B.

The answers to questions (1-8) from the surveys A and B, indicate we met our objectives and outcomes for this project. Of the 44 respondents surveyed in the 01/2018 workshop, 4 gave no answer and 34 indicated they do not use new herbicides (Fig. 1A). Six had used FreeHand 1.75G, and one of the six had also used Biathlon, Tower 6EC and Marengo/Specticle (Fig. 1A). However, by the second survey one year later, 01/2019, the project had made a considerable impact on the MI industry. 14, 13, 12 and 10, of 40 respondents, now had tried Biathlon, FreeHand 1.75G, Fortress, and Tower 6EC, respectively (Fig. 1B). 13, 13, and 4, had also tried Gemini G, Marengo G and Marengo SC, respectively (Fig. 1B). This was a considerable change from the 34 respondents, or 77% of the audience, indicating just one year before that they never used new herbicides (Fig. 1A). Via the implementing these 8 lower active ingredient loading herbicides, growers would have reduced the pesticides applied per acre. These 8 new adopted innovations or herbicides, also have longer efficacy than older products, reducing the pounds required per acre, and increasing environmental safety and thus meeting outcome 4 indicator 2a, 2b and 2c; outcome 5 indicator 2. The results further indicate, from these workshops (A and B) that more than 21 growers adopted 8 new herbicides as BMP's contributing to meeting outcome 4, indicator 2a, 2b and 2c of 40 growers. The remaining 19 growers were reached via the 3 presentations at the MNLA GLTE. These three presentations actual reached 245 growers, over and above the 2 workshops. Far exceeding outcome 4 indicator 2a.

In the first survey 88% of participants answered in Qu. 10 that they were spending more than 50% of their current work time on weed control. By the second survey, 43% responded <25% of their time on weed control and 35% of respondents indicated < 50% of their time (Fig. 2). To value this reduction in weeding time, if a company like Walters Gardens who was spending $376 Mn on hand weeding at the start of the project, cut their weeding time in half, this would be a savings of $188 Mn annually. With this one MI HP company we far exceeding Outcome 8, indicator 5 of $5 Mn increased revenue.

Qu. 11 answers are shown in Fig. 2A with 50% of respondents indicating one thing that they learned from the program was worth $2,000.00 to their business; 20% up to $6,000; 7.5% up to $10,500; 12.5% worth $19,500; and 7.5% worth $27,000.00 to their business. The pie chart of Fig. 2A responses are shown in Fig. 2B and indicates that although 50% answered $2,000, 59% of this audience's savings were represented by those answering $19,500.00 and $27,000.00. By 30% responding an average saving of $23,250 for each single practiced learned this represents 2.3 Mn in savings for the 30% of 330 presentation attendees at the five MNLA GLTE outreach sessions from this project.

Outcome 3 indicator (1a) was to reach 500 consumers and 250 to gain knowledge and Outcome 5, indicator 8 was for 100 growers receiving science-based tools. With five articles written about the project results and circulated in to 8,200 readers each time, these outcome and indicators were greatly outperformed

Outcome Measures
Select the Outcome Measure(s) that were approved for your project.

- ☐ **Outcome 1**: Enhance the competitiveness of specialty crops through increased sales (required for marketing projects)
- ☐ **Outcome 2:** Enhance the competitiveness of specialty crops through increased consumption
- ☑ **Outcome 3**: Enhance the competitiveness of specialty crops through increased access (for new growers)
- ☑ **Outcome 4**: Enhance the competitiveness of specialty crops though greater capacity of sustainable practices of specialty crop production resulting in increased yield, reduced inputs, increased efficiency, increased economic return, and/or conservation of resources
- ☑ **Outcome 5**: Enhance the competitiveness of specialty crops through more sustainable, diverse, and resilient specialty crop systems
- ☐ **Outcome 6**: Enhance the competitiveness of specialty crops through increasing the number of viable technologies to improve food safety

☐　　**Outcome 7**: Enhance the competitiveness of specialty crops through increased understanding of the ecology of threats to food safety from microbial and chemical sources

☑　　**Outcome 8**: Enhance the competitiveness of specialty crops through enhancing or improving the economy as a result of specialty crop development.

Outcome Indicator(s)

Provide the indicator approved for your project and the related quantifiable result. If you have multiple outcomes and/or indicators, repeat this for each outcome/indicator.

1. **Outcome 3, Indicator 1.a.** Of the 500-total number of consumers or wholesale buyers reached, 250 will gain knowledge about producing and preserving specialty crops.
   - We reached 330 consumers and wholesale buyers via trade presentations at GLTE outreach sessions not including workshops.

2. **Outcome 4, Indicator 2.a.** Adoption of best practices and technologies resulting in increased yields, reduced inputs, increased efficiency, increased economic return and conservation of resources. 40 growers/producers will indicate adoption of recommended practices.
   - From workshops (A and B) at GLTE 21 growers adopted 8 new herbicides as BMP's contributing to meeting outcome 4, indicator 2a, 2b and 2c of 40 growers. The remaining 19 growers were reached via the 3 presentations at the MNLA GLTE. These three presentations actual reached 245 growers, over and above the 2 workshops. Far exceeding outcome 4 indicator 2a.

3. **Outcome 4, Indicator 2.b** 40 growers/producers will be reporting reduction in pesticides used per acre.
   - Each of the 8 new herbicides, have longer efficacy than older products, reducing the pounds required per acre, and increasing environmental safety and thus meeting outcome 4 indicator 2b.

4. **Outcome 4, Indicator 2.c** 40 producers will be reporting reduced costs per acre.
   - Each of the 8 new herbicides, have longer efficacy than older products, reducing the pounds required per acre and costs per acre and meeting outcome 4 indicator 2b.
   - Additionally, a 50% reduction in weeding time was found and valued at $188 Mn annually for one company, exceeding outcome 4, indicator 2c.

5. **Outcome 4, Indicator 2.d** 400 acres will be in best management practices developed in this grant.
   - Walters Gardens has 1,500 acres in field grown daylilies and Hosta. We developed 14 new herbicide programs for these two crops, far surpassing outcome 4, indicator 2d with just this one company.

6. **Outcome 5, Indicator 2.** Number of innovations adopted 8.

- 77% of survey respondent at the project start indicated never using new herbicides (Fig. 1A). However, by the second survey, 8 new lower active ingredient loading herbicides were adopted meeting outcome 5 indicator 2.

7. **Outcome 5, Indicator 6.** Number of first respondents trained in early detection and rapid response to combat plant pests (i.e. weeds) 20.
   - We had 60 attendees with 44 respondents at the first workshop, and 40 attendees with 40 respondents at the second workshop. Originally, we had hoped to train 20 growers/ producers as first responders for outcome 5 indicator 6. We greatly exceeded this expectation by training 135 of which 84 we were able to tally into the results for Fig. 1 A and B.

8. **Outcome 5, Indicator 8.** Number of growers/producers that gained knowledge about science-based tools through outreach and education programs 100.
   - Several new science-based tools (i.e. new herbicides/herbicide timings/herbicide tank mixes/ Hp herbicide rotations) were delivered to 2000 growers via three presentations, two workshops and five trade magazine articles, exceeding the 100 growers originally indicated 20 times.

9. **Outcome 8, Indicator 5.** Increased revenue/ increased savings (in dollars) $5,000,000.
   - In the first survey 88% of participants answered in Qu. 10 (p.7) that they were spending more than 50% of their work time on weed control. By the second survey, 43% responded indicated <25% of their time was spent on weed control, and 35% of respondents indicated < 50% of their time (Fig. 2) (p.9). If a company like Walters Gardens, who was spending $376 Mn on hand weeding at the start of the project, has cut their weeding time in half, for a savings of $188 Mn annually, Outcome 8, indicator 5 was exceeded.

Data Collection

Explain what data was collected, the collection, evaluation, and data analyses methodology to derive the quantifiable indicator(s).

(See Research Results listed below pages 21- 47)

Research Results.

Table 2. Walters Gardens, Zeeland, MI seven species as listed at the top of each sub-table were evaluated with one herbicide applied **Dec. 20, 2017** (as a 1st round of applications) followed by five treatments for five species and eight treatments for two species (as a 2nd round of applications). Each phytotoxicity mean represents three replications, of three rows of plants, with 6 plants per row, for a total of 54 plants/mean (Fig. 4). Unfortunately, the field was periodically hand weeded by the grower, so efficacy values are as reflective as they could have been. Shoot heights and fresh weights were collected at the initiation of the 2nd round of applications (**May 16, 2018**) (one week after planting). At the trial conclusion shoot height and two perpendicular measures of width were collected and put into an equation to calculate Growth index values (GI). Phytotoxicity and efficacy ratings were taken at 4 weeks at the second treatment (4WA2T) or 25 weeks after the first treatment (25 WAT), respectively. All subsequent evaluations are listed only as after the second treatment i.e., 9 WA2T, 13 WA2T and 20 WA2T as are the heights and GI's at 20 WA2T. Various herbicides applied alone or in combination to fulfill Obj. 1 and 2 of the grant and towards completion of objective 3. Legend at the bottom of sub-table G.

A. *Amsonia* 'Blue Ice'

Initiation – Dec 20, 17 1st round: Pre-plant -SureGuard applied across field	21 WAT 1st round Ht (in) Planted 5/07/18	20 WA2T Ht (in)	20 WA2T GI (in)³	21 WAT 1st round Shoot Wt. (g) Planted 5/07/18	Treatment 2nd Applied 05/16/2018 21 WAT 1st round	Rate/ac	4 WA2T[z] & 25 WAT Phyto.[y]	4 WA2T 25 WAT Efficacy[x]	9 WA2T Phyto.	9 WA2T Efficacy	13 WA2T Phyto.	13 WA2T Eff.	20 WA2T Phyto.	20 WA2T Efficacy	Av. Phyto.
10 oz/ac	2.8	9.8	949.93	0.73	Control	--	1.2a[≠]	9.8a	2.2a	8.3b	1.6a	7.0a	1.8a	3.8a	1.7a
10 oz/ac	4.7	7.9	235.44	1.39	Tower 6EC	21 oz	3.2b	10b	6.4bc	8.3b	6.4b	8.7b	5.3b	4.0a	5.0b
10 oz/ac	3.7	9.3	674.38	0.9	Tower 6EC + Dimension 2EW	21 oz + 2 pt.	4.5bc	10b	5.3b	10c	6.4b	10b	4.7b	4.0a	5.2b
10 oz/ac	3.7	5.3	96.74	1	Pennant Magnum	2 pt.	4.8c	10b	6.9c	10c	8.1c	8.7b	6.0b	**7.0b**	6.5b
10 oz/ac	3.1	6.6	171.85	1.1	Pennant Magnum + Tower 6EC	2 pt. + 21 oz	4.2bc	10b	7.6c	10c	8.8c	10b	5.3b	4.0a	6.5b

B. *Coreopsis verticillata* 'Sassy Saffron'

Initiation – Dec 20, 17 1st round: Pre-plant -SureGuard applied across field	21 WAT 1st round Ht (in) Planted 5/07/18	20 WA2T Ht (in)	20 WA2T GI (in)^3	21 WAT 1st round Shoot Wt. (g) Planted 5/07/18	Treatment 2nd Applied 05/16/2018 21 WAT 1st round	Rate/ac	4 WA2T[z] & 25 WAT Phyto.[y]	4 WA2T 25 WAT Efficacy[x]	9 WA2T Phyto.	9 WA2T Efficacy	13 WA2T Phyto.	13 WA2T Eff.	20 WA2T Phyto.	20 WA2T Efficacy	Av. Phyto.
10 oz/ac	1.2	9.5	1655.8	0.5	Control	--	0.8a[≠]	10a	2.7a	10a	1.2a	7.5a	0.8a	4.8a	1.4a
10 oz/ac	0.8	8.8	761.3	0.3	Tower 6EC	21 oz	6.1c	10a	5.2b	10a	2.7b	10b	**2.7b**	**8.3b**	4.2b
10 oz/ac	0.6	9.8	1045.6	0.4	Tower 6EC + Dimension 2EW	21 oz + 2 pt.	6.8c	10a	6.0b	10a	3.9b	9.0b	3.2b	**8.7bc**	5.0b
10 oz/ac	0.4	10.7	1260.6	0.2	Pennant Magnum	2 pt.	3.2b	10a	3.1a	10a	1.4a	9.67b	**2ab**	**8.7bc**	2.4a
10 oz/ac	1.2	9.3	1217.6	0.4	Pennant Magnum + Tower 6EC	2 pt. + 21 oz	6.7c	10a	5.8b	10a	3.0b	10b	**2.3b**	**10c**	4.5b

C. *Sanguisorba minor* 'Little Angel'

Initiation – Dec 20, 17 1st round: Pre-plant -SureGuard applied across field	21 WAT 1st round Ht (in) Planted 5/07/18	20 WA2T Ht (in)	20 WA2T GI (in)^3	21 WAT 1st round Shoot Wt. (g) Planted 5/07/18	Treatment 2nd Applied 05/16/2018 21 WAT 1st round	Rate/ac	4 WA2T[z] & 25 WAT Phyto.[y]	4 WA2T 25 WAT Efficacy[x]	9 WA2T Phyto.	9 WA2T Efficacy	13 WA2T Phyto.	13 WA2T Eff.	20 WA2T Phyto.	20 WA2T Efficacy	Av. Phyto.
10 oz/ac	1.2	2.8	155.9	0.5	Control	--	1.0a	8.8a	1.2a	7a	1.1a	5.5a	0.8a	5.5a	1.0a
10 oz/ac	0.8	1.8	53.5	0.3	Tower 6EC	21 oz	1.9ab	9.8a	5.8b	9b	5.1b	8.7bc	4.3bc	**8.7bc**	4.3b
10 oz/ac	0.6	1.7	15.5	0.4	Tower 6EC + Dimension 2EW	21 oz + 2 pt.	2.8b	10a	8.4c	10b	8.1c	10c	7.1d	**10c**	6.6c
10 oz/ac	0.4	2.3	75.6	0.2	Pennant Magnum	2 pt.	1.9ab	10a	5.7b	10b	5.9b	10c	**3.7b**	**10c**	4.3b

| 10 oz/ac | 1.2 | 1.5 | 35.5 | 0.4 | Pennant Magnum + Tower 6EC | 2 pt. + 21 oz | 1.8ab | 10a | 7.4c | 10b | 7.4c | 8.3b | 5.3c | **8.3b** | 5.5bc |

D. *Kniphofia thomsonii 'Gold Rush'*

Initiation – Dec 20, 17 1st round: Pre-plant -SureGuard applied across field	21 WAT 1st round Ht (in) Planted 5/07/18	20 WA2T Ht (in)	20 WA2T GI (in)³	21 WAT 1st round Shoot Wt. (g) Planted 5/07/18	Treatment 2nd Applied 05/16/2018 21 WAT 1st round	Rate/ac	4 WA2T[z] & 25 WAT Phyto.[y]	4 WA2T 25 WAT Efficacy[x]	9 WA2T Phyto.	9 WA2T Efficacy	13 WA2T Phyto.	13 WA2T Eff.	20 WA2T Phyto.	20 WA2T Efficacy	Av. Phyto.
10 oz/ac	2.8	11.6	13603	5.96	Control	--	0.0a	9.2a	0	4.8	0	3.8	0	3.8	0
10 oz/ac	3.9	11.0	14927	9.67	Tower 6EC	21 oz	1.4ab	10a	2.1	8.7	2.7	10	**2.3**	**10**	2.1
10 oz/ac	5.1	11.7	12478	10.77	Tower 6EC + Dimension 2EW	21 oz + 2 pt.	0.4ab	10a	1.9	6.7	1.7	7.7	**3.0**	**7.7**	1.8
10 oz/ac	4.7	11.1	14384	8.78	Pennant Magnum	2 pt.	1.1ab	10a	1.4	10	0.7	7.0	**1.7**	**7.0**	1.2
10 oz/ac	3.2	12.3	13628	7.7	Pennant Magnum + Tower 6EC	2 pt. + 21 oz	0.7ab	10a	1.2	10	1.0	6.3	**2.0**	6.3	1.2

E. *Kniphofia pyromania*™ series 'Orange Blaze'

Initiation – Dec 20, 17 1st round: Pre-plant -SureGuard	21 WAT 1st round Ht (in)	20 WA2T Ht (in)	20 WA2T GI (in)^3	21 WAT 1st round Shoot Wt. (g)	Treatment 2nd Applied 05/16/2018 21 WAT	Rate/ac	4 WA2T^z & 25 WAT Phyto.^{y}	4 WA2T 25 WAT Eff.^{x}	9 WA2T Phyto.	9 WA2T Eff.	13 WA2T Phyto.	13 WA2T Eff.	20 WA2T Phyto.	20 WA2T Efficacy	Av. Phyto.
10 oz/ac	2.8	22.6	10155	7	Control	--	0.3a	8.6a	0a	6a	2c	6a	1.3ab	6a	0.9
10 oz/ac	3.9	24.9	12696	10.2	Tower 6EC	21 oz	0.4a	10a	1.1ab	10c	0.5ab	8.3b	**1.3ab**	**8.3b**	0.8
10 oz/ac	5.1	19.9	596.2	6.1	Tower 6EC + Dimension 2EW	21 oz + 2 pt.	0.3a	10a	1ab	10c	0a	8b	**1.5b**	**8b**	0.7
10 oz/ac	4.7	23.4	8391	9.7	Pennant Magnum	2 pt.	0.9a	10a	0.6ab	10c	0.8ab	9b	**1.3ab**	**9b**	0.9
10 oz/ac	3.2	20.8	8220	10.7	Pennant Magnum + Tower 6EC	2 pt. + 21 oz	1.3a	10a	1.5b	10c	0a	9b	**2b**	**9b**	1.2
10 oz/ac	2.8	29.9	12801	6	FreeHand 1.75G	150 lb	0.4a	10a	1.8b	10c	0a	9.3b	**2.5b**	**9.3b**	1.2
10 oz/ac	3.9	24.6	7378	9.7	Fortress	150 lb	0.1a	9.7a	0.6ab	8b	1ab	8b	**0.8ab**	**8b**	0.6
10 oz/ac	5.1	26.3	11918	10.8	Marengo G	200 lb	0a	9.5a	0.3ab	6.8a	1.5bc	8.3b	**0.3ab**	**8.3b**	0.5

F. *Penstemon 'Prairie Dusk'*

Initiation – Dec 20, 17 1st round: Pre-plant -SureGuard	21 WAT 1st round Ht (in)	20 WA2T Ht (in)	20 WA2T GI (in)^3	21 WAT 1st round Shoot Wt. (g)	Treatment 2nd Applied 05/16/2018 21 WAT	Rate/ac	4 WA2T^z & 25 WAT Phyto.^{y}	4 WA2T 25 WAT Efficacy^x	9 WA2T Phyto.	9 WA2T Efficacy	13 WA2T Phyto.	13 WA2T Eff.	20 WA2T Phyto.	20 WA2T Efficacy	Av. Phyto.
10 oz/ac	4.3	6.9	684.2	2.2	Control	--	1.2a	10a	0.7a	7a	2.6a	3a	0a	3a	1.1
10 oz/ac	3.2	4.6	305.2	2.2	Tower 6EC	21 oz	4.2c	10a	3.8b	10b	4.6bc	8bc	**2bc**	**8bc**	3.7
10 oz/ac	2	4.5	292.5	2.0	Tower 6EC + Dimension 2EW	21 oz + 2 pt.	5.7c	10a	6c	10b	5.7c	10d	3.3c	**10d**	5.2

| 10 oz/ac | 3.2 | 5.1 | 456.2 | 2.5 | Pennant Magnum | 2 pt. | 2.6a | 10a | 3.5b | 10b | 3.8ab | 7b | **1.7b** | **7b** | 2.9 |
| 10 oz/ac | 2.6 | 5.0 | 324.1 | 3.0 | Pennant Magnum + Tower 6EC | 2 pt. + 21 oz | 2.4a | 10a | 5c | 10b | 4.4bc | 9.3cd | **2.3bc** | **9.3cd** | 3.5 |

### G. *Penstemon 'Midnight Masaquerade'*

Initiation – Dec 20, 17 1st round: Pre-plant -SureGuard	21 WAT 1st round Ht (in)	20 WA2T Ht (in)	20 WA2T GI (in)^3	21 WAT 1st round Shoot Wt. (g)	Treatment 2nd Applied 05/16/2018 21 WAT	Rate/ac	4 WA2T[z] & 25 WAT Phyto.[y]	4 WA2T 25 WAT Efficacy[x]	9 WA2T Phyto.	9 WA2T Efficacy	13 WA2T Phyto.	13 WA2T Eff.	20 WA2T Phyto.	20 WA2T Efficacy	Av. Phyto.
10 oz/ac	4.3	14.5	960.6	2.2	Control	--	0.0a	9.7a	1.2a	8.3ab	1.7b	9.0c	0a	6.6a	1.9
10 oz/ac	3.2	12.5	940.9	2.2	Tower 6EC	21 oz	3.4b	10b	5.7bc	10c	5.7d	7.7ab	**2.7b**	6.8ab	4.4
10 oz/ac	2	10.8	573.7	2.0	Tower 6EC + Dimension 2EW	21 oz + 2 pt.	4.1b	10b	6.9cd	10c	5.8d	9.7c	3.3bc	**8.8c**	5.0
10 oz/ac	3.2	12.7	736.4	2.5	Pennant Magnum	2 pt.	1.0a	10b	5.3b	10c	3.3c	8.7bc	3.3bc	**8.0ab**	3.2
10 oz/ac	2.6	10	458	3.0	Pennant Magnum + Tower 6EC	2 pt. + 21 oz	3.2b	10b	7.3d	10c	7.2d	8.7bc	4.7c	**7.9ab**	5.6
10 oz/ac	4.3	12.8	782.7	2.2	FreeHand 1.75G	150 lb	1.3a	10b	5.0b	9.3bc	1.3ab	7.0a	**0a**	**7.0a**	1.9
10 oz/ac	3.2	14.0	1174.9	2.2	Fortress	150 lb	0.1a	10b	0.4a	10c	0a	9.3c	**0a**	**8.3bc**	0.1
10 oz/ac	2	13.2	850.4	2.0	Marengo G	200 lb	1.0a	10b	0.7a	7.7a	1ab	10c	**0a**	**9.7c**	0.7

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 = Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

≠ = Treatments with different letters signify efficacy was statistically different at p=0.05 using LS means following ANOVA in SAS.
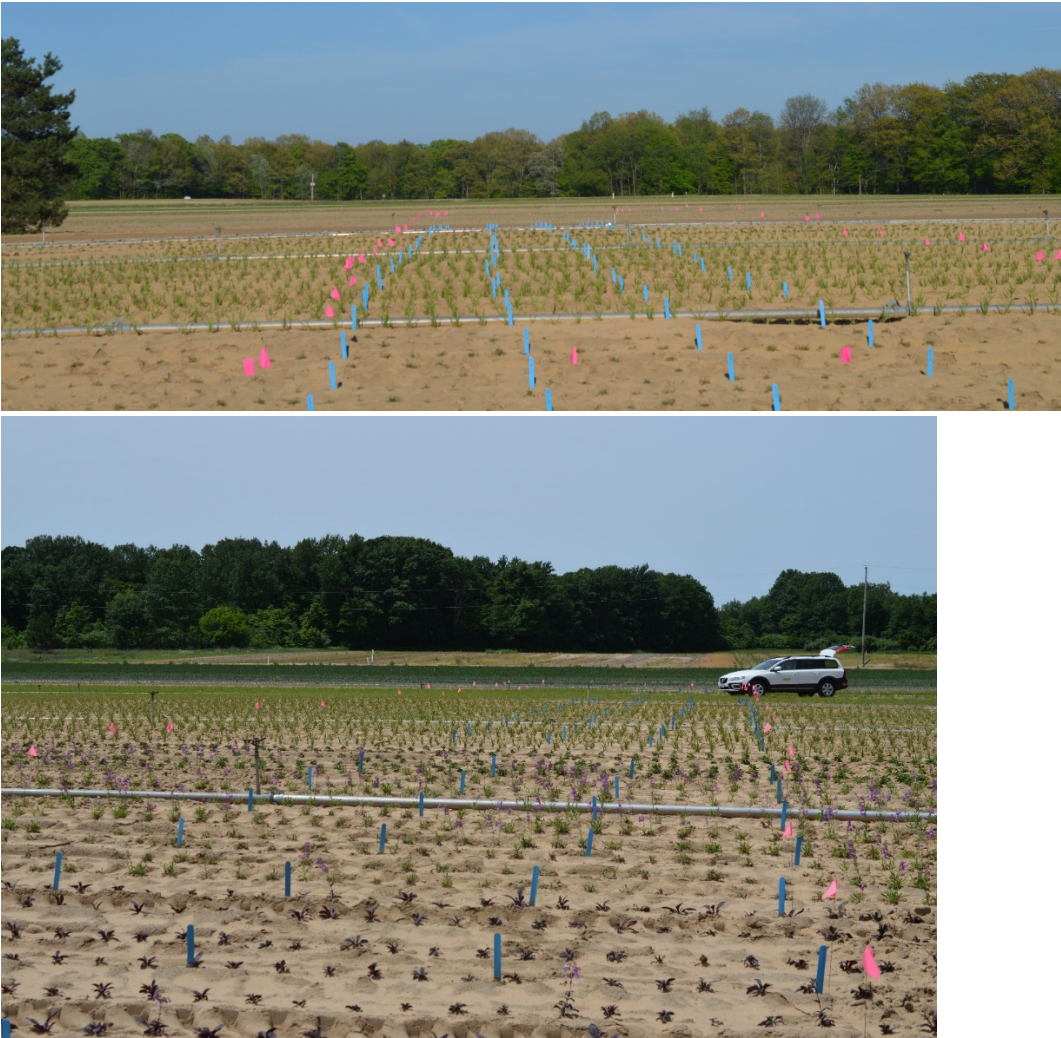
Fig. 4 Walters Gardens, Zeeland, MI first trial initiation showing half of the trial (top) and other half (bottom) that contained seven species and five to eight treatments depending on species with three replicates and 18 subsamples per replicate or 56 plants per treatment per species. Note all plants had just been planted as small plugs from the greenhouse one week before and were in very tender growth.

Table 3. Walters Gardens, Zeeland, MI four species as listed at the top of each sub-table were evaluated with the herbicides listed on **July 18, 2018**. Each phytotoxicity mean represents four replications, of three rows of plants, with 6 plants per row, for a total of 72 plants/mean (Fig. 5). The field was periodically hand weeded by the grower and thus it became a phytotoxicity trial. Shoot heights and two perpendicular measures of width were collected at the trial initiation and end. These were put into an equation to calculate Growth index values (GI) (see footnotes at bottom of table D). Phytotoxicity and efficacy ratings are explained in the footnotes and occurred at 4 weeks after treatment (4 WAT). At 11 WAT only phytotoxicity was recorded. Various herbicides were applied to fulfill Obj. 1, 2 and 3.

A. *Coreopsis verticillata* 'Red Hot Vanilla'

Treatment	Rate (/ac)[V]	Initial Ht[i] (in)	Initial GI (in)³	Ending Ht (in)	Ending GI (in)³	4 WAT[z] Efficacy[x]		4 WAT Phytotoxicity		11WAT Efficacy	11WAT Phytotoxicity		Δ[w]GI		Av Phy	
Gemini G	200 lb	19.5	3002	20.0	5003	10	b[≠]	0.1	a	--	0	a	2001	ns	0.05	a
Biathlon	100 lb	14	2004	17.8	4310	9	b	0.5	a	--	0	a	2306	ns	0.3	a
FreeHand 1.75G	150 lb	16	2642	17	4757	9.6	b	0	a	--	0	a	2115	ns	0	a
Fortress	150 lb	16.5	2600	17	4232	10	b	1.1	a	--	1.0	a	1632	ns	1.1	a
Control	--	16	2675	18	4399	7.0	a	0	a	--	0	a	1724		0	a

B. *Coreopsis verticillata* 'Curry Up'

Treatment	Rate (/ac)[V]	Initial Ht (in)	Initial GI (in)³	Ending Ht (in)	Ending GI (in)³	4 WAT[z] Efficacy	4 WAT Phytotoxicity		11WAT Efficacy	11WAT Phytotoxicity		ΔGI		Av Phy	
Gemini G	200 lb	14	2124	14.5	2217	9	0.4	a	--	0.3	a	93	ns	0.4	a
Biathlon	100 lb	13	1470	15.4	2414	8	0.3	a	--	0.3	a	944	ns	0.3	a
FreeHand 1.75G	150 lb	11	1143	15.6	2657	9.3	0.8	a	--	0	a	1514	ns	0.4	a
Fortress	150 lb	14	1579	15.5	2062	8.0	0	a	--	0	a	483	ns	0	a
Control	--	13	1967	14.4	2115	6.5	0.2	a	--	0	a	148		0.1	a

C. *Vernonia* 'Southern Cross'

Treatment	Rate (/ac)[V]	Initial Ht[i] (in)	Initial GI (in)³	Ending Ht (in)	Ending GI (in)³	4 WAT[z] Efficacy[x]		4 WAT Phytotoxicity		11WAT Efficacy	11WAT Phytotoxicity		ΔGI		Av Phy	
Gemini G	200 lb	15	1063	20.6	7269	8	b	4	c	--	2	b	6206	ns	3	c
Biathlon	100 lb	14	891	22.3	8197	8.3	b	2.1	bc	--	0	a	7306	ns	1.1	ab
FreeHand 1.75G	150 lb	17	1810	19	6401	8	b	1.5	b	--	2.2	b	4591	*	1.9	b
Fortress	150 lb	14	1212	21	7205	10	c	3	bc	--	2	b	5993	ns	2.5	bc
Control	--	15	1207	19	7620	6	a	0	a	--	0	a	6413		0	a

D. *Aster novae-angliae* 'Purple Dome'

Treatment	Rate (/ac)[V]	Initial Ht (in)	Initial GI (in)³	Ending Ht (in)	Ending GI (in)³	4 WAT[z] Efficacy		4 WAT Phytotoxicity		11WAT Efficacy	11WAT Phytotoxicity		Δ[w]GI		Av Phy	
Gemini G	200 lb	7	445	19	4316	9.8	b	3.4	a	--	0.2	a	3871	ns	1.8	a
Biathlon	100 lb	7	397	19.8	4800	10	b	3.5	a	--	1.6	bc	4403	ns	2.6	a
FreeHand 1.75G	150 lb	9	634	20.7	5048	9	ab	3.5	a	--	1.0	ab	4414	ns	2.3	a
Fortress	150 lb	8	567	15.6	3865	8.5	ab	3.6	a	--	2.6	c	3298	*	3.1	a
Control	--	7.8	564	19.8	4697	7.8	a	3.9	a	--	1.6	bc	4133		2.8	a

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 = Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

≠ = Treatments with different letters signify efficacy was statistically different at p=0.05 using LS means following ANOVA in SAS.

ns = not significant and * means significant reduction relative to the control with Dunnett's t-test at p=0.05.

i = HT represents Height at start of trial and at the end of the trial.

t = GI represents Growth index (in³) and was calculated as GI=Pi (Ht)(r2), where Ht. (in) was the starting or final height, respectively, r was half of the average of W1+W2 (two perpendicular measurements taken of plant diameter (in)) and Pi was "π". The GI provides a volume measure of the plant which helps with quality determinations not necessarily evident by heights and widths alone or by visual observations.

w = Δ represents delta or the change in average heights and average GI's from the start to completion of the trial.

Fig. 5 Walters Gardens, Zeeland, MI second trial initiation showing *Coreopsis verticillata* 'Curry Up' (left) and *Coreopsis verticillata* 'Red Hot Vanilla' on July 18, 2018. Applications were made over the top of actively growing plants results are shown in Table 3. There were four replicates and 18 subsamples per replicate or 72 plants per treatment per species.

Table 4 A and B. Walters Gardens, Zeeland, MI Hosta planted October 9, 2018, 4 replications, initiated **04/24/2019**. The Hosta (A) were dormant at application (Fig. 6), with only grass seeded for winter protection showing. However, the daylilies (B) were actively growing (Fig. 8). The field was periodically hand weeded by the grower and thus the efficacy ratings may not be correct but are relative to the control. Shoot heights and two perpendicular measures of width were collected at 7 WAT for the Hosta again because they were dormant at initiation. The daylily growth measures were taken at trial initiation as they were not dormant. The growth measures for Hosta and daylily were put into an equation to calculate Growth Index values (GI) (see footnotes at bottom of table B). Phytotoxicity and efficacy ratings are explained in the footnotes and occurred at 7 weeks after treatment (7 WAT), 12 and 17 WAT. Various herbicides were applied to fulfill Obj. 1, 2 and 3.

A. *Hosta 'Francee'*

	Treatment Applied 04/24/2019 Dormant Hosta	Rate/ac	7 WAT[z] Phyto.[y]	7 WAT Efficacy[x]	12 WAT Phyto.	12 WA1T Eff.	17 WAT Phyto.	17 WAT Efficacy	Av. Phyto.	Av. Eff.	Av GI [t]
1	Basagran T/O	24 oz	2.6bc[≠]	9.7a	1.0a	7.0bc	0.7a	6.5b	1.4	7.7	3540.4a
2	Dimension 2EW + Pennant Magnum	2 pt + 2 pt	2.8bc	10a	3.0b	9.5d	2.5bc	8.9c	2.8	**9.5**	3439.9a
3	Tower 6EC + Basagran	15.8 oz + 12oz	2.6bc	9.6a	3.3b	7.0bc	3.9c	5.7b	**3.3**	7.4	4944.9b
4	Tower 6EC + Basagran	10.5 oz + 24oz	3.3bc	10a	3.0b	6b	2.3b	4.0a	2.9	6.7	3309.5a
5	Indaziflam	7 oz	2.8bc	10a	3.0b	7.0bc	3.8c	6.3b	3.2	7.8	3825.5a
6	Fortress	150 lb.	1.9b	9.8a	0a	8.1cd	0a	6.3b	0.6	8.1	4124.6ab
7	Marengo G	200 lb.	0a	10a	0a	9.0d	0a	8.5c	**0.0**	9.2	**7155.2c**
8	Control	--	1.0ab	9.5a	1.0a	4.0a	1.0a	3.0a	**1.0**	**5.5**	5623.2bc

Fig. 6. (left) *Hosta 'Francee'* Walters Gardens, Zeeland, MI planted October 9, 2018, 4 replications, initiated **04/24/2019**. The Hosta were dormant at application. Only grass seeded for winter protection was showing.

Fig. 7 A, B and C. (Right and below) *Hosta 'Francee'* Walters Gardens, Zeeland, MI planted October 9, 2018, 4 replications, initiated **04/24/2019**. **(A)** (Right) The best treatment from Table 4A, measure by zero phytotoxicity and excellent weed control 17 weeks after treatment (WAT) was treatment 7 (Marengo G). The increase in plant mass, measured as Growth index (GI), (Table 4A) is evident relative to the chalk board with treatment 7 (Marengo G) versus treatment 4 **(B)** (Lower left) (Tower 6EC + Basagran) and **(C)** (Lower right) the control, both of which provided non-commercially acceptable weed control at 17 WAT.

B. Stella D'Oro daylily (*Hemerocallis* 'Stella D'Oro')

	Treatment Applied 04/24/2019 Dormant Hosta	Rate/ac	7 WAT[z] Phyto.[y]	7 WAT Efficacy[x]	12 WAT Phyto.	12 WA1T Eff.	17 WAT Phyto.	17 WAT Efficacy	Av. Phyto.	Starting Av GI [t]
1	Basagran T/O	24 oz	1.5b≠	10a	0	10a	0a	10a	0.5a	499.2d
2	Dimension 2EW + Pennant Magnum	2 pt + 2 pt	5.3c	10a	4.2	10a	3.0c	10a	4.2d	405.2bc
3	Tower 6EC + Basagran	15.8 oz + 12oz	5.2c	10a	3.0	10a	1.5b	10a	**3.2cd**	253.4a
4	Tower 6EC + Basagran	10.5 oz + 24oz	2.3b	10a	1.5	10a	1.0a	10a	1.6b	454.7cd
5	Marengo SC	7 oz	2.2b	10a	2.0	10a	1.4ab	10a	1.9bc	336.7ab
6	Fortress	150 lb.	1.4ab	10a	1.0	10a	0.8a	10a	1.1ab	318.5a
7	Marengo G	200 lb.	0a	10a	0	10a	0a	10a	**0a**	**255.9a**
8	Control	--	0.7a	10a	0.3	10a	0.3a	10a	0.4a	295.7a

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 = Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

≠ = Treatments with different letters signify efficacy was statistically different at p=0.05 using LS means following ANOVA in SAS.

t = GI represents Growth index (in³) and was calculated as GI=Pi (Ht)(r2), where Ht. (in) was the starting or final height, respectively, r was half of the average of W1+W2 (two perpendicular measurements taken of plant diameter (in)) and Pi was "π". The GI provides a volume measure of the plant which helps with quality determinations not necessarily evident by heights and widths alone or by visual observations.

Fig. 8. (Left) *Hemerocallis* 'Stella D'Oro' at Walters Gardens, Zeeland, MI planted October 9, 2018, 4 replications, initiated **04/24/2019**. The daylily was actively growing at application as shown.
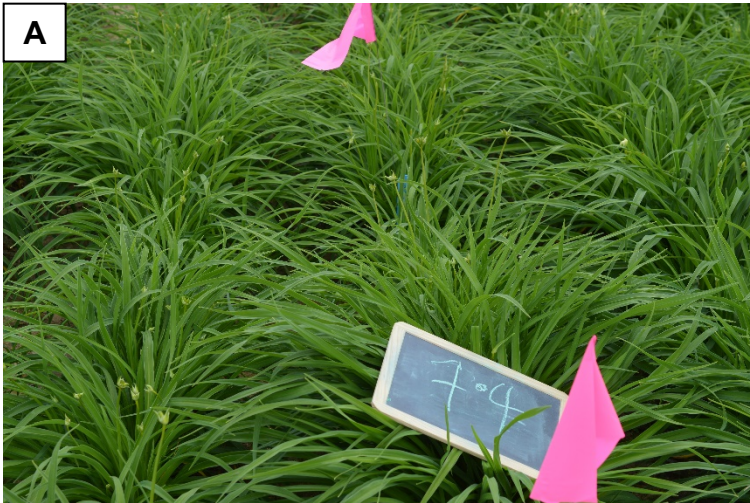
Fig. 9. **A, B and C. (Left and below)** *Hemerocallis* 'Stella D'Oro' Walters Gardens, Zeeland, MI planted October 9, 2018, 4 replications, initiated **04/24/2019**. **(A)** (Left) The best treatment from Table 4B, measure by zero phytotoxicity and perfect weed control 17 weeks after treatment (WAT) was Treatment 7 (Marengo G) (Table 4B). The decrease in plant mass resulting from increased average phytotoxicity for Treatment 2 **(B)** (Dimension 2EW + Pennant Magnum) and Treatment 3 **(C) (**Tower 6EC + Basagran) (Table 4B) are evident along with increased yellowing with Treatment 2 and to a lesser extent Treatment 3.

Table 5. Walters Gardens, Zeeland, MI Marengo Flo Trial on Fall 2018 planted Stella de Oro daylily (*Hemerocallis* 'Stella D' Oro'). Trial initiated in **02/2019**. First evaluation 04/24/2019 including measures for growth index (GI) calculations. At 21 WAT application the 6 oz Marengo was applied to the plots that had received 9 oz Marengo in November 2018, i.e. treatments 5 and 6. Only the July 15, 6 oz applications of Marengo used 100 gal/ac rates, all others were applied in 30 gal/ac of water. All Marengo applications with the exception of the July 15, 2019 6 oz applications include Roundup 32 oz + Salvo 16oz. Additional treatment 2 which represented the conventional practice at Walters Gardens contained Gallery 32 oz versus Marengo and Pendulum 64 oz. The whole trial was hand weeded before the 25 WAT evaluations so although efficacy scores were collected the ratings have no value and are not presented. Each mean represents the values of three rows and 4 replications. Shoot heights and two perpendicular measures of width were collected at 10 WAT for the daylilies as a measure of treatment impacts on growth. The growth measures were put into an equation to calculate Growth Index values (GI) (see footnotes at bottom of table). Phytotoxicity and efficacy ratings are explained in the footnotes and occurred at 10 weeks after treatment (10 WAT), 17 WAT and 25 WAT. The 25 WAT also occurred 4 weeks after the July applications or 4WA2T. This study meets objective 3 and 4 for season-long environmentally sound program development using newer herbicides compared to older less environmentally sound herbicides.

Tmt No.	Rate (oz/A)	Application Timing	Notes	10 WAT [z] Phyto. [y]	10 WAT Eff. [x]	10 WAT GI [t]	17 WAT Phyto.	17 WAT Eff.	25 WAT (4 WA2T) Phy.
1	Untreated Check			1.5ab[≠]	8.0a	342.5ab	2.3ab	4.4a	0a
2	Gallery 32oz + Roundup 32 oz + Salvo 16oz + Pendulum 64 oz	Applied mid-October 2018 after fall planting 2018	30 gal/ac	2.5b	8.6ab	273.2a	1.7a	8.8c	1.0a
3	Marengo FLO 12oz + Roundup 32 oz + Salvo 16oz	Feb. 2019 (dormant)	30 gal/ac	0.5a	10c	**551.2c**	**3.3bc**	9.6c	0.8a
4	Marengo Flo 12oz+ Roundup 32 oz + Salvo 16oz	Applied mid-October 2018 after fall planting 2018	30 gal/ac	0.5a	10c	372.7b	3.0bc	9.8c	0.0a
5	Marengo Flo 9oz Roundup 32 oz + Salvo 16oz followed by 6oz Marengo	Nov. 2018 followed by July 15 app.	9oz at 30 gal/ac Apply 6 oz in 100 gal/A **not washed off**	2.0b	9.9bc	269.6a	2.1a	9.3c	4.7b

| 6 | Marengo 9oz Roundup 32 oz + Salvo 16oz followed by 6oz Marengo | Nov. 2018 followed by July 15 app | 9oz at 30 gal/ac Apply 6 oz in 100 gal/A **washed off** | 2.3b | 10c | 266.9a | **4.2c** | 7.0b | 4.1b |

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 = Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

≠ = Treatments with different letters signify efficacy was statistically different at p=0.05 using LS means following ANOVA in SAS.

t = GI represents Growth index (in^3) and was calculated as GI=Pi (Ht)(r2), where Ht. (in) was the starting or final height, respectively, r was half of the average of W1+W2 (two perpendicular measurements taken of plant diameter (in)) and Pi was "π". The GI provides a volume measure of the plant which helps with quality determinations not necessarily evident by heights and widths alone or by visual observations.

Fig. 10. **A, B and C. (Below)** *Hemerocallis* 'Stella D'Oro' Walters Gardens, Zeeland, MI planted October 9, 2018, 4 replications, initiated **04/24/2019**. **(A)** (below left) Treatment 5 and 6 from Table 5, showed increased phytotoxicity when Marengo SC was applied at 6 oz/ac in July 2019. The impact on plant mass and significant chlorosis and necrosis is evident versus **(B and C)**. **(B)** shows the best treatment (Tmt 4) within the blue flags compared to the Control between the orange flags. **(C)** shows the (Control) at 25 weeks after treatment (WAT).
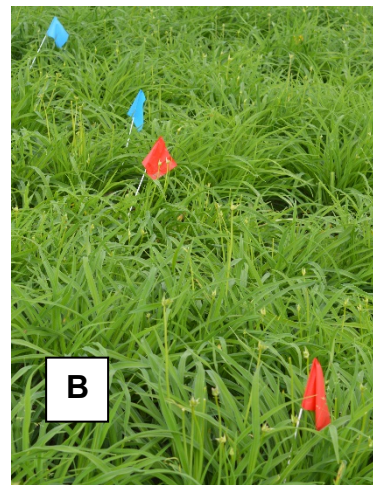
Table 6. Walters Gardens, Zeeland, MI planted spring 2019 'Happy Returns' daylily (*Hemerocallis* 'Happy Returns'). Trial initiated in **06/12/2019**. The growth measures of height and two perpendicular widths were put into an equation to calculate Growth Index values (GI) (see footnotes at bottom of table). Phytotoxicity and efficacy ratings are explained in the footnotes and occurred at 9 weeks after treatment (9WAT). The trial area was hand-weeded before treatments were applied and 579.08 grams of weeds were harvest over the 484 sq. ft areal. No herbicides had been applied to the area before the test treatments on 06/21/2019.

	Treatment Applied 06/12/2019	Rate/ac	19 WAT [z] Phyto. [y]	9 WAT Efficacy [x]	9 WAT Av GI [t]
1	½ X Tower 6EC + ½ X Pennant Magnum	10.5 + 16 oz	2.3bc [≠]	8.3b	1733.6a
2	1X Tower 6EC + ½ X Dimension 2EW	21 oz + 16 oz	1.5ab	8b	2175.4a
3	2/3 X Tower 6EC + ½ X Pennant Magnum	14 oz + 12oz	3.5cd	10c	1625.3ab
4	Tower 6EC + Pendulum Aqua Cap (~150 lb. FreeHand 1.75G)	24 oz + 50.4oz	4.8d	10c	1083.6bc
5	1.5X Tower 6EC + Pendulum Aqua Cap (~200 lb. FreeHand 1.75G)	32 oz + 67.2 oz	4.8d	10c	1430.3b
6	1X Pennant Magnum + Pendulum Aqua Cap	32 oz + 50.4oz	6.5e	10c	750.0c
7	Control	--	0a	4.5a	2167.1a

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 = Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

≠ = Treatments with different letters signify efficacy was statistically different at p=0.05 using LS means following ANOVA in SAS.

t = GI represents Growth index (in^3) and was calculated as GI=Pi (Ht)(r2), where Ht. (in) was the starting or final height, respectively, r was half of the average of W1+W2 (two perpendicular measurements taken of plant diameter (in)) and Pi was "π". The GI provides a volume measure of the plant which helps with quality determinations not necessarily evident by heights and widths alone or by visual observations.

Fig. 11. A, B, C and D. (Above and Left) *Hemerocallis* 'Happy Returns' Walters Gardens, Zeeland, MI planted May 2019, 4 replications, initiated **06/12/2019**. **(A)** (above far left) Treatment 2 (1X Tower 6EC + ½ X Dimension 2EW) from Table 6 was the best treatment with the lowest phytotoxicity of any treatment in this research plot. The impact on plant mass, chlorosis and necrosis was evident with Treatment 5 **(B)** (above middle) and Treatment 4 **(C)** (above far right) relative to Treatment 2 **(A)** and **(D)** (left) the untreated control at 9 WAT.

Table 7. Walters Gardens, Zeeland, MI planted spring 2019 'Captain Kirk' Hosta (Hosta 'Captain Kirk'). Trial initiated in **06/12/2019**. First evaluation First evaluation 9WAT, including measures for growth index (GI) calculations. No herbicides had been applied to the area before the test treatments on 06/21/2019. Area had minimal weed growth before applications and weights were not collected. Phytotoxicity and efficacy ratings are explained in the footnote.

	Treatment Applied 06/12/2019	Rate/ac	9 WAT [z] Phyto. [y]	9 WAT Efficacy [x]
1	½ X Tower 6EC + ½ X Pennant Magnum	10.5 + 16 oz	1.5a[≠]	9.8b
2	1X Tower 6EC + ½ X Dimension 2EW	21 oz + 16 oz	2ab	9b
3	2/3 X Tower 6EC + ½ X Pennant Magnum	14 oz + 12oz	3.5c	10b
4	Tower 6EC + Pendulum Aqua Cap (~150 lb. FreeHand 1.75G)	24 oz + 50.4oz	1.3a	10b
5	1.5X Tower 6EC + Pendulum Aqua Cap (~200 lb. FreeHand 1.75G)	32 oz + 67.2 oz	3.3bc	10b
6	1X Pennant Magnum + Pendulum Aqua Cap	32 oz + 50.4oz	2.3b	9.8b
7	Control	--	0.5a	4a

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 = Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

≠ = Treatments with different letters signify efficacy was statistically different at p=0.05 using LS means following ANOVA in SAS.

Fig. 12. A and B. (Left). *Hosta 'Captain Kirk'* Walters Gardens, Zeeland, MI planted May 2019, 4 replications, initiated **06/12/2019**. **(A)** (Far left) One of the best treatment from Table 7. There were several good treatments in this research plot but (½ X Tower 6EC + ½ X Pennant Magnum) is shown. The efficacy of this treatment regardless of its low phytotoxicity (1.5) is evident compared to **(B)** (left) the control at 9 WAT.

Fig. 13. Lynn Mayer's Great Lakes Glads, Bronson, MI seven treatments applied to **field grown peonies** with eight replications per treatment. The trial was initiated on **03/28/2018** when plants were dormant. The grower assigned an area at the head of a field. Since the plants were dormant some applications were inadvertently conducted on misses in the row. This occurred even in the controls. Evaluations were performed on 05/17/2018 or 7 WAT. Five treatments, including the control, had mean ratings over 3 indicating they injured the peonies more than commercially acceptable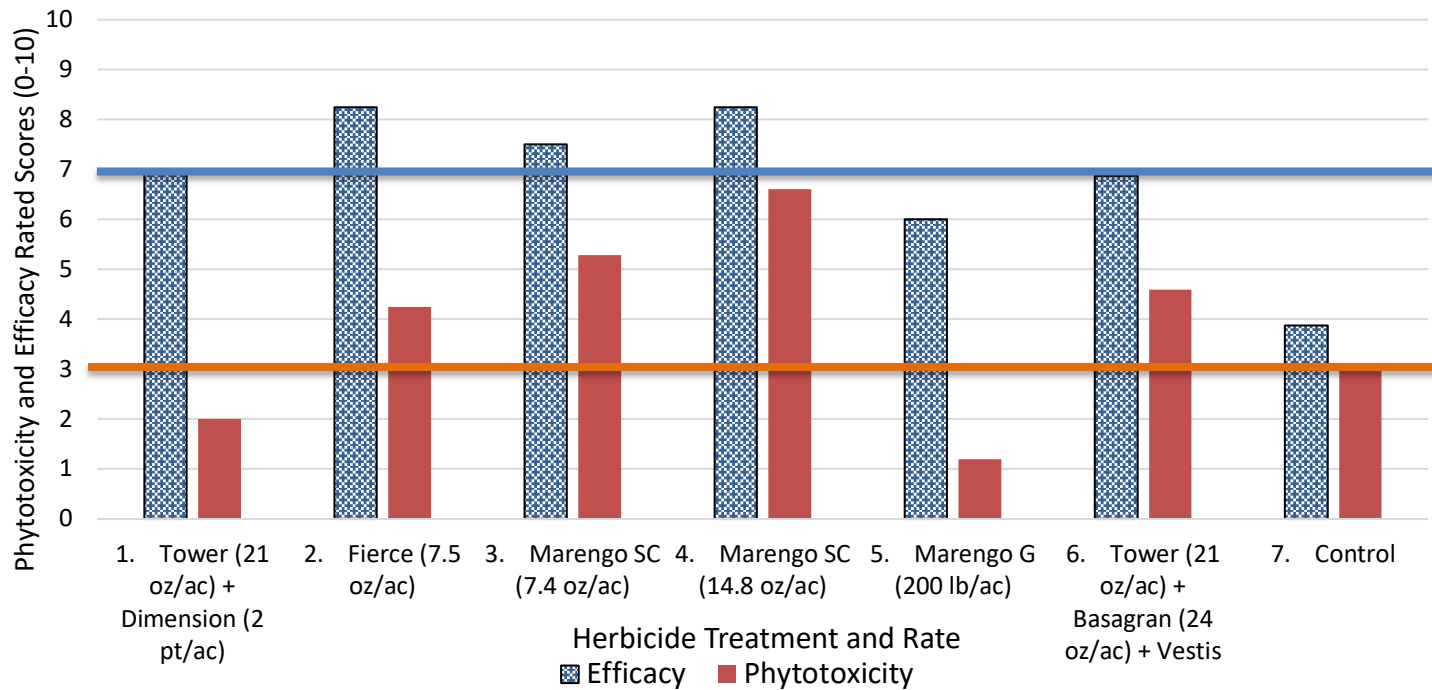. Phytotoxicity ratings based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable. Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

Table 8. Ray Wiegand's Nursery, Lenox, MI five species as listed at the top of each sub-table were evaluated with eight treatments applied **03/30/2018**. Each phytotoxicity mean represents eight replications of one-gallon containerized herbaceous plants. Phytotoxicity and efficacy ratings were taken at 6WAT on May 11, 2018, 11 WAT on June 13, 2018 and 16 WAT, July 19, 2018. Various herbicides applied alone or in combination to fulfill Obj. 1 and 2. Legend at the bottom of sub-table E.

A. *Rudbeckia fulgida* var. Sullivantii 'Little Goldstar'

Treatment	Rate (/ac)^V	6 WAT^z Efficacy		6 WAT Phytotoxicity		11WAT Efficacy		11WAT Phytotoxicity		16 WAT Eff	16 WAT Phyto	Av Eff		Av Phy	
Fortress	150 lb.	10	a	7.50	d	10	a	6.88	d	**9.3d**	6.4c	9.8	d	6.9	d
Biathlon	100 lb.	6.00	b	3.50	ab	10	a	0.00	a	**7c**	4b	7.7	b	2.5	b
Fortress	300 lb.	10	a	4.00	b	10	a	3.50	c	**9d**	3.1ab	9.7	d	3.5	bc
Marengo G	200 lb.	9.63	a	3.00	ab	10	a	1.25	b	4.9b	3.5ab	8.2	bc	2.6	b
Tower 6EC 2X	52 oz	9.88	a	6.13	cd	9.25	a	3.63	c	5.6bc	5bc	8.3	bc	4.9	c
Tower 6EC 1X	26oz	10	a	5.38	bc	9.75	a	2.50	bc	**8.9d**	**2.4a**	9.6	cd	3.4	bc
Tower 6EC + Dimension 2EW	(26 + 2 pt/ac)	10	a	7.38	d	10	a	7.00	d	**9d**	6c	9.6	cd	7.0	d
Control	---	10	a	2.25	a	10	a	2.60	b	0a	2a	6.7	ab	0.7	a

B. *Penstemon schmidel* 'Red Riding Hood'

Treatment	Rate (/ac)^V	6 WAT^z Efficacy		6 WAT Phytotoxicity		11WAT Efficacy		11WAT Phytotoxicity		16 WAT Eff	16 WAT Phyto	Av Eff		Av Phy	
Fortress	150 lb.	10	a	1.38	a	9.75	a	2.38	b	**9.5cd**	**1.0a**	9.8	b	1.6	bc
Biathlon	10 lb.	9.38	a	0.00	a	3.00	b	2.00	b	5.4b	4.8d	5.9	a	2.3	bc
Fortress	300 lb.	10	a	1.38	a	10	a	0.63	a	**10d**	**0.4a**	10	b	0.8	ab
Marengo G	200 lb.	9.75	a	1.00	a	10	a	0.00	a	6.4b	**2.5bc**	8.7	b	1.2	ab
Tower 6EC 2X	52 oz	8.75	a	0.63	a	9.38	a	2.38	b	**8.3c**	**1.9b**	8.8	b	1.6	bc
Tower 6EC 1X	26oz	10	a	0.00	a	9.88	a	0.38	a	**9cd**	**1.3ab**	9.6	b	0.6	ab
Tower 6EC + Dimension 2EW	(26 + 2 pt./ac)	10	a	6.88	c	10	a	6.63	c	**9.1cd**	6.4e	9.7	b	6.6	d
Control	---	9.60	a	2.80	b	9.60	a	2.80	b	0a	3c	6.4	a	2.9	c

C. *Panicum virgatum* 'Shenandoah'

Treatment	Rate (/ac)[v]	6 WAT[z] Efficacy		6 WAT Phytotoxicity		11WAT Efficacy		11WAT Phytotoxicity		16 Wat Eff	16 WAT Phy	Av Eff		Av Phy	
Fortress	150 lb.	9.38	ab	0.25	ab	7.13	c	3.25	b	**7.9c**	**1.0a**	8.1	d	1.5	ab
Biathlon	10 lb.	4.50	c	0.00	a	3.13	b	3.13	b	2a	3.3c	3.6	b	2.1	b
Fortress	300 lb.	8.13	b	1.25	ab	6.38	c	2.00	ab	5.3b	**2.5bc**	6.6	c	1.9	b
Marengo G	200 lb.	4.88	c	1.88	b	3.75	b	2.38	b	5.0b	**2.6bc**	4.6	b	2.3	b
Tower 6EC 2X	52 oz	8.00	b	1.63	b	8.00	c	2.25	ab	5.9b	**1.4ab**	7.3	cd	1.6	b
Tower 6EC 1X	26oz	8.13	b	2.75	c	8.00	c	1.88	ab	5.8b	**1.6b**	7.3	cd	2.1	b
Tower 6EC + Dimension 2EW	(26 + 2 pt./ac)	10	a	1.88	b	10	d	0.88	a	**10d**	**0a**	10	e	0.9	ab
Control	---	0.00	d	5.00	d	0	a	5.00	c	0a	2bc	0	a	4.0	c

D. *Iris sibirica* 'Sparkling Rose'

Treatment	Rate (/ac)[v]	6 WAT[z] Efficacy		6 WAT Phytotoxicity		11WAT Efficacy		11WAT Phytotoxicity		16 WAT Eff	16 WAT Phy	Av Eff		Av Phy	
Fortress	150 lb.	8.88	ab	2.25	bc	8.38	bc	1.88	b	**8.9cd**	**0.8ab**	8.7	bc	1.7	b
Biathlon	10 lb.	8.00	a	2.0	bc	6.00	a	2.00	b	**7.0b**	**1.8bc**	7.0	a	1.9	b
Fortress	300 lb.	9.5	b	1.25	ab	10	d	0.25	a	**9.5d**	**0.1a**	9.7	c	0.6	ab
Marengo G	200 lb.	8.63	ab	2.25	bc	7.50	b	0.38	a	**7.8bc**	**1.0ab**	8.0	ab	1.2	ab
Tower 6EC 2X	52 oz	9.13	b	0.88	a	9.63	cd	0.00	a	**9.6d**	**1.8bc**	9.4	c	0.9	ab
Tower 6EC 1X	26oz	10	b	3.38	c	10	d	1.25	ab	**10d**	**0.4ab**	10	c	1.7	b
Tower 6EC + Dimension 2EW	(26 + 2 pt./ac)	9.88	b	0.75	a	9.75	d	0.38	a	**9.4d**	3.0c	9.7	c	1.4	ab
Control	---	10	b	0.00	a	9.75	d	1.00	ab	0a	0a	6.6	a	0.3	a

E. *Asclepias incarnata*

Treatment	Rate (/ac)[v]	6 WAT[z] Efficacy		6 WAT Phytotoxicity		11WAT Efficacy		11WAT Phytotoxicity		16 WAT Eff	16 WAT Phy	Av Eff		Av Phy	
Fortress	150 lb.	10	b	5.63	c	9.5	b	0.50	ab	**9.5cd**	**0.6a**	9.7	b	6.7	d
Biathlon	10 lb.	9.00	b	2.50	ab	8.50	b	0.75	ab	**7.9b**	**0a**	8.5	b	1.1	ab
Fortress	300 lb.	10	b	2.00	a	9.88	b	0.13	a	**9.9cd**	**0a**	9.9	b	0.7	ab
Marengo G	200 lb.	9.63	b	3.88	b	9.00	b	0.38	ab	**9.5cd**	**0a**	9.4	b	1.4	ab
Tower 6EC 2X	52 oz	9.63	b	8.38	d	9.75	b	4.63	d	**9.3bcd**	**1.0a**	9.6	b	4.7	c
Tower 6EC 1X	26oz	9.63	b	3.00	ab	9.25	b	1.13	ab	**8.4bc**	**0a**	9.1	b	1.4	ab

Tower 6EC + Dimension 2EW	(26 + 2 pt./ac)	10	b	8.13	d	10	b	1.88	bc **10d**	**0.8a**	10	b	3.6	c
Control	---	5.33	a	3.00	ab	2.00	a	3.00	c	0a	0a	2.4	a	2.0	b

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 = Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

≠ = Treatments with different letters signify efficacy was statistically different at p=0.05 using LS means following ANOVA in SAS.

ns = not significant and * means significant reduction relative to the control with Dunnett's t-test at p=0.05.

Fig. 14. Ray Wiegand's Nursery, Lenox, MI trial initiation with eight treatments, five species and eight replicates per species and treatment. Treatments were applied in a polyhouses with end walls open for air circulation on 03/30/2018. Note all plants were dormant at time of application except for the *Penstemon schmidel* 'Red Riding Hood' which was actively growing. The *Rudbeckia fulgida* 'Little Goldstar' was also just beginning to grow.

Table 9. Ray Wiegand's Nursery, Lenox, MI five species were originally evaluated. Unfortunately, some very cold temperatures were experienced in the over wintering houses at the end of January that killed *Lavandula angustifolia* 'Hidcote Blue' and *Coreopsis* 'Red Elf' (Li'l Bang™ Series) both zone 5 plants. The remaining three species are labelled at the top of each sub-table, with the five treatments that were applied and observed between 07/19/2018 to 04/25/2019. Each phytotoxicity mean represents six replications of one-gallon containerized herbaceous plants. Phytotoxicity and efficacy ratings were taken after overwintering to observe phytotoxicity and efficacy of late summer application 40 WAT. Only granular herbicides newer in the ornamental market were applied. Legend at the bottom of sub-table c.

A. Hemerocallis **'Going Banana's'**

Treatment	Rate (/ac)^V	Starting GI's	40 WAT Phytotoxicity		40 WAT Efficacy		Ending GI		40 WAT Weed Weight
Gemini G	200 lb.	13273.2	1.2	ab	7.0	b	1083.2		62.2
Biathlon	100 lb.	11785.9	2.3	b	8.6	c	386.7		35.6
FreeHand 1.75G	150 lb.	14335.1	1.0	ab	7.6	bc	675.0		25.2
Fortress	150 lb.	13131.4	1.0	ab	7.7	bc	1118.8		37.8
Control	---	13243.4	0.7	a	4.0	a	1251.9		88.8

B. Sedum spurium **'Dragon Blood'**

Treatment	Rate (/ac)^V	Starting GI's	40 WAT Phytotoxicity		40 WAT Efficacy		Ending GI		40 WAT Weed Weight
Gemini G	200 lb.	433.0	6.0	c	8.6	b	295.6		10.4
Biathlon	100 lb.	475.2	2.8	b	9.2	b	505.0		3.2
FreeHand 1.75G	150 lb.	170.2	2.2	b	10.0	b	800.0		0.0
Fortress	150 lb.	180.9	2.8	b	9.6	b	319.3		2.1
Control	---	171.7	0.6	a	4.0	a	311.0		71.2

C. Echinacea purpurea **'Pow Wow™ White'**

Treatment	Rate (/ac)^V	Starting GI's	40 WAT Phytotoxicity		40 WAT Efficacy		Ending GI (cu in)		40 WAT Weed Weight (g)
Gemini G	200 lb.	603.2	6.2	b	4.8	b	116.5		107.9 c

Biathlon	100 lb.	763.4		8.2	c	4.2	b	13.4		54.0 b
FreeHand 1.75G	150 lb.	739.2		8.0	c	7.4	C	47.3		16.9 a
Fortress	150 lb.	722.4		7.5	bc	4.8	b	61.1		61.7 b
Control	---	701.9		4.4	a	2.8	a	48.5		123.0 d

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 = Efficacy (Eff.) ratings are based on a 0-10 scale with 10 being complete control, 0 no weed control, and >7 commercially acceptable control.

≠ = Treatments with different letters signify efficacy was statistically different at p=0.05 using LS means following ANOVA in SAS.

Fig. 15. Ray Wiegand's Nursery, Lenox, MI showing weed mass collected from five species that were originally evaluated and initiated on 07/19/2018 and recorded 40 WAT on 04/25/2019. Some very cold temperatures were experienced in the over wintering houses at the end of January that killed *Lavandula angustifolia* 'Hidcote Blue' and *Coreopsis* 'Red Elf' (Li'l Bang™ Series) the remaining three species are listed in Table 9. From left to right, Control, Fortress, Biathlon, Freehand and Gemini. Table 1 show the same relative ranking as above with the best to worse treatment being Freehand 1.75G, Biathlon, Fortress and Gemini G Gemini G was providing about the same efficacy by mass as the control at 40 WAT.

Table 10. Summarizes by herbicide tested and number of times it was evaluated Walters Gardens, Zeeland, MI (Tables 2-7); Lynn Mayer's Great Lakes Glads, Bronson, MI (Fig. 4); and, Ray Wiegand's Nursery, Lenox, MI (Tables 8-9) compared to the number of times it was rated as the best herbicide across species alone or in combination with another product from Table 1.

Best treatment	No. times best treatment	No. of trials where used	Best treatment (%)
Pennant Magnum	6	7	86
FreeHand 1.75G	8	10	80
Tower 6EC	4	13	31
Fortress	9	19	47
Tower 6EC + Dimension 2EW	12	17	71
Marengo G	6	9	67
Pennant Magnum + Tower 6EC	5	9	56
Fierce (V-10233)	1	0	0
Gemini G	1	7	14
Biathlon	7	12	58
Tower + Basagran T/O	1 (Tower at ¾ rate)	5	20
Basagran T/0	1	2	50
Marengo SC	2	5	40

Pennant Magnum + Dimension 2EW	1	2	50
Gallery SC + Gly + 2,4-D + Pendulum 3.3 EC (applied October)	1 (fall applied only)	1	100
Marengo SC + Gly + 2,4-D (applied October)	1 (fall applied only)	3	33
Pennant Magnum + Pendulum Aqua Cap	1	2	50
Tower 6EC + Pendulum Aqua Cap	1 (applied at rate to be ~ to 150# FreeHand)	4	25
Total Herbicides = 18 + SureGuard = 19			