Comprehensive Time Savings Labor Review

Sponsor:

Chad Noyes
Campaign Activation Manager - Lawn & Ornamentals
Environmental Science U.S. LLC
5000 CentreGreen Way
Suite 400
Cary, NC 27513
chad.noyes@envu.com

Principle Investigator:

Dr. Hannah Mathers
Independent Researcher and Consultant
Mathers Environmental Science Services, LLC
Gahanna, OH
Mathers326@gmail.com
Mobile: 614-371-0886
www.mathersenvironmental.com

I. Introduction:

Initial purpose:

Indaziflam is the active ingredient in Marengo at 0.0224%. Marengo G (EPA Reg. No. 101563-149) is registered for weed control in container nurseries. Indaziflam is known to be steadily degraded in aerobic soil (half-lives >150 days (Eckelmann et al., 2020; Shanner, 2014). New active ingredients with increased selective efficacy at low application rates, combined with an optimal toxicological and environmental safety profile has resulted in an increasing number of chiral agrochemicals having been launched over the last years (Jeschke, 2018). Indaziflam is such a chiral agrochemical that consists of three chiral centers (Eckelmann et al., 2020). All three chiral centers of indaziflam can be considered isometrically stable which means indaziflam has increased environmental benefit (Eckelmann et al., 2020). The half-life of indaziflam is 2.5 times longer than the other longest half-life active ingredient i.e., isoxaben in Snapshot® 2.5 T. Neal and Harrow (2014) also found the control provided by Marengo G at 150 lb/ac was longer for spurge, bittercress and eclipta compared to Broadstar and OH2. Marengo G has the newest registration (2012) and by far the lowest active loading of the three major competitors including Broadstar, FreeHand 1.75 TG and Snapshot 2.5 TG (as described below.

1) Broadstar™ (EPA Reg. No. 59639-128, NuFarm) (first registered 2003) [flumioxazin 0.25% (Group 14)] (Shaner et al., 2014); Broadstar is applied at 150 lb/ac (0.375 lb a.i./ac. Broadstar contains flumioxazin which has a ½ life of only 17.5 days in aerobic soils (Shaner et al., 2014); however, many studies and the label indicates 8-12 weeks of weed control. Broadstar has only moderate control on annual grasses and reports of its failure on any thistle species are numerous.
2) FreeHand® 1.75G (EPA Reg. No. 7969-273, BASF) (first registered 2008) [dimethamid-p 0.75% (Group15) (Shaner et al., 2014) + pendimethalin 1.0% (Group 3)]. FreeHand (Group 15 +3) at 24 weeks is present for MI, and 36- week season for OR and FL at 150 lb/ac. However, FreeHand achieves 12-weeks of control in most studies if applied at 200 lb/ac (3.53 lb a.i./ac). Thus Table 4 presents the costs for FreeHand at 200 lb/ac. Dimethamid-p has a soil residue of 6 weeks and pendimethalin 44 days (Shaner et al., 2014). The label reads that some plants need 16 weeks between applications, and some weeds are not control unless 200 lb/ac is used. Although reapplication at 8 weeks is allowed, on many labelled species, in most studies FreeHand 1.75G lasts 12 weeks if applied at 200lb/ac. FreeHand has good control of annual grasses. FreeHand is poor

at controlling spotted spurge and needs the 200 lb/ac rate in warmer climates. It also loses control of bittercress at 8 weeks in many studies including citations below.

3) Snapshot® 2.5 TG (EPA Reg. No. 62719-175, Corteva) (first registered 1991) [trifluralin 2.0% (photodegradation 44 days) (Group 3) + isoxaben 0.5% (photodegradation 60 days) (Group 21)] (Shaner et al., 2014). SnapShot 2.5 TG (group 3 + 21 herbicides) applied at 200 lb/ac was evaluated and presented at (5 lb a.i./ac). Snapshot 2.5 TG contains trifluralin (with a photodegradation of 42 days or 6 weeks) (Shaner et al., 2014) and isoxaben (with a field degradation of 94.3 days when applied as 45.45% solution) (Shaner et al., 2014.) However, Snapshot 2.5 TG contains only 2% trifluralin + 0.5% isoxaben. The Snapshot 2.5 TG label reads wait at least 60 days (8. 5 weeks) after the first application; however, in many studies Snapshot 2.5 TG does not last 8.5 weeks. It has poor control of Bittercress and other mustards, and other weeds cited below, and loses commercial control before 8 wk. The label states if bittercress is germinated, the control is extremely poor. This has been verified in the studies reported below.

4) **Split applications of Marengo G and FreeHand 1.75G** were compared for extend control to 20 week-intervals in warmer climates like South Florida and California. At 2 applications this covers a 40-week or 10-month growing season in these two locations. Hand weeding and herbicide expenses are listed for these split- application for 20-week interval herbicides i.e., FreeHand (Group 15 +3) at 150 X applied 0 and 6 weeks and then again after 20 and 26 WA1T. FreeHand and Marengo G have shown longer residual activity on a variety of weeds when applied in this split applications method (Marble, 2020 – Appendix 3). The label reads for some desired plants, a 16-week interval between applications is required and some weeds are not control unless 200 lb/ac is used.

For Marengo G split-app., control was lost of bittercress, large crabgrass, doveweed, eclipta, oxalis, and spurge to 12, >20, 8, 20, 20 %, at 8 WA1T, respectively (Marble 2020 – Appendix 3). The lost control of these species is reflected in the labor costs for FreeHand) and Marengo G (Table 5) with the extension to 20-weeks. Marengo 200 lb/ac was also compared to UTC (Table 6) at 12-wk intervals.

The older herbicides like Snapshot® 2.5 TG (200 lb/ac) were considered to have a duration in nursery containers of 10 weeks (Barolli et al., 2005). In the same

study Broadstar showed weed control in nursery containers to 12 weeks (Barolli et al., 2005). Marengo G thus would have utility for at least 24 weeks or 6 months (a whole growing season). 24 wk. growing seasons exist in MI (i.e., May to October). Marengo's long residual, lower active loading, chiral properties and different mode of action than any other herbicide used in nursery containers, positions it to be the number one choice in the nursery industry. However, many nursery growers make choices for plant protection products based on price and the price of Marengo G is considered to be too high. The objective of this cost-savings study is to determine the true cost of weed control comparing the four herbicides listed above, in the four largest nursery production states in the US including CA, FL, OR and MI. Thes four states have very different lengths of growing seasons which is reflected in the methodology.

There are many papers that cite the cost of hand weeding (Case et al., 2005; Darden and Neal, 1999; Gilliam et al., 1990; Ingram et al., 2016 and 2017; Khamare et al., 2022) but **not one** of these published papers provided citations or materials and methods of actual studies on which their costs of supplemental weeding between applications and/or weed-to-clean costs or the herbicides used were based. Ingram et al. (2016) states their estimates of hand-weeding between applications were based on an "**assumption'** of 6-hr. Further, Ingram et al. (2016) only provides hand-weeding costs as a percentage of the total production system costs (TPSC) (i.e., $0.0950) and provides no costs for the materials of the herbicides themselves, only their application costs (i.e., 0.2826 % of TPSC). Ingram et al. (2017) states hand weeding would average 1203 labor h/ha/year. Although Khamare et al. (2022) references Ingram and Ingram et al., (2016 and 2017) hand-weeding control costs can exceed $10,000 per acre but as states above neither Ingram et al. (2016 nor 2017) indicate any cost per acre, let alone $10,000 per ac. Despite the non-data-based reports of Ingram et al. (2016 and 2017) these two papers are widely cited for cost of weed controls in container nurseries and unfortunately contribute to the belief that no actual time to supplemental- and weed-to-clean timing studies versus untreated controls are required.

The paper that comes closes, to being based on anything concrete is Gillman et al. (1990) which surveyed thirty-two nurseries in Alabama in 1987, randomly selected and ranging in size from 2.5 to 50+ ac. Gillman et al. (1990) makes no claim to represent any other state but AL and in 1987 hourly wages ranged from $3.53 to $3.97 among the different nursery sizes. In 1987 they found hand-weeding cost $246 to $567/acre, annually, and more expensive for <11 and >50 acres. The weeding costs were also based on the use on OH2 and Rout herbicides. applied on average 2.9-3.2 applications per year, with application interval provided (Gillman et al.,1990).

For comparison purposes, the hours to hand-pull cited in Gillman et al. (1990) would match our weed-to-clean hours. Utilizing Gilliam et al. (1990), hours to hand weed-to-clean would 142.82 or nurseries ≤ 50 acres and more for nurseries > 50 acres. The surveys were conducted by personal interviews, but **no proof** of hand-weeding times were required, and no supplemental weeding requirements were considered. Hours reported by growers and were taken at face value (Gillman et al., 1990). Therefore, our supplemental *plus* weed-to-clean costs hours concur with Gillman et al. 1990, for Snapshot, which we compare to OH2 in terms of longevity. Gillman et al. (1990) predated Snapshot 2.5TG, Broadstar, FreeHand 1.75 TG and Marengo G and Barolli et al. (2005) predated FreeHand and Marengo, and even in 2005 did not consider Snapshot 2.5 TG an industry standard for 10 wk. weed control in CT container nurseries (Barolli et al., 2005)

Timeliness:

Weed control has always been the most expensive part of container nursery plant protection programs. In today's economy it has become even more expensive and difficult with labor shortages and increased wages. Dormant and in-season applications have shown utility in optimizing labor during down-times in the season. Therefore, a 40-week growing season was evaluated to represent any state utilizing a split-dormant-season application. The table actually constructed for a 40-week season was for CA and FL, as these states have 40-week growing seasons.

Target audience:

The target nursery container grower in this study still utilizes only (or predominantly) hand-weeding and container growers who have less effect herbicide programs because they believe the cost of Marengo G is too high.

II. Materials and Methods:

Container growers in the four largest nursery production states (i.e., CA, FL, OR and MI) in the US were evaluated utilizing H2A labor costs as required by the Adverse Effect Wage Rates (AEWRs) (https://flag.dol.gov/wage-data/adverse-effect-wage-rates, 2025). Many nursery containers growers have reported utilizing the H2A workers for labor intensive activities, ex. hand-weeding. Therefore, the AEWRs by state approximate as close as possible an *industry standard* wage for hand-weeding. The AEWRs change by state, with CA having the highest hourly rate, and FL the lowest. All state rates are listed in their respective tables based on their growing season length (i.e., MI 24-wk, OR and

N-FL 36-wk), CA and S-FL- 40-wk.) Marengo G was compared to its three major market competitors (Broadstar, FreeHand 1.75 TG and SnapShot 2.5 TG) and they are described in the introduction. Depending on herbicide's required interval of application (based on previous research of longevity of weed control), and the growing season length within the four states, different tables were constructed. Snapshot 2.5 TG was evaluated on an 8-wk and 12-wk application interval (Table 1) and for 24- and 40-weeks (Table 7). The 40-week season with Snapshot TG (Table 7) was *only* calculated for *comparison purposes*, as it would never be considered an economically viable choice. Broadstar 150 lb/ac (Table 2), FreeHand 150 lb/ac (Table 3) and Marengo 200 lb/ac (Table 6) were evaluated on a 12-wk. application intervals. A study by Joe Neal in North-Carolina, of five major container weed species [spotted spurge (*Euphorbia maculata*); Doveweed (*Murdannia nudiflora),* eclipta (*Eclipta prostata*), crabgrass *(Digitaria sanguinalis)* and bittercress (Cardamine sp.)] at 10 week-after treatment (WAT), in circa 2015, shows the significant difference in weed control between FreeHand 1.75G and Snapshot 2.5 TG (Appendix 2). FreeHand 1.75 TG at 150 lb/ac based on personal experience and Appendix 2 was considered quite suitable at a 12-week application interval (Appendix 2) for N-FL and OR (Table 3). However, in Appendix 2 we can see eclipta and probably doveweed breaking-through at 10 WAT. Therefore, the 200 lb/ac rate of FreeHand 1.75 TG was considered necessary for S-FL and CA (Table 4), the FreeHand 1.75 TG label itself specifies the 200 lb/ac rate is required for tougher weeds.

Broadstar 150 lb/ac also requires supplemental weeding as reflected in its utilization in OR and North-Florida (Table 2). Flumioxazin provided approximately 7 weeks of complete (100%) hairy bittercress control regardless of rate (Wehtje et al., 2012). Hairy bittercress control was marginal and highly variable activity to 18-wk after treatment (Wehtje et al., 2012). Flumioxazin provided 2- and 4-wk complete spotted spurge control, depending on rate (Wehtje et al., 2012). No spotted spurge control was evident after about 8 WAT (Wehtje et al., 2012). Subjecting the less-variable data to nonlinear regression (Wehtje et al. (2012) revealed that the time required for 50% reduction in flumioxazin activity was approximately 5.5- and 6.6-wk for the two rates, respectively. These Wehtje et al. (2012) studies were conducted in Auburn, AL and agree with OR and North-FL growing season lengths and weed species at 12-week intervals (Table 2 and 7). Only Marengo and FreeHand 1.75 TG were calculated for 20-week application intervals as spit-applications at 0 and 6 WAT of 150 lb/ ac/ application (Table 5 and 7) and for a 12-week interval at 200 lb/ac (Table 4 and 6, respectively). Since the split application is not on the FreeHand 1.75 TG label, it was not used in the summary table (Table7). The labor cost/ac of containers are then assessed based on the various growing season lengths, ex. 24

wk. or 168 d growing season (MI); a 36 wk. or 252 d growing season OR and North Florida; or a 40 wk. or 280 d. growing season CA and South FL.

The AEWRs for CA are the highest at $19.97/ h, followed by OR at $19.83/h, then MI at $18.15/h and the lowest is FL at $16.23. Supplemental hand-weeding was required with all herbicides and time intervals were based on past studies of longevity of control (Appendix 1- Barolli et al., 2005; Judge and Neal, 2006; Marble, 2020; Appendix 4- Mathers, 2023; Saha et al., 2017; Walker et al., 2010; Stewart et al., 2017) using these respective studies for times when efficacy fell below commercially acceptable i.e., >70% (efficacy scale 0-100%, with 100% representing complete control). Barolli et al. (2005) is the **only study** which actually performed the timings of supplemental- (between re-applications) and weed-to-clean before re-application (i.e., 2nd, 3rd, etc.) compared to untreated controls (left weedy at respective intervals of reapplication and pulling times recorded in h/ac).

Judge and Neal, 2006; Appendix 3- Marble, 2020; Appendix 4- Mathers, 2023; Saha et al., 2017; Walker et al., 2010 and countless other studies detail intervals at which various weed species control is lost. Snapshot 2.5 TG in S- and N-FL, and wherever southern weed species weeds like Doveweed (*Murdannia nudiflora) and* Artillery weed (*Pilea microphylla)* occur, would be an inappropriate choice, as reapplication for SnapShot would necessitate major weeding to clean times at 8-week reapplication intervals, incongruous with current labor shortages in the industry. The 8-week reapplication interval for SnapShot 2.5 TG (Table 1) was based on doveweed control falling to only 10% at 5 weeks after treatment (WAT), 13% at 8 WAT weeks and 0% at 10 WAT (Walker et al., 2010); and 74% with Artillery weed at 8 WAT, and 41% at 10 WAT (Saha et al., with 2017). Additionally, with northern and southern weed species like. groundsel (*Senecio vulgaris*) and prostrate spurge (*Euphorbia sp.*), if there was any weed seedling emergence (even without any visible leaves), control fell below commercially acceptable (48%) at just 4 WAT (Judge and Neal, 2006). The same two species, with no visible emergence at application provided only 81% control at 9 WAT (Ahrens et al., 2004). The Judge and Neal (2006) findings emphasized the need for *pain-staking* and *extensive* hand-weeding with Snapshot 2.5 TG if used on an even an 8-week interval in southern states. Unlike Broadstar and Marengo, SnapShot 2.5 TG has no post-emergence activity (Judge and Neal, 2006) thus with even just epicotyl emergence and no hypocotyl emergence, Snapshot's efficacy is considerably compromised. Unexpected benefits from our cost comparisons study similar to what occurred with Dove's survey (i.e., regarding body image), have been speculated.

Although an 8-week interval is unrealistic, labor wise, for SnapShot 2.5 TG in any state but MI in 2025 (Table 1), calculations were conducted for 24-wk and 20-wk application intervals (Table 7). However, these Snapshot 2.5 TG estimates do not properly reflect the actual hand-weeding costs in OR, FL and CA, as studies have never been conducted regarding supplemental- and weed-to-clean times with Snapshot 2.5 TG in those three states. There are studies of percent control with FreeHand 1.75 TG compared to Marengo G (Marble, 2020, Appendix 3) but no timing studies for supplemental- and weed-to-clean were conducted by Marble, 2020. The calculations of time to hand weed. 1-gallon plant-less containers, including weed counts, timing at each interval of removal, i.e., 8-, 10- and 12-week intervals (Appendix 1 -Barolli et al., 2005) were the starting calculations for all four herbicides evaluated. Barolli et al. (2005) was conducted in Granby, CT at the former Imperial Nurseries, including untreated controls and comparing flumioxazin 0.25 G and OH-2. At the time Barolli et al. (2005) was conducted, OH-2 was the container industry standard (Ahrens et al., 2004) and a liquid-application (not part of this study) of isoxaben and oxyfluorfen was also standard). OH-2 in several studies has provided similar weed species and duration of control to SnapShot (ex. Judge and Neal, 2006; Wooten et al., 2004). Therefore, we substituted Snapshot 2.5 TG for the OH-2 data for hand weeding times (Barolli et al., 2005) in our cost-comparisons (Table 1 and 7). The CT location was thought to be the most similar to MI of the four states evaluated in our cost saving study. We did calculate Snapshot2.5 TG for use in OR, FL and CA but again this data is based on no studies, as they do not exist and are only for comparison purposes.

Hand-weeding times were estimated for the three states besides MI, based on research published regarding when weed control fell below commercially acceptable (70%, on a scale of 0 to 100%, where 100% is perfect control). Some of these studies were conducted with Broadstar, FreeHand 1.75 TG and Marengo G including, (Appendix 1-Barolli et al., 2005 (comparison for MI); Judge and Neal, 2006 (comparison for N-FL); Appendix 3- Marble, 2020 (comparison for S-FL); Appendix 4- Mathers, 2023 (comparison for MI); Saha et al., 2017 (comparison for S-L) and Neal and Harrow, 2014; Walker et al., 2010 (comparison for N-FL). In CA additional difficult weeds like cudweed (*Gnaphalium starmineum*), pearlwort (*Sagina procumbens);* willowherbs *(Epilobium spp.)* and prostrate spurge *(Chamaesyce maculata)* predominated (Wilen et al., 2020) and different crops like palms (Inci et al., 2025) made supplemental- and weed-to-clean timings similar to South FL (Wilen et al., 2020).

It was obvious from previous research studies that the duration of weed control varied based on warmer vs colder temperatures, weed species required to be

controlled, and the growing season length between the North Central, Pacific Northwest, Southern, and Pacific Southwest regions representing the four major nursery production states. Thus, weeding times were calculated utilizing Barolli et al. (2005) for the start points and the studies cited above for educated valuations. Natural weed infestation or blow-in were used in the Barolli et al. (2005) study. Blow-in is the most common form of weed infestation in container nurseries (Adams, 1990). Common groundsel (*Senecio vulgaris*), horseweed (*Conyza canadensis*), woody seedlings (*Populus, Acer*) and crabgrass (*Digitaria sanguinalis*) were abundant in Barolli et al. (2005) study. I was present at the 2005 Northeast Weed Science Society (NEWSS) presentation given by Dr. John Ahrens for the Barolli et al. (2005) study. I also obtained a copy of the PowerPoint presentation from the authors and thus was able to consult in detail their methodology. Their 2005 PowerPoint presentation is attached as Appendix 1.

FreeHand 1.75 TG was calculated at 150 lb/ac (Table 3) and 200 lb/ac (Table 4) at 12-week application intervals. Still, in several studies, and based on the label if you want a full 12-week residue, especially with more difficult weeds universal weed species in the four states evaluated, and with many southern weeds, in the southern region, 200 lb/ac is required. In the summary table (Table 7), only Marengo at 200 lb/ac split for a 20-wk application interval in OR, FL and CA is conducted. Again, the split-application is not on any of the labels, with the exception of Marengo G.

III. **Results and discussion:**

The results are presented in six tables (Table 1-6) and a summary of results (Table 7) that also included the percentages of savings versus hand weeding by season length, and herbicide evaluated. Table 1 is for an 8-wk. interval herbicide like Snapshot 2.5TG applied at 200 lb/ac and including supplemental- and weed-to-clean times (in hr./ac) at 8, 16 and 24-wk for utility in MI. Snapshot 2.5 TG was primarily calculated for MI as a 24-wk season (Table 1) but it was also presented in the summary table, for a 40-week season (Table 7). Table 2 shows the calculations for a 12-week application intervals herbicide, ex. Broadstar in a 36-wk growing season ex. OR and northern FL, at 150 lb/ac and weed-to-clean before re-application (Table 2). Table 3 was calculated for FreeHand 1.75 TG applied at a 12-week application interval. FreeHand 1.75 TG in 36-wk (OR and northern FL), applied at 150 lb/ac and weed-to-clean at each 12-week interval is shown (Table 3). Table 4 is FreeHand 1.75 TG at 12-week application intervals also in a 36-week growing season, for CA and s-FL, but at 200 lb/ac (Table 4). The primary reason (besides published research) for two tables for Freehand (150 lb/ac – Table 3) and (200 lb/ac – Table 4) was to satisfy

the label recommendations. Although, the 1X rate for FreeHand is 150 lb/ac (Table 3), the label lists many weed genera and species that cannot be controlled with less than 200 lb/ac (Table 4). Since there are no studies comparing hand-weeding costs at 150 lb/ac vs 200 lb/ac with FreeHand 1.75 TG the hours were calculated considering the different species to be controlled in warmer versus colder states (Table 3 and 4, respectively). Table 5 shows a split-application of FreeHand 1.75G and Marengo G at 150 lb/ac, at 0 and 6 WAT, calculated at 20 and 40-weeks, for a 40-wk growing seasons (S-FL and CA). Since a split application is not recommended on the FreeHand 1.75 G label, again, the FreeHand data (Table 5) was not used in the summary (Table 7). Table 6 was calculated for Marengo G, at 200 lb/ac, at 12-week application intervals, including reapplication at 12-, 24- and 36-week seasons. A summary of all four herbicides vs hand-weeding costs for 12, 24, 36 weeks after the first application (WA1T) for all states were calculated (Table 7). Table 7 summarizes (Table 1-6), and presents the four herbicides, in the four states, with their respective costs of weeding and herbicide application product costs, compared to untreated control times to weed. The percentages of time-saved, for the four herbicides, versus the untreated controls or only hand-pulled pots are also calculated in each state, based on whether they have a 24-, 36-, or 40-week growing season. A summary of the least expensive and most time-saved versus UTC are presented (Table 8).

Table 1. Pre-emergence herbicides that require ***8.0-week application intervals*** **such as SnapShot 2.5TG** are calculated for a **24-wk.** growing season ex. **MI** are listed. Hand weeding and herbicide expenses for **SnapShot 2.5 TG**, group 3 + 21 herbicide, applied at 200 lb/ac is presented (5 lb a.i./ac). The cost of Snapshot 2.5 TG is $2.10/lb at (2 applications) at 8-week intervals or 16 WA1T, the total cost of SnapShot was $1218.43/ac at 24 WA1T the cost was $1942.44/ac. The hand weeding cost in the untreated (UTC) at 16 WA1T was $1976.54/ac, and 24 WA1T **$3698.97/ac**. In a 24 week growing season **(May – Oct) in MI** with the 2025 H2A wage ($18.15/h) (https://flag.dol.gov/wage-data/adverse-effect-wage-rates) (May-Oct) Snapshot saved **$1756.53/ac** vs hand weeding or 47.5% vs hand weeding**.**

Herbicides	**lb ai/A/ lb/ac**	**8.0 WA1T (A) (hours)**	**10 WA1T (B) (hours)**	**12-WA 1T (C) (hours)**	**8 WA1T** with 1, 16 WA1T with appl. 8.0 wk. intervals [8 wk. = A X $18.15; 16 wk. = (A + B + C + 1/2A) X $18.15; 24 wk. = (A + B + C) X 2 X $18.15] **(D)** ***Labor cost***	Snapshot at appl. at 8, 16 and 24 wk. with 8 wk. interval weeded to clean = 2.10/lb X 200 lb/ac rate = (1XG) / ***Herbicide cost***	*Snapshot at 8,16 and 24 with 8 wk. interval* ***Total cost***	UTC at 8, 16 and 24-wk hand weeding cost
Untreated (UTC)	0	14.0	17.2	70.7				8 wk. = $254.10 16 wk. = $1976.54 **24 wk. = $3698.97**
Snapshot 2.5 TG	5/200	4.1	5.7	9.0	8 wk. = $74.42 16 wk. = $378.43 24 wk. = $682.44	8 wk. = $420 16 wk. = $840 24 wk. = $1260	8 wk. = $494.42 16 wk. = $1218.43 **24 wk. = $1942.44**	

Footnote: Weeks after treatment (WAT); Weeks after first treatment (WA1T); Cost presented as /ac of 1-gal nursery containers.

Table 2. Pre-emergence herbicides requiring **12-*week application intervals such as Broadstar at 150 lb/ac*** are listed for **36 WA1T (OR and northern FL).** Hand weeding and herbicide expenses are listed for these 12-week interval herbicides i.e., Broadstar (Group 14) at 36 weeks growing season (ex. OR and northern FL). The cost of Broadstar is $2.51/lb applied at 12-week intervals the total cost in **Oregon** for the 36 WA1T, growing season was **$1664.91**. In **North Florida** at 3 applications at 12 wk. intervals or 36 WA1T growing season the cost was **$1567.71**. The **hand weeding** cost in the **untreated (UTC)** in **OR** at 36 WA1T was **$6062.03** versus (vs) in N-FL at 36 WA1T **$4961.51**. In a 36 week growing- season (Mar. to Nov.) in OR or N-FL with the 2025 H2A wage of OR ($19.83/h), and FL ($16.23/h) (https://flag.dol.gov/wage-data/adverse-effect-wage-rates), Broadstar saved in **$4397.12 vs hand weeding** or 72.5% in OR, and in **$3393.80** /ac or 68.4% in North FL.

Herbicides	**lb a.i./A/ lb/ac**	**8 WA1T (A)**	**10 WA1T (B)**	**12-WA 1T (C)**	**In OR, 36 WA1T** with 3 appl. at 12 wk. intervals (A+ B + C) X 3 X $19.83 **(D) OR** *UTC* ***Labor cost***	**In Northern FL, 36 WA1T** with 3 appl. at 12 wk. intervals (A + B + C) X 3 X $16.23 **(E) N-FL** *UTC* ***Labor cost***	**Broadstar at 12 wk. intervals** 2.51/lb X 150 lb/ac **X 3 (36 WA1T** or 9 mo.) ***(F) Herbicide cost***	**Per Acre Total Cost Broadstar in OR** at 36 WA1T D + F	**Per Acre Total Cost Broadstar in N-FL** at 36 WA1T E + F
Untreated (UTC)	0	14.2	17	70.7	**36 wk. = $6062.03**	**36 wk. = $4961.51**			
Broadstar	0.375/ 150	2.3	3.3	3.4	36 wk. = $535.41	36 wk. = $438.21	36 wk. = $1129.50	**36 wk. = $1664.91**	**36 wk. = $1567.71**

Footnote: Weeks after treatment (WAT); Weeks after first treatment (WA1T); Cost presented as /ac of 1-gal nursery containers.

Table 3. Pre-emergence herbicides requiring **12-*week application intervals like FreeHand at 150 lb/ac*** are listed for 36 WA1T (OR and FL). Hand weeding and herbicide expenses are listed for these 12-week interval herbicides i.e., FreeHand (Group 15 +3) at 36- week season for OR and FL at 150 lb/ac. The cost in OR for FreeHand is $2.16/lb at 3 applications at 12 wk. intervals or 36 WA1T, the cost was **$2459.25** and in N-FL**, $2189.25.** Although a rotation to another herbicide for the 2nd application is recommended. The hand weeding cost in OR, in the untreated (UTC) at 36 WA1T was **$6062.03.** The hand weeding cost in N-FL in the untreated (UTC) at 36 WA1T it was **$4961.51.** In a 36 wk. season (Mar. to Nov.) **in OR** with the 2025 H2A wage of $19.83 (https://flag.dol.gov/wage-data/adverse-effect-wage-rates) FreeHand saved **$3602.78/ ac vs hand weeding** or 59.4% vs hand weeding **and N-FL** with an 2025 wage rate of $16.23/h, FreeHand saved **$2772.26/ac vs Hand weeding** or 55.9%.

Herbicides	**lb ai/A / lb/ac**	**8 WA1T (A)**	**10 WA1T (B)**	**12-WA 1T (C)**	**In OR, 36 WA1T** with 3 appl. at 12 wk. intervals (A + B + C) X 3 X $19.83 **(D) OR** *UTC* ***Labor cost/ac***	**In Northern FL, 36 WA1T** with 3 appl. at 12 wk. intervals (A + B + C) X 3 X $16.23 **(E) N-FL** *UTC* ***Labor cost/ac***	**FreeHand at 12 wk. intervals** 2.16/lb X 150 lb/ac rate **X 3 (36 WA1T** or 9 mo.) ***(F) Herbicide cost/ac***	**Per Acre Total Cost FreeHand in OR** at 36 WA1T D + F	**Per Acre Total Cost FreeHand in N-FL** at 36 WA1T E + F
Untreated (UTC)	0	14.2	17	70.7	**36 wk. = $6062.03**	**36 wk. = $4961.51**			
FreeHand 1.75G	2.65/ 150	3.0	6.0	16.0	36 wk. = $1487.25	36 wk. = $1217.25	36 wk. = $972.00	**36 wk. = $2459.25**	**36 wk. = $2189.25**

Footnote: Weeks after treatment (WAT); Weeks after first treatment (WA1T); Cost presented as /ac of 1-gal nursery containers.

Table 4. Pre-emergence herbicides requiring **12-*week application intervals like FreeHand at 200 lb/ac*** are listed for 36 WA1T (CA and FL). Hand weeding and herbicide expenses are listed for these 12-week interval herbicides i.e., FreeHand (Group 15 +3) at 36-week season for CA and FL at 200 lb/ac. The cost in CA for FreeHand is $2.16/lb at 3 applications at 12 wk. intervals or 36 WA1T, the cost was **$2314.47** and in S-FL**, $2123.73.** Although a rotation to another herbicide for the 2nd application is recommended. The hand weeding cost in CA, in the untreated (UTC) at 36 WA1T it was **$6104.83.** The hand weeding cost in S-FL in the untreated (UTC) at 36 WA1T it was **$4961.51.** In a 36 wk. season (Mar. to Nov.) **in CA** with the 2025 H2A wage of $19.97 (https://flag.dol.gov/wage-data/adverse-effect-wage-rates) FreeHand saved **$3790.36/ac vs hand weeding** or 62.1% vs hand weeding **and S-FL** with an 2025 wage rate of $16.23/h, FreeHand saved **$2837.78/ac vs Hand weeding** or 57.2%.

Herbicides	**lb ai/A / lb/ac**	**8 WA1T (A)**	**10 WA1T (B)**	**12-WA 1T (C)**	**In CA, 36 WA1T** with 3 appl. at 12 wk. intervals (A + B + C) X 3 X $19.97 **(D) OR** *UTC* ***Labor cost/ac***	**In Southern FL, 36 WA1T** with 3 appl. at 12 wk. intervals (A + B + C) X 3 X $16.23 **(E) N-FL** *UTC* ***Labor cost/ac***	**FreeHand at 12 wk. intervals** 2.16/lb X 200 lb/ac rate **X 3 (36 WA1T** or 9 mo.) ***(F) Herbicide cost/ac***	**Per Acre Total Cost FreeHand in CA** at 36 WA1T D + F	**Per Acre Total Cost FreeHand in S-FL** at 36 WA1T E + F
Untreated (UTC)	0	14.2	17	70.7	**36 wk. = $6104.83**	**36 wk. = $4961.51**			
FreeHand 1.75G	3.53/ 200	2.0	4.0	11.0	36 wk. = $1018.47	36 wk. = $827.73	36 wk. = $1296.00	**36 wk. = $2314.47**	**36 wk. = $2123.73**

Footnote: Weeks after treatment (WAT); Weeks after first treatment (WA1T); Cost presented as /ac of 1-gal nursery containers.

Table 5. Split applications of Marengo G are needed for extend control to 20 week-intervals in warmer climates like South Florida and California. Marengo G is applied at 150lb/ac at 0 and 6 wk. after the first and second application. Note at 0 and 6 wk. after each application the weeds are removed to clean. Weeding to clean is also done at 20 WAIT and 40 WAIT. At 2 applications this covers a 40-week or 10-month growing season in these two locations. For Marengo G split-app. control was lost of bittercress, large crabgrass, doveweed, eclipta, oxalis, and spurge at 12, >20, 8, 20, 20, and 8 WA1T, respectively (Marble 2020). The lost control of these species is reflected in the labor costs for Marengo G with the extension to 20 weeks. For a 40-week growing season, in FL, Marengo G saved $3829.04/ac vs hand weeding or 69.2% and in CA, it saved $5036.32/ac vs hand weeding or 73.8%.

Herbicides	**lb a.i/A at 150 lb/ac 0 & 6 WA1T**	**6 WA1T (A) Labor (h/ac)**	**20 WA1T (B) Labor (h/ac)**	**Cost in FL 16.23/h (C) at** 20 wk. = (A + B) X $16.23 40 wk. = (A + B) X 2 X $16.23	**Cost in CA 19.97/h (D) at** 20 wk. = (A + B) X $19.97 40 wk. = (A + B) X 2 X $19.97	**Herbicide Cost Marengo G (E)** 20 wk. = 2.35/lb X 150 X 2 40 wk. = 2.35/lb X 150 X 4	**Per Acre Total Cost FL Marengo** 20 wk. = C + E 40 wk. = C + E	**Per Acre Total Cost CA Marengo** 20 wk. = D + E 40 wk. = D + E
Untreated (UTC)	0	80.1	90.3	20 wk. = $2765.59 **40 wk. = $5531.18**	20 wk. = $3402.89 **40 wk. = $6805.78**			
Marengo G Split 0 & 6 wk.	(0.0336 X 2= 0.0672) or 300	2.5	6.5	20 wk. = $146.07 40 wk. = $292.14	20 wk. = $179.73 40 wk. = $359.46	20 wk. = $705.00 40 wk. = $1410.00	20 wk. = $851.07 **40 wk. = $1702.14**	20 wk. = $884.73 **40 wk. = $1769.46**

Footnote: Weeks after treatment (WAT); Weeks after first treatment (WA1T); Cost presented as /ac of 1-gal nursery containers.

Table 6. Pre-emergence herbicides requiring **12-*week application intervals like Marengo G at 200 lb/ac*** are listed for 36 WA1T (OR and FL) and 24WA1T (MI). Hand weeding and herbicide expenses are listed for these 12-week interval herbicides i.e., Marengo G (Group 29) at 36-week season for OR and FL and 24-week season for MI at 200 lb/ac. The cost in OR for Marengo G is $2.35/lb at 3 applications at 12 wk. intervals or 36 WA1T, the cost was **$1856.18** and in N-FL**, $1775.18** and in MI, **$1030.75** (2 applications at 24 WA1T)**.** Although a rotation to another herbicide for the 2nd application is recommended. The hand weeding cost in OR, in the untreated (UTC) at 36 WA1T was **$6062.03.** The hand weeding cost in N-FL in the untreated (UTC) at 36 WA1T it was **$4961.51.** The hand weeding cost in MI in the UTC at 24 WA1T was **$3698.97.** In a 36 wk. season (Mar. to Nov.) **in OR** with the 2025 H2A wage of $19.83 (https://flag.dol.gov/wage-data/adverse-effect-wage-rates) Marengo G saved **$4205.86/ac vs hand weeding** or 69.4% vs hand weeding **and N-FL** with an 2025 wage rate of $16.23/h, Marengo G saved **$3186.33/ac vs Hand weeding** or 64.2%. In MI, with a 2025 wage rate of $18.15/h, Marengo G saved **$2668.22/ac vs hand weeding** or 72.1%.

Herbicides	**lb ai/A / lb/ac**	**12 WA1T (A)**	**24 WA1T (B)**	**36-W A1T (C)**	**In MI, 24 WA1T** with 2 appl. at 12 wk. intervals B X $18.15 **(D) OR** *UTC* ***Labor cost/ac***	**In OR, 36 WA1T** with 3 appl. at 12 wk. intervals C X $19.83 **(E) OR** *UTC* ***Labor cost/ac***	**In Northern FL, 36 WA1T** with 3 appl. at 12 wk. intervals C X $16.23 **(F) N-FL** *UTC* ***Labor cost/ac***	**FreeHand at 12 wk. intervals** 2.16/lb X 200 lb/ac rate **X 3 (36 WA1T** or 9 mo.) ***(G) Herbicide cost/ac***	**Per Acre Total Cost Marengo G in MI** at 24 WA1T D + G	**Per Acre Total Cost Marengo G in OR** at 36 WA1T E + G	**Per Acre Total Cost Marengo G in N-FL** at 36 WA1T F + G
Untreated (UTC)	0	101.9	203.8	305.7	**24 wk. = $3698.97**	**36 wk. = $6062.03**	**36 wk. = $4961.51**				
Marengo G	0.0448/ 200	5.0 (0.0 in MI)	15.0 (5.0 in MI)	22.5 (n/a in MI)	24 wk. = $90.75	36 wk. = $446.18	36 wk. = $365.18	24 wk. = $940.00 36 wk. = $1410.00	**24 wk. = $1030.75**	**36 wk. = $1856.18**	**36 wk. = $1775.18**

Footnote: Weeks after treatment (WAT); Weeks after first treatment (WA1T); Cost presented as /ac of 1-gal nursery containers.

Table 7. Marengo G in MI and OR, N-FL S-FL and CA price compared to Snapshot, Broadstar, FreeHand at 24- & 36-week seasons.

Herbicide	24 wk. season (MI) (8 wk. interval)			% Saved vs UTC	36 wk. season (OR, N-FL) (12 wk. interval)			% Saved vs UTC	40 wk. season (S-Fl, CA) (20 wk. interval)		% Saved vs UTC
	8	16	**24**		12	24	**36**		20	**40**	
UTC (Labor)	$254.10	$1976.54	**$3698.97**		$1849.49 (MI) $2020.68 (OR) $1653.84 (FL) $2034.94 (CA)	**$3698.97 (MI)** $4041.35 (OR) $3307.67 (FL) $4069.89 (CA)	n/a (MI) **$6062.03 (OR)** **$4961.51 (FL)** **$6104.83 (CA)**		**$3092.76 (MI)** $3379.03 (OR) $2765.59 (FL) $3402.89 (CA)	n/a (MI) **$6758.06 (OR) $5531.18 (FL) $6805.78 (CA)**	
SnapShot (Labor + Herbicide) (200 lb/ac) (2.10/lb)	$494.42	$1218.43	**$1942.44**	**47.5**		**$1942.44 (MI)** $2005.61 (OR) $1870.25 (FL) $2019.87 (CA)		**47.5** 50.4 43.5 50.6		n/a (MI) **$3342.68 (OR)** **$3117.08 (FL)** **$3351.45 (CA)**	n/a **50.5** **43.6** **50.8**
BroadStar (Labor + Herbicide) (150 lb/ac) (2.51/lb)					$539.85 (MI) $554.97 (OR) $522.57 (FL) $556.23 (CA)	**$1079.70 (MI)** $1109.94 (OR) $1045.14 (FL) $1112.46 (CA)	n/a (MI) **$1664.91 (OR)** **$1567.71 (FL)** **$1668.69 (CA)**	**70.8** **72.5** **68.4** **72.7**			
FreeHand 1.75G (Labor + Herbicide) (200 lb/ac) (2.16/lb)					$740.55 (MI) $769.11 (OR) $707.91 (FL) $771.49 (CA)	**$1481.10 (MI)** $1538.22 (OR) $1415.82 (FL) $1542.98 (CA)	n/a (MI) **$2307.33 (OR)** **$2123.73 (FL)** **$2314.47 (CA)**	**60.0** **61.9** **57.2** **62.1**			
FreeHand 1.75G (Labor + Herbicide) (150 lb/ac) (2.16/lb)					$777.75 (MI) $819.75 (OR) $729.75 (FL) $823.25 (CA)	**$1555.50 (MI)** $1639.50 (OR) $1459.50 (FL) $1646.50 (CA)	n/a (MI) **$2459.25 (OR)** **$2189.25 (FL)** **$2469.75 (CA)**	**57.9** **59.4** **55.9** **59.5**			
Marengo G (Labor + Herbicide) 200 lb/ac (2.35/lb)					$470.00 (MI) $569.15 (OR) $551.15 (FL) $569.85 (CA)	**$1030.75 (MI)** $1237.45 (OR) $1183.45 (FL) $1239.55 (CA)	n/a (MI) **$1856.18 (OR)** **$1775.18 (FL)** **$1859.33 (CA)**	**72.1** **69.4** **64.2** **69.5**			
Marengo G (Labor + Herbicide) (150 lb/ac) (2.35/lb)	18.15 MI 19.83 OR	16.23 FL 19.97 CA	324						**$868.35 (MI)** $883.47 (OR) $851.07 (FL) $884.73 (CA)	n/a (MI) **$1766.94 (OR)** **$1702.14 (FL)** **$1769.46 (CA)**	**71.9** **73.9** **69.2** **74.0**

Footnote: Weeks after treatment (WAT); Weeks after first treatment (WA1T); Cost presented as /ac of 1-gal nursery containers.

IV. Conclusions

The four herbicides in their respective growing season lengths, 24-, 36- and 40-week by state indicate Marengo G is often the least expensive herbicide choice (Table 7 and 8). However, an even better indicator of the optimal herbicide to utilize is percentage of time saved versus total reliance on hand-pulling (i.e., untreated control) (Table 7 and 8). All four herbicides in 24,- 36-, and 40-wk growing seasons provided significant savings over total reliance on hand-weeding (Table 7). This study shows that any container grower still relying on hand-pulling as their primary form of weed control are spending at least 50% more than their fellow nursery growers and compared to the three newer herbicides 60 and 70% more (Table 7). This is money saved for market expansion with closer control and more available cash to increase stock quality and thus sales. The most expensive herbicide was Snapshot due to this 8-wk application interval (Table 7), need for extensive weeding of even any emergence from the weed seed, and lack of post-emergence ability (Judge and Neal, 2006). FreeHand 1.75 TG, Broadstar and Marengo G all had extended control versus SnapShot 1.75 TG and showed utility at 12-wk reapplication intervals, with some supplemental weeding. Marengo G exhibited even greater extended control applied as a split-application of 150 lb/ac. Thus, Marengo G was the only herbicide capable of utilization at 20-wk intervals (Table 7) and making it the least expensive herbicide program at 20-week intervals (Table 7 and 8) and the greatest % saved time vs total hand-pulling reliance (Table 8).

Table 8. Summary from Table 7 of the least expensive and greatest savings by state

State	Least Expensive	Greatest % Saved vs Hand-weeding
MI	Marengo G 200 (24 wk.) $1030.75	**72.1%**
	Marengo G Split (0 and 6 and 20 wk.) $868.35	71.9%
OR	Broadstar (36 wk. -12 wk. interval $1664.91) However, for only $102.03, additional 4-wks of control **Marengo G split (0 & 6 and 40 wk.- 20 wk. interval ($1766.94)**	72.5% **74%**
FL	Broadstar (36 wk. -12 wk. interval $1567.71) However, for only $134.43, additional 4-wks of control **Marengo G (40 wk.- 20 wk. interval ($1702.14)**	68.4% **69.2%**
CA	Broadstar (36 wk. -12 wk. interval $1668.69) However, for only $100.76, additional 4-wks of control	72.7%

	Marengo G split (0 and 6 and 40 wk.- 20 wk. interval ($1769.46)	**74%**

Proposed Budget:
Was provided in the proposal of 12/13/24

Due date for final report:
As indicated in 12/13/24 proposal was Feb. 25/25.

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BUDGET: 12/13/2024 *(Note: NC means no charge)*

BUDGET FOR - ORGANIZATION AND ADDRESS:				Chad Noyes Campaign Activation Manager - Lawn & Ornamentals Envu Environmental Science US
Project Director: **Dr. Hannah Mathers** **Mathers Environmental Science Services, LLC; Gahanna, OH** *Host Site:* Mathers Environmental Science Services *(Contact: Hannah Mathers)*				**Duration Proposed Mo.:** **2 months (January 2, 2025, to February 25, 2025)**
				Funds Requested by Proposer
A.	**Salaries and Wages** (Includes set-up and 10 evaluations)			
	1. No. of Senior Personnel	1		$4,500.00
	b. 1			
	e.			
	Total salaries and Wages			**$4,500.00**
B.	Fringe Benefits (included in salaries)			$0.00
C.	**Materials and Supplies**: N/A			NC
D.	Computer Costs (Data collection tablet, EBSCO databases search)			NC
E.	**Total Direct Costs (A through F)**			**$4,500.00**
F.	**Total Amount: Required for development of Time-Savings analyses for Marengo G versus hand-weeding and three competitor products, plus potential benefits to market expansion.**			
Non-Cash Contributions: (Various container nursery time and data regarding current wages, weed control costs and time,)				NC
Project Director: DATE 12/13/2024				**SIGNATURE: Hannah Mathers**