Title: Evaluating Chemical Mowing as an Integrated Weed Management Strategy for Christmas Tree Production in Michigan

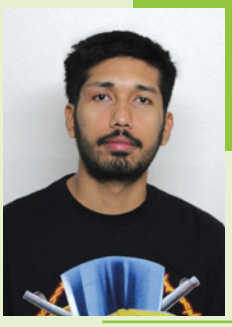



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Figure 2 – *Herbicide treatment application at Runyan's Country Tree Farm (in Canaan fir).*

Background:

Michigan is one of the leading Christmas tree producers in the Unites States. In terms of number of trees harvested, Michigan ranks third nationally after Oregon and North Carolina (1). Michigan generates more than $45 million in sales of wreaths, cut boughs, garland, trees and other cut greens (2). More than 500 commercial Christmas tree farms operate across Michigan, covering more than 33000 acres of land. Growers in Michigan produce over a dozen Christmas tree species, more than any other state in the country.

Despite the strength of this industry, weed management remains one of the major challenges in Christmas tree production. Weeds compete with trees for nutrients, light, and space and harbor pests and pathogens. Weed competition can negatively affect Christmas trees at any stage of growth but seedlings and young trees are more vulnerable (3,4). Research on Monterey Pine has shown that the above ground biomass of Christmas tree in weed free conditions can be up to 25 times greater than that of trees growing under heavy weed pressure (5).

There is a heavy reliance on chemical herbicides for weed control among growers. However, repeated and excessive use of herbicides has contributed to herbicide-resistant weeds and environmental concerns. For example, clopyralid-resistant common ragweed has been reported in Montcalm county, in Michigan (6).

One promising approach to manage weeds is chemical mowing. Chemical mowing, an integrated weed management system in which lower doses of chemical herbicides are used to supress weed growth and reduce/eliminate the need of frequent mechanical mowing. This concept originated from roadside vegetation management research (7). Chemical mowing has been successfully tested and recommended for Florida citrus production systems (8,9). Studies have also shown that combining herbicides with mowing can provide effective control of weeds like smooth crabgrass (10).



Figure 1 – *Christmas tree (Scotch Pine variety) experiment plot at Whispering Pines tree Farm.*

Glyphosate is recommended for chemical mowing in North Carolina Christmas tree production system (11), but relying on a single herbicide can increase the risk of resistance development among the weed species. Therefore, this research aims to evaluate efficacy of four difference herbicides applied at reduced rates along with mechanical mowing, to identify practical and sustainable weed management options for Christmas tree growers that can provide effective weed control while reducing environmental impacts.

Our Approach:

With the objective of evaluating the effectiveness of chemical mowing for weed management in Christmas tree systems, field trials were conducted across three commercial farms in Michigan. The goal of this study was to integrate chemical and mechanical weed management practices to develop an approach that is beneficial to both growers and the environment.

Field Trial (Methods):

Field experiments were conducted in summer and fall of 2025 (Figure 1) at three locations; Flushing, MI (Whispering Pines Tree Farm); Clio, MI (Runyan's Country Tree Farm), and Gobles, MI (Wahmhoff Tree Farm and Nursery). Three Christmas tree species were selected based on availability: Fraser Fir (*Abies fraseri*) at Whamhoff Farms, Scotch Pine (*Pinus sylvestris*) at Whispering Pines, and Canaan Fir (*Abies balsamea*) at Runyan Country Tree Farm. Before any weed control treatments were applied, the dominant weed species at each plot were recorded (Table 1,2,3). Weed control treatments included, four different herbicides which were Roundup Pro concentrate

(glyphosate), Stinger (clopyralid), Frequency (topramezone), and GoalTender (oxyfluorfen) and their possible combination treatments (Table 4). A control was also included which did not received any herbicides or mowing. The experiment was a Randomized Complete Block Design (RCBD) with four replications per treatment. Treatments were applied as directed sprays (Figure 2) using a Carbon dioxide backpack sprayer (calibrated at 27 gallons per acre output) to the lower 18 inches of trees in early summer (Table 4). Mechanical mowing using a weed wacker (string trimmer) or a lawn mower for Canaan Fir (Clio) and Fraser Fir (Gobles) was done at 30 days and 60 days after treatment application. Scotch Pines at Flushing did not require mowing during the study period depending upon the weed pressure.

For data collection, weed control and phytotoxicity were visually estimated at 30, 60, and 90 days after treatment

Table 1: Dominant weed species found in Scotch Pines field at whispering Pine Tree farm.

SN	Common Name	Scientific Name
1	Sheep Sorrel	*Rumex acetosella L.*
2	Thyme-leaf sandwort	*Arenaria serpyllifolia L.*
3	Spotted Knapweed	*Centaurea stoebe L.*
4	Horseweed	*Erigeron canadensis L.*

Table 2: Dominant weed species found in Canaan Fir field at Runyan's Country Tree Farm.

SN	Common Name	Scientific Name
1	Canada Goldenrod	*Solidago canadensis*
2	Virginia Creeper	*Parthenocissus quinquefolia*
3	Reed Canary Grass	*Phalaris arundinacea*
4	Horseweed	*Erigeron canadensis*
5	Common Ragweed	*Ambrosia artemisiifolia*

Table 3: Dominant weed species found in Fraser Fir field at Wahmhoff's Tree Farm and Nurseries.

SN	Common Name	Scientific Name
1	Milkweed	*Asclepias incarnata*
2	Nutsedge	*Cyperus rotundus*
3	Reed Canary Grass	*Phalaris arundinacea*
4	Velvetleaf	*Abutilon theophrasti*
5	Common Ragweed	*Ambrosia artemisiifolia*
6	Horseweed	*Erigeron canadensis*

Table 4: Weed control treatments used in the field trials with their trade names, active ingredients, and rates of application.

SN	Trade Names	Active ingredients	Rate of Application
1	Roundup Pro concentrate	glyphosate	4 fl oz/A
2	Stinger	clopyralid	4 fl oz/A
3	Frequency	topramezone	2 fl oz/A
4	GoalTender	oxyfluorfen	8 fl oz/A
5	Roundup Pro concentrate + Stinger	glyphosate + clopyralid	4 fl oz /A + 4 fl oz /A
6	Roundup Pro concentrate + Frequency	glyphosate + topramezone	4 fl oz /A + 2 fl oz/A
7	Roundup Pro concentrate + GoalTender	glyphosate + oxyfluorfen	4 fl oz /A + 8 fl oz/A
8	Stinger+ Frequency	clopyralid + topramezone	4 fl oz /A + 2 fl oz/A
9	Stinger + GoalTender	clopyralid + oxyfluorfen	4 fl oz /A + 8 fl oz/A
10	Frequency + GoalTender	topramezone + oxyfluorfen	2 fl oz/A+ 8 fl oz/A
11	Roundup Pro concentrate + Stinger + Frequency + GoalTender	glyphosate + clopyralid + topramezone + oxyfluorfen	4 fl oz /A + 4 fl oz /A + 2 fl oz/A + 8 fl oz/A
12	Control (no herbicides, no mowing)	Control (no herbicides, no mowing)	NA

Table 5: The date of herbicide applications, name Christmas tree species, name of farm and weather condition including humidity, wind velocity, and temperature for each farm at the time of treatment application.

Date of Application	Name of Christmas Tree Species	Farm	Weather Condition
6/4/2025	Scotch Pine	Whispering Pines	Cloudy, Temperature: 25°C (77 °F), Humidity: 68%, Wind velocity: 14.8 km/h (9.2 mph)
6/6/2025	Canaan Fir	Runyan Country Tree Farm	Sunny, Temp: 25°C (77 °F),Humidity 64%, Wind Velocity: 9.9 km/h (6.1 mph)
6/17/2025	Fraser Fir	Wahmhoff Farm	Sunny, Temp: 28°C (82.4 °F), Humidity 52%, Wind Velocity: 5 km/h (3.1 mph)

application, both in a scale of 0-100%. Weed control was estimated based on percentage ground cover by weeds, where 100% indicates complete weed control and 0% indicates no weed control. Phytotoxicity ratings ranged from 0% (no visible injury) to 100% meaning complete branch death.

Although weed control and phytotoxicity evaluation were conducted at 30, 60 and 90 days after treatment DAT, only 90 DAT data are presented and discussed. The final evaluation best reflects season-long efficacy and long-term differences among herbicide programs. All weed control data were analysed by ANOVA in R Studio 4.4.2 and means were separated out by Tukey's HSD test. Phytotoxicity data did not meet assumptions of normality even after transformations. Therefore Kruskal-Wallis test was used in R studio 4.4.2 to compare the treatments within each location.

Results:

Since three independent field trials for Fraser fir, Canaan fir, and Scotch pine were conducted at separate farm locations, each location was analysed individually. Treatments were compared using ANOVA and Tukey's HSD ($\alpha = 0.05$).

After 90 days of treatment application in Fraser firs at Wahmhoff Farm (Gobles), herbicide treatments had a strong and consistent effect on weed control (Table 6). All herbicide treatments showed significantly high weed control percentages ranging from 85.5%-93% in comparison to the untreated control. However, no significant difference was observed among the herbicide treatments. This indicates that all herbicides and their combinations were equally effective in controlling weeds when mowed at 30 and 60 days after treatment application.

In Canaan fir at Runyan's Country Farm (Clio), weed control was moderate (ranging from 28.8%-51%) at 90 DAT. All herbicide treatments except Stinger (clopyralid) were significantly greater than the nontreated control (Table 6). Tank mix of all four herbicides; Roundup Pro concentrate + Stinger + Frequency + GoalTender (glyphosate + clopyralid + topramezone + oxyfluorfen) produced the best weed control weeds (51.50%) when coupled with mowing. Clopyralid struggled to control weeds, providing only 28.8% control of weeds.

Table 6: Weed control percentages at 90 days after treatment at three Christmas tree varieties.

Treatments	Fraser Fir Weed control (%)	Canaan Fir Weed control (%)	Scotch Pines Weed control (%)
glyphosate	88.3a	35.0a	85.0ab
clopyralid	90.8a	28.8ab	83.5ab
topramezone	92.8a	38.8a	70.0b
oxyfluorfen	82.8a	37.5a	68.8b
glyphosate + clopyralid	93.8a	33.8a	84.3ab
glyphosate + topramezone	90.3a	43.8a	82.0ab
glyphosate + oxyfluorfen	89.5a	35.8a	82.0ab
clopyralid + topramezone	85.5a	43.8a	75.5ab
clopyralid + oxyfluorfen	88.3a	33.8a	77.3ab
topramezone + oxyfluorfen	89.0a	35.0a	82.5ab
glyphosate + clopyralid + topramezone + oxyfluorfen	93.0a	51.5a	92.8a
Control (no herbicides, no mowing)	0.0b	0.0b	0.0c

Note: Means within a column followed by the same letter are not statistically different at $P<0.05$.

Table 7: Phytotoxicity percentages at 90 days after treatment at three Christmas tree varieties.

Treatment	Fraser Fir Phytotoxicity (%)	Canaan Fir Phytotoxicity (%)	Scotch Pine Phytotoxicity (%)
Glyphosate	0	0	0
Clopyralid	2.5	0	0
Topramezone	0	0	0
Oxyfluorfen	0	2.5	0
Glyphosate + clopyralid	0	3.75	0.75
Glyphosate + topramezone	0	0	2.5
Glyphosate + oxyfluorfen	0	0	0
Clopyralid + topramezone	0	0	0.75
Clopyralid + oxyfluorfen	0	0	0
Topramezone + oxyfluorfen	0	1.25	0
Glyphosate + clopyralid + topramezone + oxyfluorfen	0	2.5	0
Control (no herbicides, no mowing)	0	0	0

Note: None of the herbicide treatment produced statistically significant differences in phytotoxicity injury for any species at $\alpha = 0.05$.

Unlike Fraser fir and Canaan fir, herbicide treatments formed three statistical groups (Table 6). The four-way tank mix of Roundup Pro concentrate + Stinger + Frequency + GoalTender (glyphosate + clopyralid + oxyfluorfen + topramezone) provided highest weed control of 92.8%. Singular application of Frequency (topramezone) and GoalTender (oxyfluorfen) provided the least weed (ranging from 68% to 70%). Whereas combinations of these herbicides among themselves showed intermediate efficacy in control of weeds (ranging from 75% to 85%).

Phytotoxicity symptoms across the three conifer species were generally low for all treatments (Table 7). Fraser fir displayed negligible overall injury with the only measurable response (2.5%) occurring under (Stinger). Canaan fir showed modest phytotoxicity in few treatments, including 3.75% under Roundup Pro Concentrate + Stinger and 2.5 under Goaltender alone or the four-way tank mix. Scotch pine showed minimal injury with highest value of 2.5% observed for Roundup Pro Concentrate (glyphosate) + Frequency (topramezone) while the other treatments showed slight injury. All other treatments resulted in 0% phytotoxicity across species, including untreated control.

Discussion:

All four herbicides used in this trial have diverse mechanisms of action (MOA). Roundup Pro concentrate (glyphosate) is a non-selective systemic, post-emergent, WSSA group 9 herbicide which inhibits EPSP. Stinger (clopyralid), a synthetic auxin which falls under WSSA group 4 herbicides, used as post-emergent herbicide while GoalTender (oxyfluorfen) is a WSSA group 14 herbicide (inhibitor of PPO) with both pre and post activity. Frequency (Topramezone), group 27 herbicide (inhibitor of 4-HPPD), also has both preemergent and post-emergent activities. Despite the two herbicides having both pre- and post-emergent qualities, postemergence application was made for all four herbicides.

Each trial was conducted at a distinct location, environment and weed pressure and populations differed. This may be the reason for difference in weed control for different varieties. Weed was denser and more established in Canaan firs at Runyan's Country Farm (Clio) compared to other farms which we expect to be the reason for lower efficacy of treatments for Canaan firs.

The tank mix of herbicides all four herbicides was ranked top or near top for control of weeds in all three Christmas tree species. Superior performance of the mix is possibly due to spectrum broadening resulting reduced escape of weeds. Combining herbicide with different mechanisms of action provides complementary activity. Multiple MOAs also reduce selection pressure compared to repeated single-site application which ultimately helps to prevent resistance development in weeds.

Single application of GoalTender (oxyfluorfen) showed reduced control of weeds in Scotch Pine and Fraser fir. It may be due to GoalTender being contact herbicide lacking strong systemic movement. When mixed with other herbicides the weed control increased, this reinforces the importance of pairing PPO inhibitors with systemic partners or using in tank mixtures for more robust control of weeds.

The lack of significant differences in phytotoxicity among herbicide treatments may be explained by the relatively low herbicide dosage used in this study. All three species with nearly all observation showing almost no visible damage at 90 DAT suggests that the reduced application rates may have been below threshold required to elicit damage to plants. Another contributing factor may be the timing of injury assessment, 90 DAT, because any early season injury that may have occurred could have reduced through new growth over the time.

Summary:

Across all three Christmas tree species evaluated, treatments consistently improved weed suppression compared to untreated controls. While Fraser fir and Scotch Pine field showed strong responses to most herbicides and combinations, Canaan fir field exhibited more modest control. It likely reflects that the differences in the initial weed pressure and site conditions. Several treatments were similarly effective within each species; no clear winner which could outperform other treatments was found. Phytotoxicity of treatments to the trees remained very low indicating that the herbicide rates used in the trial were very safe for Fraser fir, Canaan fir, and Scotch pine under field conditions. Overall, multiple herbicide options when paired with timely mowing can be integrated successfully into weed management plan for Christmas tree production. To check consistency of the results, trials will be repeated in summer 2026.

Key results:

- All herbicide treatments improved weed control compare to the untreated control for Fraser fir, Canaan fir, and Scotch pine.
- Caanan fir field had moderate control of weeds likely due to higher initial weed pressure.
- No herbicide or tank mix consistently outperformed other across all species.
- Four way tank mix (Glyphosate + Clopyralid + Oxyfluorfen + Topramezone) provided the highest weed control in Scotch pine field.
- Phytotoxicity was minimal in all species, indicating that the tested herbicide rates were safe for Christmas trees.
- Integrating herbicides with mowing (Chemical mowing) at properly timed interval improved overall weed management in Christmas tree production.

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Age	Size	100 - 499	500 - 1000
Abies balsamea ~ Balsam Fir			
* Limited crop			
2-1 / P+1	8 - 14"	1.75	~~1.25~~
2-2 / P+2	10 - 18"	2.50	~~1.95~~
Abies balsamea phanerolepis ~ Canaan Fir			
* Limited crop			
2-1 / P+1	10 - 15"	1.85	1.65
P+2	10 - 18"	2.50	~~2.00~~ (1000 + Inquire)
Abies concolor ~ Concolor Fir			
* Limited crop			
2-0 / 3-0	12 - 18"	1.25	0.95
3-1 / P+1	8 - 14"	2.00	~~1.75~~
2-2	12 - 18"	2.25	~~1.95~~
Abies fraseri ~ Fraser Fir			
* Limited crop			
3-0	9 - 12"	0.95	0.75
3-1 / P+1	8 - 14"	1.65	1.45
3-2 / P+2	10 - 18"	2.25	~~1.95~~ (1000+ Inquire)

Age	Size	100 - 499	500 - 1000
Picea abies ~ Norway Spruce			
3-0	10 - 15"	0.85	0.65
2-1	10 - 16"	1.65	1.45
2-2	15 - 24"	2.25	~~1.75~~ (1000+ Inquire)
Picea glauca ~ White Spruce			
3-0	9 - 15"	0.95	0.70
2-1 / 2-2	15 - 24"	1.95	1.75
Picea pungens "Glauca" ~ Colorado Blue Spruce			
3-0	9 - 15"	0.95	0.70
2-1 / P+1	8 - 14"	1.65	1.45
2-2	16 - 22"	1.85	1.65 (1000+ Inquire)
Picea omorika ~ Serbian Spruce			
2-2	12 - 16"	1.65	1.45
2-2	16 - 22"	1.95	1.75
Picea glauca "Densata" ~ Black Hills Spruce			
2-2	9-12"	1.65	1.25

Age	Size	100 - 499	500 - 1000
Pinus resinosa ~ Red Pine			
2-0 / 3-0	8 - 14"	0.95	0.75
2-2	8 - 14"	1.75	1.45
2-2	14 - 22"	1.95	1.65
Pinus strobus ~ Eastern White Pine			
3-0	6 - 12"	0.95	0.75
2-1 / 3-1	10 - 16"	1.95	1.75
2-2	14 - 20"	2.25	1.95
Pseudotsuga menziesii ~ Douglas Fir			
3-0	9 - 15"	0.95	0.75
2-2	12 - 16"	1.95	1.75
2-2	15 - 24"	2.25	1.95
Thuja occidentalis ~ American Arborvitae [Eastern White Cedar]			
2-0 / 3-0	18 - 24"	1.25	0.95
2-1 / 3-1	10 - 16"	2.25	1.95

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