ALTERNATIVES TO GLYPHOSATE FOR WEED CONTROL IN CHRISTMAS TREE PRODUCTION

Ashley Jeon[1], Greta Gallina[2], Bill Lindberg[3], and Debalina Saha[4*]

[1]Undergraduate Research Assistant, Department of Horticulture, Michigan State University
[2]Graduate Research Assistant, Department of Horticulture, Michigan State University
[3]Christmas Tree Extension Educator, Michigan State University Extension
[4]Assistant Professor, Department of Horticulture, Michigan State University

*Corresponding author

INTRODUCTION

Glyphosate was discovered in 1950 by a Swiss chemist, Henri Martin. Twenty years later, John Franz, a Monsanto chemist, discovered its herbicidal properties. Glyphosate was found to kill plants by preventing the synthesis of certain amino acids, which happens in the shikimic acid pathway. It is the only herbicide that targets the 5-enolpyruvyl-3-shikimate phosphate synthase (EPSPS) pathway (Duke, 2018). As a result, the plants are starved for these amino acids. Symptoms develop at the growing points as tissue turns yellow or white in herbaceous species and progresses to severely injuring or killing the plant. In the case of woody species, symptoms may not be visible initially, but subsequent exposures lead to symptoms such as chlorosis (Figure 1) and irregular growth (referred to as *witches' broom*) (Figure 2). Glyphosate is a nonselective, systemic herbicide. As a systemic herbicide, it works by being taken up into the plant and then it is translocated within plant tissue to the site of action. Being nonselective means it will generally kill all plants. However, exceptions occur in the form of plants tolerant of glyphosate through genetic engineering (that is, Roundup-ready

crops) or through unintended selection for glyphosate-tolerant weeds. Transgenic crops have been a major contributor to the extreme popularity of glyphosate as it allows growers to apply glyphosate to their fields without damaging their crops but controlling most of the weeds. Over 90% of transgenic crops planted in U.S. fields are estimated to be herbicide-resistant crops and the majority of those are glyphosate resistant (ISAAA, 2016). Most of these Roundup-ready crops are soybean and corn. According to the U.S. Department of Agriculture (USDA) Economic Research Service (2022), the percent of domestic soybean acres planted in the U.S. with herbicide-tolerant (HT) seeds rose from 17% in 1997 to 68% in 2002, before plateauing at 94% in 2014. However, adoption rates for HT corn grew relatively slowly and the rates increased following the turn of the century. Currently, approximately 89% of domestic corn acres are produced with HT seeds (USDA Economic Research Service, 2022).

Figure 1. Discoloration and chlorosis of conifer needles due to repeated application of glyphosate. Photo credit: Bill Lindberg, MSU Extension.

Figure 2. Irregular and stunted growth of conifer in Christmas tree production due to glyphosate application. Photo credit: Bill Lindberg, MSU Extension.

Glyphosate is also popular for use in Christmas tree production. When used properly, it causes relatively little risk to trees, and it controls most common weeds (Figure 3). Glyphosate can be safely applied around most conifers before budbreak or after growth is hardened, as the waxy coating on hardened conifer needles protects sensitive tissues from the herbicide during this time. It can also be applied as a directed spray to weeds at other times (Kuhns, 2018). Glyphosate must be applied to actively growing weeds for good translocation and effective control. This results in a potentially narrow window for safe application between when the weeds are actively growing and when the buds are broken, or when the weeds are still growing and the trees have hardened off. Glyphosate puts immense selection pressure on weeds due to its excessive use. As a result, an unprecedented number of weeds have become resistant to glyphosate (ISAAA, 2016). Christmas tree production systems

contain many of these weeds. Due to development of glyphosate-resistant weeds and perceived issues related to the impact of glyphosate on human health, many growers desire alternative approaches to managing weeds.

Figure 3. Glyphosate application at the Christmas tree farm for weed control. Photo credit: Debalina Saha, Department of Horticulture, MSU.

ADVANTAGES OF GLYPHOSATE

Due to its systemic nature, glyphosate is especially useful in controlling weeds with large underground structures such as perennials (Marble et al., 2020). Because glyphosate is nonselective, growers can often use it to control all their problematic weeds including grasses and broadleaves rather than having to use different herbicides for different kinds of weeds (Marble et al., 2020). Glyphosate has minimal residual activity. After it is applied, glyphosate binds to soil particles and is not subject to runoff. Binding to soil particles keeps it from moving down through the soil to the region where the Christmas tree roots are, which can keep it from being taken up by the tree roots and harming the trees (Marble et al., 2020). Glyphosate is nonvolatile so it will not vaporize, drift away from the intended area, and damage unintended plants (Saha et al., 2020). Manufactured by many companies, glyphosate is relatively inexpensive (Marble et al., 2020). It has a relatively low toxicity to humans and the environment when it is used properly (Marble et al., 2020), especially when compared to the nonselective herbicides it replaced such as Paraquat (ISAAA, 2016).

DISADVANTAGES OF GLYPHOSATE

Although hardened conifer foliage is relatively tolerant of glyphosate, it will damage new growth if contact occurs due to drift or misapplication. If sensitive conifer foliage is treated, it can be translocated throughout the tree and even kill it (Marble et al., 2020). Glyphosate application must be controlled and targeted, or the application must be done before budbreak or after growth has hardened in fall (Zandstra & O'Donnell, 2018). Even if precautions are taken by using shielded sprayers, there is always a risk of accidental tree contact if it is applied during active growth. There is also a strong risk of herbicide-resistant weeds and additional weeds developing resistance from continued use. Some glyphosate-resistant weeds common in Christmas tree production systems include

annual ryegrass *(Festuca perennis* Lam.), horseweed (*Erigeron canadensis* [L.] *Cronquist*), bentgrass (*Agrostis spp.* L.), perennial ryegrass (*Lolium perenne* L.), common ragweed (*Ambrosia artemisiifolia* L.), smooth pigweed (*Amaranthus hybridus* L.), barnyardgrass (*Echinochloa crus-galli* [L.] Beauv.), prickly lettuce (*Lactuca serriola* L.), and perennial ryegrass (*Lolium perenne* L.) (Heap, 2022). Repeated applications may be needed for hardy annual and perennial weeds such as Canada thistle (*Cirsium arvense* [L.] Scop.), horsenettle (*Solanum carolinense* L.), yellow and purple nutsedges (*Cyperus esculentus* L. and *Cyperus rotundus* L.), milkweed (*Asclepias syriaca* L.), and field bindweed (*Convolvulus arvensis* L.) (Kuhns, 2018).

Concerns about glyphosate in relation to human health are not backed by scientific evidence. Following extensive study, the U.S. Environmental Protection Agency, along with many other agencies, has maintained its findings that "there are no risks of concern to human health when glyphosate is used in accordance with its current label" (U.S. Environmental Protection Agency, 2022).

GLYPHOSATE ALTERNATIVES FOR CHRISTMAS TREE PRODUCTION

NONCHEMICAL ALTERNATIVES

Prevention

Preventing the introduction of new weeds into Christmas tree production systems is the most important first step for successful weed control. Ensure all equipment, trees, mulch, and people that come into a Christmas tree production system are not contaminated with weed seeds. Scout fields to observe and note any weeds present (Saha et al., 2020). Next, determine overall weed population and the type of weeds present (for example, annuals vs. perennial, grasses vs. broadleaved). Note whether any weeds present are likely to be glyphosate resistant.

Mechanical Control

Mechanical control is the act of physically removing the weeds from the soil using methods such as hand picking, mowing, or cultivation (Appleton & Hill, 1997). Cultivation physically removes weeds from and loosens the soil. Mowing cuts down taller weeds but does not manage roots. Both cultivation and mowing may involve large machinery, which can be difficult

to get up and down the rows between trees and could potentially damage them (Appleton & Hill, 1997). Hand weeding can be labor intensive, time consuming, and expensive. Mechanical methods are good options for combating herbicide resistance as they can be used to strategically remove the weeds before they set seed if they are not killed by the herbicides initially applied.

Mulch

Mulch is a good weed control option and offers more preemergence control than glyphosate as well as reduces the weed problems later as well. Mulch is good to use in combinations with herbicides as it can increase the effectiveness and length of herbicidal effects. Mulches may be organic or inorganic (for example, plastic sheeting); however, most growers use organic mulches, such as ground bark or wood chips, due to their low cost and ease of handling. Mulches act as a physical barrier blocking or limiting the growth of weeds. In addition, organic mulches help maintain the soil temperature and moisture retention, which is advantageous for tree roots and survival of the transplants during the establishment phase of the Christmas trees (Cregg et al., 2009). A 2009 study (Cregg et al.) found the use of wood chip mulch can increase height and caliper growth of Christmas trees. Organic mulches can also release nutrients into the soil (Chalker-Scott, 2007). The main downside to mulching is material handling and labor requirement to apply. Mulch materials can be more expensive than glyphosate and can have issues with acidity, pests, and other diseases. But when applied at right depths (approximately 2 to 3 inches) and obtained from a reliable source as good quality, mulch can help in managing weeds significantly.

Cover Crops

Cover crops are plants intentionally planted in the rows between Christmas trees. These plants directly compete with weeds for nutrients and space, which makes them a good weed control option for Christmas tree production. Like mulch, cover crops are also more of a preemergence control as they will prevent the emergence of weeds by taking up the space, water, and nutrients that would regularly be used by weeds. This can decrease the need for using herbicides later. They can also prevent soil erosion and can add nutrients to the soil. However, cover crops may compete with Christmas trees for water and nutrients, they might bring and harbor pests, and they will increase water use and cost (Nikiema et al., 2012). Cover crops must be used as winter annuals that will die off once trees are established so they will not compete with the trees. Hence, timing of cover crops is important.

Biological Control

Biological control is not commonly used in Christmas tree production, so it is probably not a viable alternative to glyphosate. In true biological control, there is one specific host for every one specific predator. This is difficult to come by and not often seen in Christmas tree production. A few options do exist. The flea beetle and cinnabar moth are natural enemies to tansy ragwort (*Senecio jacobaea*), a weed found in Christmas tree production systems. Klamath beetles can be used to control St. Johnswort

(*Hypericum perforatum*). Biological control agents can become a problem themselves especially those not native to the area. Many regulations hinder the use and research of biological control agents (Morin, 1996).

Livestock

Livestock are relatively nonselective making them similar in scope to glyphosate. They will eat the weeds and not the trees, but they are not the best choice for many growers. Take care in the choice of livestock so that they do not eat or step on the trees; sheep tend to be the best option (Appleton & Hill, 1997). Shropshire sheep are widely used for weed control in Christmas tree and orchards in Europe, especially in the United Kingdom. This breed prefers to graze on grasses and herbaceous weeds rather than trees.

Flame Weeding

Flame weeding involves using a propane torch to control weeds. It is nonselective, making it a potential glyphosate alternative. Flame weeding does not disturb the soil and can provide long-term control against weeds. It is most effective against smaller weeds, but it can be quite dangerous to Christmas trees, people, and anything else nearby. It can be difficult to do in the moist spring and dangerous to do in hot, dry summers. The risk of the fire getting out of control, burning down trees, or spreading uncontrollably makes flame weeding an undesirable choice for use in Christmas tree production systems (Peachey et al., 2017).

POSTEMERGENCE CHEMICAL ALTERNATIVE HERBICIDES:

A variety of postemergence herbicides can be used instead of or in combination with glyphosate. Some herbicides can replace glyphosate entirely, while others can be used with glyphosate to control glyphosate-resistant weeds. The following summary includes herbicides that are selective to control either broadleaves or grass, nonselective herbicides that will control both, and some herbicides that can also act as preemergence herbicides.

For Broadleaf Weed Control

Synthetic Auxins

Synthetic auxin herbicides are one option for controlling broadleaf weeds. These include triclopyr triethylamine salt (Garlon), clopyralid (Stinger), and 2,4-D (Defy Amine, Turret). These herbicides are also systemic, which make them a similar alternative to glyphosate (Shaner, 2014). Triclopyr triethylamine salt and 2,4-D selectively kill herbaceous and woody broadleaved weeds (Kuhns, 2018), while clopyralid works specifically against certain broadleaves, such as legumes, composites, plantains, nightshade, thistles, and smartweeds (Zandstra & O'Donnell, 2018). Clopyralid is safe to spray over established conifers, but the others should only be applied before spring budbreak or after growth has hardened in fall (Ahrens & Bennett, 2011), making them similar to glyphosate. Douglas-fir and white pine may show sensitivity to synthetic auxin

herbicides (Zandstra & O'Donnell, 2018). Unlike glyphosate, 2,4-D can volatilize and move in the vapor phase after the herbicide has dried on the soil or plant surface and damage nearby plants. The use of low-volatile esters, oil soluble amines, and applications to dormant trees greatly reduces the hazard of injury to adjacent crops (Rodgers & Vodak, 1983).

Bentazon (Basagran)
A glyphosate alternative that specifically controls nutsedge as well as some other broadleaf weeds is bentazon which is a photosystem II site B inhibitor (Shaner, 2014). Bentazon should be applied directly to the weeds as it can burn the needles of conifers, especially spruce and fir, if sprayed over the tops of them (Kuhns, 2018).

For Selective Grass Control

ACCase Inhibitors
The Acetyl CoA Carboxylase (ACCase) Inhibitors, clethodim (Envoy Plus), fluazifop-P (Fusilade), and sethoxydim (Segment) (Shaner, 2014) are selective systemic herbicides used to control annual grasses as well as many perennial grasses in Christmas tree production systems. Some perennial grasses may require repeated applications. They do not affect broadleaved weeds and are safe to use near Christmas trees in all periods of growth; however, they must be applied to actively growing grasses (Kuhns, 2018).

For Managing Grasses and Broadleaves (Nonselective)

One method to control grasses and broadleaves is to simply mix two of the herbicides mentioned previously or apply one of the following herbicides.

Glufosinate (Finale)
Glufosinate is perhaps one of the most similar herbicides to glyphosate. A nonselective, contact herbicide, it kills only parts of the weed it directly contacts. Glufosinate is a glutamine synthase inhibitor (Shaner, 2014). It has no soil activity and works best when weeds are small and actively growing (Mann, 2022). Glufosinate should not be applied over actively growing trees (Peachey et al., 2017).

Asulam (Asulox)
Asulam is an inhibitor of 7,8 dihydro-pteroate synthetase (DHP) (Shaner, 2014). It should only be applied after growth has hardened. It can control many annual and perennial broadleaved weeds as well as grasses. In particular, it provides a specific alternative for glyphosate for control of dock species (*Rumex spp.* L.) and bracken ferns (*Pteridium aquilinum* [L.]) (Shaner, 2014). Apply only once per season (Zandstra & O'Donnell, 2018).

Flasaulfuron (Mission)
Flasaulfuron is an herbicide that can act as both preemergence and postemergence weed control, which is an advantage over glyphosate. Flasaulfuron is an acetolactate synthase (ALS) inhibiting herbicide that controls annual grasses and annual broadleaves (Zandstra & O'Donnell, 2018). Apply Flasaulfuron directly to weeds to avoid injury to actively growing trees and do not apply within the first year of growth (Peachey et al., 2017); however, it can be applied over the tops of dormant trees. Wait a minimum of three months between applications (Zandstra & O'Donnell, 2018).

Hexazinone (Velpar)
Hexazinone is a photosystem II inhibitor at site A. Apply on Christmas trees that are two years or older and do not use in nurseries or seedbeds (Zandstra & O'Donell, 2018). Hexazinone needs to be applied after soil has settled around seedlings and roots of the Christmas trees in the field (Zandstra & O'Donell, 2018). Hexazinone can be a groundwater hazard; therefore, apply it in early spring, not late winter. Glyphosate has a much lower leaching potential so this risk will need to be considered. Hexazinone controls many annual broadleaves and grasses well, including common ragweed, horseweed, and annual bluegrass (Poa annua L.) (Zandstra & O'Donnell, 2018). Hexazinone can even be effective against trailing blackberries (Peachey et al., 2017), which are poorly controlled by glyphosate.

Pelargonic Acid (Scythe)
Pelargonic acid (scythe) is a postemergence, contact herbicide that can control small broadleaf weeds but can injure perennials and larger annual weeds (Neal & Senesac, 2018). It is often considered as a herbicidal soap but is not a certified organic option. An advantage of scythe is its rapid symptom development (within less than 30 minutes) (Neal & Senesac, 2018).

Ammonium Nonanoate (Axxe)
Ammonium nonanoate is an Organic Materials Review Institute–certified formulation of pelargonic acid and has the same active ingredient as scythe. It is also a nonselective, contact-type herbicide, which is fast acting. Once it comes in contact with the plant surface, it can destroy the integrity of the leaf surface and can cause damage to the cell walls. Repeated application may be required for an effective weed control. Do not apply over the tops of the Christmas trees. This can be used in organic Christmas tree production system.

PPO Inhibitors
Oxyfluorfen (Goaltender), lactofen (Cobra), and flumioxazin (SureGuard) are protoporphyrinogen oxidase (PPO) inhibiting herbicides. They can also be used as preemergence herbicides. Apply right after transplanting, prior to budbreak, over the tops of the trees or as a directed spray. Flumioxazin and oxyfluorfen can also be applied after growth has hardened in the later season (Zandstra & O'Donnell, 2018). They can control broadleaves and grasses. Overall, they are a good glyphosate alternative.

THE REALITIES OF USING GLYPHOSATE ALTERNATIVES

Alternatives to glyphosate have many of their own advantages and disadvantages. Many of the alternative methods, especially the nonchemical ones, are not as effective as glyphosate and must be combined with other methods. In addition, each herbicide has its own risks, and some may be greater than the risks associated with glyphosate. For example, phenoxy

herbicides like 2,4-D and Garlon can be dangerous to other crops. Since Christmas trees are often grown with a variety of other crops, be aware of the other crops and their locations near the farm and avoid the drift of herbicides. Even if they are not particularly dangerous to trees, they might harm other nearby things (Kudinov, 1972). Other herbicides such as hexazinone are active in the soil and may have issues with runoff. Some may not be as effective as glyphosate in either being selective or contact type.

Over the years, glyphosate has been widely used, and as discussed previously, several weeds have already become resistant to it. So, even if these alternative methods are just used in combination with glyphosate, that will still decrease the use of glyphosate, help to manage glyphosate-resistant weeds, and reduce developing resistance among other weeds. In addition, concerns among growers or their customers about possible health impacts of glyphosate can be easily overcome by opting to glyphosate alternatives. All growers can benefit from applying glyphosate alternatives as they can incorporate integrated weed management strategies by combining both nonchemical and chemical methods and avoiding application of glyphosate only. By rotating different herbicides with different modes of action and combining chemical methods with nonchemical methods, growers can manage weeds more efficiently causing less damage to the environment.

ACKNOWLEDGMENTS

The authors thank Dr. Bert Cregg, Department of Horticulture and Department of Forestry, Michigan State University; and Dr. Erin Burns; Department of Plant, Soil and Microbial Sciences; Michigan State University; for their helpful review and feedback.

REFERENCES

Ahrens, J. F., & Bennett, K. P. (2011). *2011 New England guide to chemical weed and brush control in Christmas trees.* University of New Hampshire Cooperative Extension. http://www.christmas-trees.org/2011_NE_Guide.pdf

Appleton, B. L., & Hill, D. B. (1997). *Kentucky Christmas tree production workbook: Vegetation control.* University of Kentucky Cooperative Extension Service.

Chalker-Scott, L. (2007). Impact of mulches on landscape plants and the environment: A review. *Journal of Environmental Horticulture, 25*(4), 239–249. http://dx.doi.org/10.24266/0738-2898-25.4.239

Cregg, B. M., Nzokou, P., & Goldy, R. (2009). Growth and physiology of newly planted Fraser fir (*Abies fraseri*) and Colorado blue spruce (*Picea pungens*) Christmas trees in response to mulch and irrigation. *HortScience*, *44*(3), 660–665. https://doi.org/10.21273/HORTSCI.44.3.660

Duke, S. O. (2018). The history and current status of glyphosate; *Pest Management Science, 74*(5), 1027–1034. https://doi.org/10.1002/ps.4652

Heap, I. (2022). *International herbicide-resistant weed database.* http://www.weedscience.org/Home.aspx

ISAAA. (2016). *Global status of commercialized biotech/GM crops: 2016.* (ISAAA Brief No. 52.) https://www.isaaa.org/resources/publications/briefs/52/download/isaaa-brief-52-2016.pdf

Kudinov, V. I. (1972). Sawdust instead of manure. *Sadovodstvo, 12*(38).

Kuhns, L. J. (2018). Weed control recommendations for Christmas tree growers. *Horticulture Mimeo Series II,* 2–22.

Mann, R. (2022). *Glufosinate herbicide.* https://www.mda.state.mn.us/glufosinate-herbicide

Marble, C., Neal, J., & Senesac, A. (2020). Use of glyphosate and herbicide alternatives for weed control in Florida landscape planting beds. *EDIS, 2020*(1). UF/FAS Environmental Horticultural Department. https://doi.org/10.32473/edis-ep580-2020

Morin, L. (1996). Different countries, several potential bioherbicides, but always the same hurdles. In *Proceedings of the 9th International Symposium on Biological Control of Weeds*, Stellenbosch, South Africa, 19–26 January 1996. University of Cape Town Press. p. 546.

Neal, J., & Senesac, A. (2018). *Are there alternatives to glyphosate for weed control in landscapes?* NC State Extension. https://content.ces.ncsu.edu/are-there-alternatives-to-glyphosate-for-weed-control-in-landscapes

Nikiema, P., Nzokou, P., & Rothstein, D. (2012). Effects of groundcover management on soil properties, tree physiology, foliar chemistry and growth in a newly established Fraser fir (*Abies fraseri [Pursh] Poir*) plantation in Michigan, United States of America. *New Forests, 43*(2), 213–230. http://dx.doi.org/10.1007/s11056-011-9274-8

Peachey, E., Landgren, C. G., & Miller, T. W. (2017). *Weed and vegetation management strategies in Christmas trees* (PNW 625). Pacific Northwest Extension. https://catalog.extension.oregonstate.edu/pnw625

Rodgers, N. K., & Vodak, M. C. (1983). *Chemical site preparation and weed control for Christmas trees* (450-033). Virginia Cooperative Extension Service. https://vtechworks.lib.vt.edu/bitstream/handle/10919/55879/VCE450_033.pdf

Saha, D., Cregg, B. M., & Sidhu, M. K. (2020). A review of non-chemical weed control practices in Christmas tree production. *Forests, 11*(5), 554. http://dx.doi.org/10.3390/f11050554

Shaner, D. L. (Ed). (2014). *Herbicide handbook.* Weed Science Society of America:

U.S. Department of Agriculture Economic Research Service. (2022). *Recent trends in GE adoption.* https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-u-s/recent-trends-in-ge-adoption/

U.S. Environmental Protection Agency. (2022). *Glyphosate.* https://www.epa.gov/ingredients-used-pesticide-products/glyphosate

Zandstra, B., & O'Donnell, J. (2018). *Weed control in Christmas trees* (E3237). Michigan State University Extension. https://www.canr.msu.edu/christmas_trees/uploads/files/e3237%20wcag%202.0.pdf

Produced by the MSU Extension Educational Materials Team. 1P–07:2022–Web-PA/LG WCAG 2.0