Christmas Tree Tolerance and Weed Control with Postemergence Topramezone

Jatinder S. Aulakh[1]*, Vipan Kumar[2], Ethan Paine[3], and Ritu Mohanpuria[4]

Abstract

Topramezone was evaluated in an outdoor container experiment for tolerance of multiple conifer species in Windsor, CT and for postemergence weed control and Fraser × balsam hybrid fir tolerance on a Christmas tree farm in Enfield, CT in 2022 and 2023. In both experiments, topramezone was applied to actively growing Christmas trees at 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}), 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}), or 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}). Balsam fir [*Abies balsamea* (*L.*) *Mill. var. balsamea*], canaan fir [*Abies balsamea* (*L.*) *Mill. var. phanerolepis Fernald*], Fraser fir [*Abies fraseri* (Pursh) Poir], Nordman fir [*Abies nordmanniana* (L.)], Norway spruce [*Picea abies* (L.)] Karst), and white pine [*Pinus strobus* (L.)] in the container experiment and Fraser × balsam hybrid fir [*Abies fraseri* (Pursh) Poir] × [*Abies balsamea (L.)* Mill. *var. balsamea*] in the field experiment were not injured from topramezone rates ranging from 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}) to 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}). Colorado blue spruce [*Picea pungens* (Engelm)] in 2022 and 2023 and Douglas fir [*Pseudotsuga menzeisii* (Mirb.) Franco] in 2023 showed temporary bleaching/yellowing of the new growth with topramezone at 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}). The highest injury was observed at 3 weeks after treatment and ranged from 9% in Colorado blue spruce to 23% in Douglas fir. Common ragweed [*Ambrosia artemisiifolia* (L.) *var. artemisiifolia*], horseweed [*Conyza canadensis* (*L.*) Cronquist], fall panicum [*Panicum dichotomiflorum* (L.)], large crabgrass [*Digitaria sangunalis* (L.) Scop.], and yellow foxtail [*Setaria pumila* (Poir.) Roem. & Schult. *ssp. Pumila*] were controlled 61 to 91%, 66 to 98%, and 45 to 99% by 4, 8, and 12 weeks after treatment, respectively, depending upon topramezone rate. Weed density 12 weeks after treatment showed a 58 to 100% reduction depending upon topramezone rate applied and weed species tested. Overall, these results suggest that postemergence topramezone at the labelled rate (98 g ai·ha^{-1} or 0.09 lb ai·A^{-1}) can be safely used for effective weed control in Christmas trees. Further research is needed to evaluate postemergence topramezone in conjunction with preemergence and other postemergence herbicides for enhanced crop safety and weed control.

Herbicides used in this study: topramezone (Frequency), 4-[3-(4,5-dihydro-1,2-oxazol-3-yl)-2-methyl-4-methylsulfonylbenzoyl]-2-methyl-1*H*-pyrazol-3-one.

Christmas tree species used in this study: balsam fir [*Abies balsamea (L.)* Mill. *var. balsamea*], canaan fir [*Abies balsamea (L.) Mill. var. phanerolepis Fernald*], Colorado blue spruce [*Picea pungens (*Engelm)], Douglas fir [*Pseudotsuga menzeisii* (Mirb.) Franco], Fraser fir [*Abies fraseri* (Pursh) Poir], Fraser × balsam hybrid fir [*Abies fraseri* (Pursh) Poir] × [*Abies balsamea (L.)* Mill. *var. balsamea*], Nordman fir [*Abies nordmanniana* (L.)], Norway spruce [*Picea abies* (L.) Karst], and white pine [*Pinus strobus* (L.)].

Weed Species used in this study: common ragweed [*Ambrosia artemisiifolia* (L.) *var. artemisiifolia*], fall panicum [*Panicum dichotomiflorum* (L.)], horseweed [*Conyza canadensis* (*L.*) Cronquist], large crabgrass [*Digitaria sangunalis* (L.) Scop.], and yellow foxtail [*Setaria pumila* (Poir.) Roem. & Schult. *ssp. Pumila*].

Index words: Christmas trees, herbicide efficacy, postemergence, weed management.

Significance to the Horticultural Industry

Selective postemergence (POST) herbicide choices for controlling broadleaf weeds in Christmas tree plantations are limited. Topramezone is registered as a preemergence (PRE) application in dormant Christmas trees before bud-break or a POST-directed application in actively growing Christmas trees. Currently, topramezone label lists a few species of fir, pine, and spruce as tolerant ornamental trees. Results from this study show that topramezone at the labelled rate (98 g ai·ha^{-1} or 0.09 lb ai·A^{-1}) did not cause injury to balsam fir, canaan fir, Colorado blue spruce, Douglas fir, Fraser fir, Nordman fir, Norway spruce, white pine, and a Fraser × balsam hybrid. Furthermore, the labelled rate of topramezone was very effective in controlling common ragweed, horseweed, fall panicum, and large crabgrass. For yellow foxtail, sequential topramezone applications at 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}) may be required for satisfactory control. Above all, topramezone adds a new mode-of-action, a p-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibitor, to supplement the POST broadleaf and grassy weed management options for Christmas tree growers.

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[1]Associate Scientist. Windsor Valley Laboratory, Connecticut Agricultural Experiment Station, 153 Cook Hill Road, Windsor, CT 06095.

[2]Associate Professor. Soil and Crop Sciences Section, School of Integrative Plant Science, Cornell University, 1115 Bradfield Hall, Ithaca, NY 14853.

[3]Research Technician I. Windsor Valley Laboratory, Connecticut Agricultural Experiment Station, 153 Cook Hill Road, Windsor, CT 06095.

[4]Graduate Research Assistant, Department of Natural Resources and the Environment, University of Connecticut, W B Young Bldg., 1376 Storrs Road, Storrs, CT 06269.

*Corresponding author email: Jatinder.Aulakh@ct.gov.

Introduction

Christmas trees are grown on approximately 141,640 ha (350,000 acres) and 25 to 30 million real Christmas trees are sold annually in the United States (N.C.T.A. 2025). On average, it takes 7 years to grow a tree of typical salable height of 1.8 m (6 feet) (N.C.T.A. 2025). Weeds not only compete with Christmas trees for light, nutrients, space, and water but also serve as a host for many insect pests and diseases (Fulbright et al. 2015). For example, bracken fern [*Pteridium aquilinum* (L.) Kuhn] serves as an alternate host for fir needle rust fungus [*Uredinopsis pteridis* (Dietel & Holw.)] (Wegwitz 1993). Common chickweed [*Stellaria media* (*L.*) *Vill. ssp. Media*] and mouse-ear chickweed [*Cerastium vulgare* (L.)] are alternate hosts for fir broom rust [*Melampsorella caryophyllacearum* (Schroet)], which infects Fraser fir, balsam fir, grand fir [*Abies grandis* (Douglas ex D. Don) Lindl.], and other true firs (*Abies spp*) (Eshenaur and lamb 2013). A lack of weed control can significantly reduce the growth and development of young transplants, deteriorate the quality of the established trees, and extraordinarily delay crop maturity (the desired marketable size).

Chemical weed control is critical for producing quality Christmas trees. A typical weed management program in Christmas trees begins with a broad-spectrum PRE herbicide such as flumioxazin or a combination of a mainly broadleaf herbicide (isoxaben, oxyfluorfen, or simazine) and a primarily grass herbicide (metolachlor, oryzalin, or pendimethalin) in spring before budbreak when the trees are still dormant (Aulakh 2020, 2016). POST herbicide applications in Christmas trees generally start 4 to 5 weeks after budbreak when the new growth has sufficiently hardened off. It is a common practice to use graminicides (clethodim, fluazifop, or sethoxydim) and clopyralid for POST control of grassy and broadleaf weeds, respectively. Graminicides or clopyralid are very safe and have rarely injured Christmas trees even when applied over-the-top at labelled rates after the new growth has hardened off. Graminicides provide effective control of most annual and perennial grasses (Brewster and Spinney 1989, Harker and O'Sullivan 1991, Rankins et al. 2005). Clopyralid effectively controls or suppresses certain broadleaf weeds in the asteraceae, fabaceae, polygonaceae, solanaceae, and violacea families but it is less effective on common lambsquarters [*Chenopodium album* (L). *var. album*], pigweeds (*Amaranthus spp*), and weeds in the mustard family (*Brassicaceae*). Furthermore, both the graminicides and clopyralid have no sedge (*Cyperus spp*) efficacy. Other herbicides available for postemergence directed (PD) application in confer plantations include bentazon, glyphosate, oxyfluorfen, and triclopyr (Ahrens and Bennett 2011). Clearly, selective POST herbicide choices for controlling broadleaf weeds and sedges are limited.

Topramezone (Frequency®; BASF Corporation LLC., Research Triangle Park, NC), a p-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibitor, is a new herbicide for PRE and POST weed control in Christmas tree plantations. It is a member of the benzoyl pyrazole herbicide family (Grossman and Ehrhardt 2007). Topramezone controls susceptible broadleaf and grass weeds by disrupting carotenoid biosynthesis (Grossman and Ehrhardt 2007). Injury symptoms in susceptible weeds begin with an initial bleaching which is soon followed by necrosis (Lee et al. 1997).

Topramezone has been known for excellent crop safety (Anonymous 2024, Arslan et al. 2016, Cox et al. 2017, Gonçalves et al. 2021, Rodriguez et al. 2023) and effectively controlled diverse weed species (Aulakh 2022, Elmore et al. 2013, Ganie and Jhala 2017, Grossman and Ehrhardt 2007, Kohrt and Sprague 2017, Kumar and Jha 2015, Peppers et al. 2023, Rodriguez et al. 2023). Negrisoli et al. (2020) reported 86 and 91% control of fall panicum 2 weeks after POST applied topramezone at 25 g ai·ha^{-1} (0.02 lb ai·A^{-1}) and 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}), respectively. However, fall panicum recovered significantly by 10 weeks after treatment (WAT) with only 23 and 44% control with topramezone at 25 g ai·ha^{-1} (0.02 lb ai·A^{-1}) and 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}), respectively. When metribuzin (2,241 g ai·ha^{-1} or 2 lb ai·A^{-1}) was tank-mixed with topramezone at 25 g ai·ha^{-1} (0.02 lb ai·A^{-1}) and 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}) fall panicum was controlled 63 and 83% respectively, by 10 WAT.

Topramezone is registered for a PRE application in dormant Christmas trees before budbreak or a POST-directed application in actively growing Christmas trees (Anonymous 2025). The topramezone label lists several species of fir, pine, and spruce as tolerant ornamental trees. The maximum single application rate for PRE or POST treatment is 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}) and the maximum seasonal application rate is 392 g ai·ha^{-1} or 0.35 lb ai·A^{-1} (Anonymous 2025). When applied POST, topramezone requires crop oil concentrate (COC), or methylated seed oil (MSO) for maximum weed efficacy. However, the use of MSO is recommended for best performance under a wide range of environmental conditions. Topramezone safety to Christmas trees and weed control effectiveness have not yet been evaluated in the northeastern U.S. The objectives of this research were to evaluate topramezone for tolerance of multiple Christmas tree species and POST weed control.

Materials and Methods

Container experiment. Topramezone was evaluated in an outdoor container experiment for over-the-top (OTT) tolerance of balsam fir, canaan fir, Colorado blue spruce, Douglas fir, Fraser fir, Nordman fir, Norway Spruce, and white pine at the Connecticut Agricultural Experiment Station (CAES) in Windsor, CT during summer 2022 and 2023. In spring 2021, bare-rooted seedlings of the tested Christmas tree species (2 + 1) were transplanted into 11.4 L (3 gal) plastic containers containing a pine bark and composted woodchips (1:1) mixture. The potting media was amended with 4.75 kg·m^{-3} (8 lb·yard^{-3}) 20N-4P-8K controlled-release fertilizer (Harrells Profertilizer; Harrells LLC, Lakeland, Florida, USA), 0.18 kg·m^{-3} (0.3 lb·yard^{-3}) micronutrients (Harrells LLC), and 2.97 kg·m^{-3} (5 lb·yard^{-3}) dolomitic limestone (Plant Products LLC, Findley, OH, USA). Pots were kept on an outdoor gravel pad and received overhead 1.25 cm (0.5 inch) irrigation daily in four cycles of 4 mins each with 3-hour interval between cycles. A controlled-release fertilizer 20N-4P-8K was applied at 28 g (1 oz) per container each spring (2022 and 2023) and all weeds were removed manually. The experimental design was a factorial combination of eight Christmas tree species and three topramezone (Frequency®; BASF Corporation LLC., Research Triangle Park, NC) rates: 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}), 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}), or 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}). There were six plant replicates at each topramezone rate for each Christmas tree species. A nontreated control (six plants per species) was also included for treatment comparison. Topramezone treatments were prepared in tap water mixed with methylated seed oil (Dyne-Amic, Helena Chemical Co., Collierville, TN) on a 1% v/v basis. Christmas trees, depending upon the species, were 4-yr old or 25 to 53 cm (10 to 21 inches) in height in 2022 and 5-yr old or 29 to 65 cm (12 to 26 inches) in height in 2023 at the treatment application time. Treatments were applied over-the-top (OTT), allowing full contact with the new growth (~4-week-old) on May 27, in 2022, and on June 7, in 2023. A compressed CO_2 research plot sprayer equipped with a single flat-fan Teejet 8002 nozzle (TeeJet Technologies, Springfield, IL) calibrated to deliver 187 $L{\cdot}ha^{-1}$ (20 $gal{\cdot}A^{-1}$) at 207 kPa and 4.8 kmph (3.0 mph) was used. Plants were allowed to dry by withholding overhead irrigation for about 4 hours after treatment application. Christmas tree injury was assessed visually at weekly intervals using a scale ranging from 0 (no injury) to 10 (dead plant). Christmas tree injury estimates were based on chlorosis, necrosis, and stunting of the new growth of the treated plants compared with the nontreated control plants.

Field experiment. A 2-year field experiment was conducted at a commercial Christmas tree farm in Enfield, CT (41°57.37N, 72°31.33W) in 2022 and 2023. The soil at the experiment site was an Agawam fine sandy loam with 21% silt, 62% sand, 17% clay, 2.7% organic matter, and 5.4 pH. The bare-rooted Fraser × balsam hybrid fir seedlings (2 + 1) were transplanted at a spacing of 1.8 m (6 feet) between rows and 1.5 m (5 feet) between plants in the spring of 2021. The experiment was established in a randomized complete block design with four replications. Each experimental plot consisted of two rows of four plants each. During both 2022 and 2023 springs, no PRE herbicide treatment was made before POST application of topramezone. Treatments comprised of a factorial combination of three topramezone rates: 49 g $ai{\cdot}ha^{-1}$ (0.04 lb $ai{\cdot}A^{-1}$), 98 g $ai{\cdot}ha^{-1}$ (0.09 lb $ai{\cdot}A^{-1}$), or 196 g $ai{\cdot}ha^{-1}$ (0.17 lb $ai{\cdot}A^{-1}$) and two application methods: OTT or semi-directed (SD). A nontreated control was included for treatment comparison. On June 3, in 2022, and June 9, in 2023, topramezone was applied OTT of Fraser × balsam hybrid transplants with a single flat-fan Teejet 8002 nozzle or semi-directed (SD) with an OC-2 nozzle (TeeJet Technologies, Springfield, IL) using a compressed CO_2 research plot sprayer calibrated to deliver 187 $L{\cdot}ha^{-1}$ (20 $gal{\cdot}A^{-1}$) at 207 kPa and 4.8 kmph (3.0 mph). Topramezone treatments were prepared in tap water mixed with methylated seed oil on a 1% v/v basis (Dyne-Amic, Helena Chemical Co., Collierville, TN). The OTT treatments were applied as a single pass over each tree row. The SD treatments were applied on both sides of each tree row with spray contacting about 10 cm (4 inches) basal tree growth. Weeds were treated OTT both between and within the rows. Common ragweed in the 4- to 6-leaf stage, horseweed 15 to 20 cm (6 to 8 inch) tall, fall panicum in the 3- to 4-leaf stage, large crabgrass in the 4- to 5-leaf stage, and yellow foxtail in the 4- to 5-leaf stage were the predominant weed species during both experiment years. Weed control and Christmas tree injury were assessed visually at 4, 8, and 12 weeks after treatment (WAT) using a scale ranging from 0 (no control) to 100% (complete control) for weed control and a scale of 0 (no injury) to 10 (dead plant) for injury. Christmas tree leader length (cm) in the field experiment was recorded from all plants in a plot at 12 WAT. Visual weed control assessments were based on chlorosis, necrosis, and stunting of treated weeds compared with the weeds in the nontreated control plots. Christmas tree injury estimates were based on chlorosis, necrosis, and stunting of the new growth of the treated trees compared with the trees in the nontreated control plot.

Statistical analyses. Data were subjected to ANOVA using the PROC GLIMMIX procedure in SAS (Version 9.4, SAS Institute, Cary, NC). Year, topramezone rate, and year × topramezone rate were treated as fixed effects whereas the replication and its interaction with the fixed effects were treated as random effects. Before the ANOVA test, data were tested for normality using PROC UNIVARIATE and homogeneity of variance with the modified Levene test. When the topramezone rate by year effect was nonsignificant, data were combined over years. Weed control data were arcsine square root–transformed to improve the normality and homogeneity of variance assumptions, but the non-transformed means are presented in the tables. The topramezone rate main effect was significant ($p < 0.05$) for the weed control data, indicating an improvement as the topramezone rate increased from 49-196 $g{\cdot}ha^{-1}$ (0.04 to 0.17 $lb{\cdot}A^{-1}$. Multiple means comparisons of significant effects were made using the "Adj = simulate" option in SAS PROC GLIMMIX at the 5% significance level.

Results and Discussion

Container experiment

Christmas tree tolerance. In both years, topramezone at 49 g $ai{\cdot}ha^{-1}$ (0.04 lb $ai{\cdot}A^{-1}$) to 196 g $ai{\cdot}ha^{-1}$ (0.17 lb $ai{\cdot}A^{-1}$) did not produce any chlorosis, necrosis, or needle stunting in balsam fir, canaan fir, Fraser fir, Nordman fir, Norway Spruce, and white pine when applied OTT to new growth (~4-week-old) (data not shown). Colorado blue spruce in 2022 and 2023 and Douglas fir in 2023 showed temporary bleaching/yellowing of the new growth with topramezone rate of 196 g $ai{\cdot}ha^{-1}$ or 0.17 lb $ai{\cdot}A^{-1}$ (twice the labelled use rate of topramezone in Christmas trees). Furthermore, not all the trees treated were injured. Averaged over 2 years, only 58% (7 out of 12) Colorado blue spruce and 42% (5 out of 12) Douglas fir trees showed chlorotic injury. This may be attributed to the genetic variability within a Christmas tree species (Ivetić et al. 2016). The highest injury was observed at 3 WAT, which was rated 9% in Colorado blue spruce and 23% in Douglas fir. By 6 WAT, the Colorado blue spruce showed complete recovery, whereas the chlorotic injury in Douglas fir was still rated 12% (data not shown). Neal and Owen (2022) also observed temporary yellowing of new growth in Fraser fir with after a budbreak application of topramezone. Limited information exists on the safety of POST application of topramezone in Christmas trees. However, POST-applied topramezone did not cause injury in many other crops, including sweet corn (*Zea mays convar.*

Table 1. **Fraser × balsam hybrid leader length at 12 WAT[z] in Enfield, CT in 2022 and 2023 following applications of topramezone.**

Topramezone[y]		Average leader length (cm)	
g ai·ha^{-1}	lb ai·A^{-1}	Year 2022	Year 2023
0	0	9.7 b[x]	17.3 a
49	0.04	9.6 b	16.9 a
98	0.09	10.1 b	17.9 a
196	0.17	9.8 b	17.1 a

[z]WAT = Weeks after POST topramezone application.

[y]Topramezone (Frequency®; BASF Corporation LLC., Research Triangle Park, NC), herbicide was applied over-the-top to new growth (~4 wk old) with on June 3, 2022, and on June 9, 2023. Topramezone treatments were prepared in tap water mixed with methylated seed oil (1% v/v basis).

[x]Means followed by the same letter between columns are not significantly different using the "Adj = simulate" option in SAS PROC GLIMMIX at $\alpha = 0.05$.

saccharata var. rugosa), sugarcane (*Saccharum officinarum*), and turfgrass (Arslan et al. 2016, Cox et al. 2017, Gonçalves et al. 2021, Negrisoli et al. 2020, Rodriguez et al. 2023).

Field experiment

Fraser × balsam hybrid tolerance. No chlorotic, necrotic, or stunting injury was reported during both experimental years. Topramezone did not cause injury to Fraser × balsam hybrid regardless of the application method and rate used (data not shown). Analysis of the final leader length data at 12 WAT indicated that only the year effect was significant ($p = 0.031$). There were no differences in leader length in response to topramezone rates averaged across application methods and rates (Table 1).

Annual grass control. The topramezone rate main effect was significant ($p < 0.05$), indicating an improvement in weed control as the topramezone rate increased from 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}) to 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}). In general, the topramezone rate labelled for use in Christmas trees was highly effective in controlling fall panicum and large crabgrass. For yellow foxtail control, the highest tested rate (196 g ai·ha^{-1} or 0.17 lb ai·A^{-1}) was relatively more effective. This suggests that sequential POST topramezone applications at labelled rates (98 g ai·ha^{-1} or 0.09 lb ai·A^{-1}) may be needed for effective control of yellow foxtail.

Topramezone was highly effective on fall panicum, with control ranging from 88 to 93% at 4 WAT as the topramezone rate increased from 49 g ai·ha^{-1} or 0.04 lb ai·A^{-1} to 196 g ai·ha^{-1} or 0.17 lb ai·A^{-1} (Table 2). All topramezone rates tested in this study were similar, with 92 to 98% control at 8 WAT and 93 to 98% control at 12 WAT. Fall panicum density data at 12 WAT showed > 94% reduction (0 to 1 plants per m^2) with topramezone rates of ≥ 49 g ai·ha^{-1} (≥0.04 lb ai·A^{-1}) when compared with the nontreated weedy check (17 plants per m^2) (Table 2). These results are consistent with Rodriguez et al. (2023), who previously reported 93, 89, and 91% fall panicum control in sweet corn at 14, 28, and 42 d after POST application of topramezone at 25 g ai·ha^{-1} (0.02 lb ai·A^{-1}). Negrisoli et al. (2020) observed 86 and 91% fall panicum control at 2 WAT which declined to 23 and 44% by 10 WAT with topramezone rates of 25 g ai·ha^{-1} (0.02 lb ai·A^{-1}) and 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}), respectively.

Table 2. **Common ragweed, horseweed, fall panicum, large crabgrass, and yellow foxtail control at 4, 8, and 12 WAT[z] in Enfield, CT following postemergence applications of topramezone.**

Topramezoney		Weed control (%)				
g ai·ha^{-1}	lb ai·A^{-1}	Common ragweed	Horseweed	Fall panicum	Large crabgrass	Yellow foxtail
4 WAT						
49	0.04	72 c[x]	62 b	88 b	73 b	61 b
98	0.09	79 b	66 b	91 ab	87 a	62 b
196	0.17	84 a	79 a	93 a	89 a	68 a
8 WAT						
49	0.04	83 c	83 b	92 b	84 b	66 b
98	0.09	89 bc	96 a	98 a	97 a	87 a
196	0.17	98 a	98 a	98 a	98 a	89 a
12 WAT						
49	0.04	82 b	79 b	93 a	78 b	45 c
98	0.09	81 b	98 a	98 a	96 a	75 b
196	0.17	96 a	99 a	98 a	98 a	85 a

[z]WAT= Weeks after POST topramezone application.

[y]Topramezone (Frequency®; BASF Corporation LLC., Research Triangle Park, NC), herbicide was applied on May 27, 2022, and on June 7, 2023. Topramezone treatments were prepared in tap water mixed with methylated seed oil (1% v/v basis).

[x]Weed control data were averaged over two years (Year main effect was not significant). Means followed by the same letter within column and WAT are not significantly different using the "Adj = simulate" option in SAS PROC GLIMMIX at $\alpha = 0.05$.

For large crabgrass control, topramezone rates of 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}) and 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}) were similar with approximately 88% control at 4 WAT and ≥ 96% control at 8 and 12 WAT. For topramezone applied at 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}), large crabgrass control was comparatively less, ranging from 73 to 84% between 4 and 12 WAT. (Table 2). Large crabgrass density data at 12 WAT was consistent with the control data. Compared to the nontreated weedy check (43 plants per m^2), 76 to 99% reduction in density of large crabgrass (0 to 11 plant per m^2) was observed as topramezone rate increased from 49 g ai·ha^{-1} or 0.04 lb ai·A^{-1} to 196 g ai·ha^{-1} or 0.17 lb ai·A^{-1} (Table 3). In a previous study, fall panicum, large crabgrass, and yellow foxtail were controlled 77, 85, and 96% at the 2- to 3-leaf stage and 62, 84, and 88% at the 5- to 6-leaf stage with topramezone at 49 g ai·ha^{-1} or 0.04 lb ai·A^{-1} (Soltani at al. 2012).

Among all weed species tested, topramezone was relatively less effective on yellow foxtail. Control of yellow foxtail ranged from 61 to 68% at 4 WAT, 66 to 89% at 8 WAT, and 45 to 85% at 12 WAT, respectively, with an increase in topramezone rate from 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}) to 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}). It appears that an additional topramezone application at the labelled rate (98 g ai·ha^{-1} or 0.09 lb ai·A^{-1}) will be required around 8 weeks after initial treatment (WAIT) for excellent season-long control of yellow foxtail. Consistent with visual control ratings, topramezone applied at 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}) to 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}) significantly reduced yellow foxtail density (7 to 13 plants per m^2) at 12 WAT as compared to nontreated weedy check (31 plants

Table 3. **Common ragweed, horseweed, fall panicum, large crabgrass, and yellow foxtail densities at 12 WAT[z] in Enfield, CT following postemergence applications of topramezone.**

Topramezone[y]		Weed density (plants per m^2)				
g ai·ha^{-1}	lb ai·A^{-1}	Common ragweed	Horseweed	Fall panicum	Large crabgrass	Yellow foxtail
0	0	18 a[x]	69 a	17 a	43 a	31 a
49	0.04	2 b	12 b	1 b	11 b	13 b
98	0.09	3 b	1 c	0 b	1 c	9 b
196	0.17	1 b	0 c	0 b	0 c	7 b

[z]WAT = Weeks after POST topramezone application.

[y]Topramezone (Frequency®; BASF Corporation LLC., Research Triangle Park, NC), herbicide was applied on May 27, 2022, and on June 7, 2023. Topramezone treatments were prepared in tap water mixed with methylated seed oil (1% v/v basis).

[x]Weed densities were averaged over two years (Year main effect was not significant). Means followed by the same letter within a column are not significantly different using the "Adj = simulate" option in SAS PROC GLIMMIX at α = 0.05.

per m^2) (Table 3). Zollinger and Ries (2006) reported variable control of yellow foxtail with different HPPD-inhibitor herbicides. In that study, topramezone (92%) and tembotrione (88%) were found more effective in yellow foxtail control than mesotrione (65%).

Broadleaf weed control. Horseweed response to topramezone differed with the application rate (Table 2). At 4 WAT, the maximum control (79%) occurred with the highest tested rate (196 g ai·ha^{-1} or 0.17 lb ai·A^{-1}), which was higher than the 66% control with the labelled rate (98 g ai·ha^{-1} or 0.09 lb ai·A^{-1}). As the season progressed, horseweed was controlled > 95% with topramezone applied at 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}) and 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}) rates. Whereas with the lowest tested rate (49 g ai·ha^{-1} or 0.04 lb ai·A^{-1}), control increased to 83% at 8 WAT and declined again to 79% at 12 WAT. Improvement in horseweed control by 8 WAT with topramezone at 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}) or 49 g ai·ha^{-1} or 0.04 lb ai·A^{-1} may be attributed to deterioration in injury symptoms from mainly chlorotic injury and stunting at 4 WAT to necrotic injury at 8 WAT. Consistent with visual control ratings, topramezone at 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}) to 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}) lowered horseweed density 83 to 100% at 12 WAT as compared to the nontreated weedy check (69 plants per m^2) (Table 3). Horseweed control may vary with the topramezone rate and horseweed size at the time of POST treatment. For instance, Fluttert et al. (2022) reported 85, 87, and 89% control of 4-inch-tall glyphosate-resistant horseweed with 12.5 g ai·ha^{-1} (0.01 lb ai·A^{-1}) topramezone at 2, 4, and 8 WAT, respectively. Our results are also consistent with Ganie and Jhala (2017), who previously reported 87 and 96% control of 7 to 12 cm (3 to 5 inches) tall or 6- to 8-leaf glyphosate resistant and glyphosate sensitive biotypes of horseweed, respectively, in a greenhouse study 3 weeks after topramezone treatment at 18.8 g ai·ha^{-1} (0.015 lb ai·A^{-1}). Bollman et al. (2008) reported 90% reduction in horseweed density at 8 WAT with topramezone at 12.5 g ai·ha^{-1} (0.01 lb ai·A^{-1}) when compared with the nontreated control. They also observed 14 to 19% improvement in horseweed control when atrazine (560 g ai·ha^{-1} or 0.5 lb ai·A^{-1}) and topramezone (12.5 g ai·ha^{-1} or 0.01 lb ai·A^{-1}) were combined. However, the topramezone and atrazine combination was not always synergistic. Koepke-Hill et al. (2010) observed no improvement in POST control of volunteer potato (*Solanum tuberosum* L.) when topramezone was tank mixed with atrazine. Previously, Mahoney et al. (2017) reported only 67% control of 15 cm (6 inches) horseweed at 8 WAT with a topramezone (12.5 g ai·ha^{-1} or 0.01 lb ai·A^{-1}) and atrazine (505 g ai·ha^{-1} or 0.45 lb ai·A^{-1}) tank mixture. In the same study, horseweed control with atrazine at 910 g ai·ha^{-1} (0.90 lb ai·A^{-1}) was only 37%.

Regarding common ragweed, control ranged from 72 to 84% at 4 WAT, 83 to 98% at 8 WAT, and 82 to 96% at 12 WAT with the topramezone rates ranging from 49 g ai·ha^{-1} or 0.04 lb ai·A^{-1} to 196 g ai·ha^{-1} or 0.17 lb ai·A^{-1} (Table 2). The topramezone rate of 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}) provided higher control than the labelled (98 g ai·ha^{-1} or 0.09 lb ai·A^{-1}) and lower (49 g ai·ha^{-1} or 0.04 lb ai·A^{-1}) rates at 8 and 12 WAT. Similar reduction (1 to 3 plants per m^2) was observed in common ragweed density at 12 WAT with topramezone rates tested in this study when compared with the nontreated check (18 plants per m^2) (Table 3). In North Dakota, Zollinger and Ries (2006) also found topramezone (0.75x and 1x) very effective in controlling common ragweed (95%) in corn (*Zea mays*). In another study, topramezone POST at 12.5 g ai·ha^{-1} (0.01 lb ai·A^{-1}) provided 95% or higher control of common ragweed (Bollman et al. 2008).

In comparison to previous studies (Bollman et al. 2008, Ganie and Jhala 2017, Mahoney et al. 2017, Negrisoli et al. 2020, Rodriguez et al. 2023, Soltani at al. 2012, Zollinger and Ries 2006), higher season-long control of common ragweed (4- to 6-leaf), fall panicum (3- to 4-leaf), horseweed (6- to 8-inch), large crabgrass (4- to 5-leaf), and yellow foxtail (4- to 5-leaf) in the current study was mainly due to a four (49 g ai·ha^{-1} or 0.04 lb ai·A^{-1}) to sixteen- (196 g ai·ha^{-1} or 0.17 lb ai·A^{-1}) times higher topramezone rates used. The maximum labelled rate of topramezone for PRE or POST weed control in Christmas trees is 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}) per application (Anonymous 2025). The highest rate of 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}) in the field experiment was included to evaluate the level of Fraser × balsam hybrid tolerance to topramezone. In separate container experiments in Connecticut, several species of true firs, spruces, and white pine tolerated OTT applications of topramezone at rates up to 196 g ai·ha^{-1} or 0.17 lb ai·A^{-1} (J.S. Aulakh, unpublished data).

In conclusion, results from this study indicated that POST-applied topramezone at 49 g ai·ha^{-1} (0.04 lb ai·A^{-1}) to 196 g ai·ha^{-1} (0.17 lb ai·A^{-1}) rate did not cause injury to balsam fir, canaan fir, Fraser fir, Nordman fir, Norway spruce, white pine, and Fraser × balsam hybrid, whereas it showed temporary chlorosis on Colorado blue spruce and Douglas fir at 3 WAT. Furthermore, topramezone at the labelled rate (98 g ai·ha^{-1} or 0.09 lb ai·A^{-1}) effectively controlled common ragweed, horseweed, fall panicum, and large crabgrass and significantly reduced their densities. In contrast, topramezone at 98 g ai·ha^{-1} (0.09 lb ai·A^{-1}) only provided moderate control of yellow foxtail. These results highlight the importance of using an effective PRE herbicide program along with the POST-applied topramezone for season-long weed control in Christmas trees. It is important to note that overreliance on POST-applied topramezone should be avoided to prevent the evolution of HPPD herbicides-resistant weed populations. Therefore, Christmas producers should also integrate other weed control tactics, including sanitation, alternate herbicide modes-of-action, and physical methods for weed control. Future studies should assess the efficacy of POST-applied topramezone in conjunction with PRE and other POST herbicides for enhanced safety and weed control in Christmas trees.

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