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Comparing alternative nonselective herbicides in Oregon and New Mexico

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Research Article

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Nomenclature:
Ammoniated soap of fatty acids; maleic hydrazide; mint oil; sodium lauryl sulfate; potassium sorbate; pelargonic acid; annual bluegrass, *Poa annua* L. 'POAAN'; bermudagrass, *Cynodon dactylon* (L.) Pers. 'CYNDA'; perennial ryegrass, *Lolium perenne* L. 'LOLPE'

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Abstract

Municipalities are considering alternatives to traditional herbicides for suppressing weeds and vegetation in areas frequented by the public. Two field experiments were conducted to test the efficacy of alternative nonselective herbicides: one in Corvallis, OR, on a mixed lawn of perennial ryegrass, annual bluegrass, and broadleaf weeds, and another in Las Cruces, NM, on a predominantly bermudagrass lawn with broadleaf weeds. The experimental objective was to quantify and compare the effects of repeated applications of 10 nonselective herbicides to terminate a lawn with mixed vegetation. Applications were made every 2 wk for four applications starting on April 15, 2022, in Corvallis and on May 26, 2022, in Las Cruces. Data collected included the percent green cover over time calculated using an area under the percent green cover progress curve (AUPGCPC), the percent green cover at the conclusion of the experiment, and the changes in monocot and dicot densities over the course of the experiment. All treatments resulted in a lower AUPGCPC compared to water only, except for mint oil + sodium lauryl sulfate + potassium sorbate. The only treatments with average percent green cover <50% were ammoniated soap of fatty acids + maleic hydrazide (47% green cover) in Corvallis and pelargonic acid (38%) in Las Cruces, suggesting that more applications would be needed to terminate the lawn under similar circumstances. At the conclusion of the experiment, the water-only plots averaged 90% and 93% green cover in Corvallis and Las Cruces, respectively. The changes in monocot and dicot densities over the course of the experiment indicated that some of the products tested may be more sensitive to dicots, or, in some cases, monocots, suggesting a potential for future selective herbicide research in certain locations and climates.

Introduction

Weed control is one of the most burdensome and costly aspects of land management throughout the United States. Nonnative and invasive weeds on both private and public lands are an important issue, resulting in damages and control costs of billions of dollars annually (Fuller and Mangold 2017; Pimentel et al. 2005). Herbicides are commonly used to suppress weeds; however, weed management in urban landscapes can be challenging, especially in areas where public exposure to pesticides is concerning. Municipal areas and school properties are of particular concern because young people are often more vulnerable to pesticides (Landrigen et al. 2004), and exposure to pesticides may affect children's behavioral and neurological development (Liu and Schelar 2012). Exposure to pesticides among students and staff at schools has been documented (Alarcon et al. 2005), indicating that more work can be done to reduce these risks. Today, most states have pesticide regulations specific to school areas (Hurley et al. 2014).

Examples of pesticide restrictions in the urban environment include a pesticide ban, except for a human health emergency, in daycare through eighth-grade schools and on their grounds in Connecticut (State of Connecticut 2005), and similar rules are in place in New York (NYSDEC 2010). Other locations with pesticide restrictions include South Portland, Maine, where only pesticides listed as "allowed" on the U.S. Department of Agriculture (USDA) National List for organic crop production (USDA-AMS 2023) or "minimum-risk pesticides" as defined by the U.S. Environmental Protection Agency (EPA 2023) may be used on municipal property (City of South Portland 2024). A School IPM law has been in place in Oregon since 2012, defining and limiting the use of "low-impact" pesticides and allowing the use of these only if nonchemical pest control measures are ineffective. This law has additional, school-specific requirements for notification, posting, and recordkeeping of pesticide applications (State of Oregon 2022).

Additionally, although some states, such as New Mexico, do not have statewide requirements or public laws regarding restricted spray zones or pesticide use around school property (New Mexico Department of Agriculture 2023), local school district policies give priority to nonchemical methods of pest control (New Mexico State Legislature 2021). For example, Santa Fe, NM, permits synthetic chemical use on public and municipal lands only as a last resort after other weed control methods have been attempted and shown to be ineffective (City of Santa Fe 2023).

Although pesticide restrictions on school property may reduce exposure to certain pesticides, a perceived decrease in athletic field quality in Connecticut has been reported following the state's pesticide ban (Bartholomew et al. 2015). At the same time, even though player safety can be degraded when the presence of weeds reduces the underfoot safety of the playing surface (Brosnan et al. 2014), a survey in Connecticut found that respondents agreed with a ban on pesticides on elementary and middle school property (67%) and on high school athletic fields (66%) (Campbell and Wallace 2020). A different survey found that there was strong support for bans on pesticides at the state and municipal levels as well as for home lawns (Wallace et al. 2016).

In lawns, weed management can be largely overcome by maintaining a dense stand of turfgrass through common cultural practices like mowing, irrigation, and fertilization (Braithwaite et al. 2020; Turgeon and Kaminski 2019). When large weed infestations do occur, a selective broadleaf herbicide is often applied along with properly timed overseeding with desired turfgrasses to fill in voids in the landscape. If renovating a lawn becomes necessary, a nonselective herbicide will often be applied prior to reestablishment of turfgrass (Braun et al. 2021). In the absence of herbicides, timely mechanical removal of all vegetation is possible, although labor intensive, which is typically followed by applying sod or sowing at recommended times, which can increase the likelihood of obtaining a manageable landscape (Brosnan et al. 2020). In areas where pesticide restrictions occur and when mechanical removal is not feasible, alternative herbicides may be an option, although only limited data are available regarding their efficacy (Reiter and Windbiel-Rojas 2020; Young 2004). Examples of alternative herbicide products include acids, such as acetic acid (vinegar) or pelargonic acid; fatty acids, such as ammonium nonanoate; and plant-derived oils, such as clove or mint oil. Only limited research has evaluated these types of products for successful lawn termination.

The majority of the few turfgrass experiments focusing on alternative nonselective herbicides to date occurred in California. It is unclear why limited research is currently available; however, in some areas of California, there is a public desire to find alternatives to nonselective herbicides like glyphosate, which is listed as a carcinogen on the California Proposition 65 list (CA.gov 2024; Reiter and Windbiel-Rojas 2020). One study compared the efficacy and costs of acetic acid, plant essentials, pine oil, and glyphosate applications necessary to suppress vegetation along roadsides (Young 2004). This study concluded that the natural products tested were not comparable from an economical or efficacious standpoint compared to the use of glyphosate in the same setting. Another field experiment in California compared alternatives like plant essential oils, chelated iron, and fatty acid soaps to glyphosate in a lawn setting using one application in Dinuba on a mixed stand of bermudagrass and broadleaf weeds and two applications in Sacramento on predominantly bermudagrass (Reiter and Windbiel-Rojas 2020). This research demonstrated that nonselective alternatives to glyphosate products yielded a quick response; however, in both settings, the vegetation recovered after one or two applications, likely because of the contact burndown activity of the products, which damaged only the leaves.

For pesticides to be used in the urban environment, safety is a high concern, and alternative products need to be effective and limited in number of applications to reduce exposure time and frequency as well as the cost of application. For this reason, it is necessary to address the knowledge gap regarding the number of applications necessary for alternative nonselective herbicides to effectively suppress vegetation. Considering this need, two field experiments were conducted, one in Corvallis, OR, and one in Las Cruces, NM, with the aim of comparing several alternative nonselective herbicides for their ability to terminate a lawn of mixed monocot and dicot plants.

Materials and Methods

The layout of the experiment was a randomized complete-block design including 10 alternative nonselective herbicides, with water as a control treatment (Table 1). Products in this experiment were selected because at the time of the experiment, all products met current and proposed municipal legislation in New Mexico, and eight products met the current and proposed legislation for applications on public schools in Oregon. Well-established mown turfgrass areas in Corvallis (established in 2017) and Las Cruces (at least 5 yr in age) were chosen for the study. The Corvallis experiment (44.33°N, 123.12°W) took place on a Malabon silty clay loam, classified as part of the Pachic Ultic Argixerolls subgroup of the USDA taxonomy (UC Davis 2024). This site is in the cool-season zone and consisted primarily of perennial ryegrass and annual bluegrass. The dominant dicot plants were white clover (*Trifolium repens* L. 'TRFRE') and common dandelion (*Taraxacum officinale* F.H. Wigg. 'TAROF'). The Las Cruces experiment (32.20°N, 106.74°W) took place on a Belen clay loam, classified as part of the thermic Vertic Torrifluvents subgroup of the USDA taxonomy (UC Davis 2024). This site is in the warm-season zone and consisted primarily of bermudagrass. The dominant dicot plants were common dandelion, white clover, and sowthistle (*Sonchus oleraceus* L. 'SONOL'). Both sites were mown at least once a week at 7.6 cm height, and clippings were removed. In Oregon, irrigation was not necessary because rainfall was sufficient during the experiment, averaging 24.5 mm wk^{-1} (Figure 1). Irrigation was applied once a week in New Mexico to maintain healthy turf and weed stands.

At both locations, treatments (Table 1) were applied with a handheld boom attached to a CO_2-pressurized (210 kPa) backpack sprayer delivering a carrier volume of 815 L ha^{-1}. In Corvallis, applications began on April 15, 2022, and were applied every 2 wk through May 27, 2022, for a total of four applications. In Las Cruces, applications began on May 26, 2022, and were applied every 2 wk through July 21, 2022, for a total of five applications. To compare the effects of treatments across both sites, the Las Cruces data presented in this manuscript include data for the first four applications (the fifth application, on July 21, 2022, is not included in these analyses). The experiment was replicated over four blocks in Corvallis and three blocks in Las Cruces. Initial application timings were reflective of target turfgrass breaking winter dormancy in Las Cruces (average of 79% green cover on May 25, 2022), and turfgrass was actively growing in Corvallis (95% green cover on April 15, 2022). Weed growth and development were satisfactory for herbicide applications in both locations and in

Table 1. Trade name, formulation, rate, and manufacturer for treatments included in the experiment in Corvallis, OR, and Las Cruces, NM.

Trade name	Formulation	Rate	Manufacturer
		% v/v	
Phydura™	1% clove oil	33	Soil Technologies (Fairfield, IA, USA)
FireWorxx™	44% caprylic acid, 36% capric acid	6	OHP (Bluffton, SC, USA)
BioSafe Weed & Grass Killer®	40% ammonium nonanoate	13	Biosafe Systems (East Hartford, CT, USA)
Avenger®	70% d-limonene	25	Cutting Edge Formulations (Buford, GA, USA)
Eco Garden® RTU	7.5% sodium chloride	100	Eco Living Solutions (Laguna Niguel, CA, USA)
Natria® Grass & Weed Control with Root Kill	22.11% ammoniated soap of fatty acids, 3% maleic hydrazide	17	SBM Life Science (Cary, NC, USA)
Weed Zap®	45% cinnamon oil, 45% clove oil	5	JH Biotech (Ventura, CA, USA)
Torched	5% mint oil, 5% sodium lauryl sulfate, 5% potassium sorbate	6	Southland Organics (Bogart, GA, USA)
Green Gobbler 20% Vinegar Weed Killer	20% acetic acid	100	EcoClean Solutions (Copaigue, NY, USA)
Scythe®	57% pelargonic acid	10	Gowan Company (Yuma, AZ, USA)
Water	100% water	100	

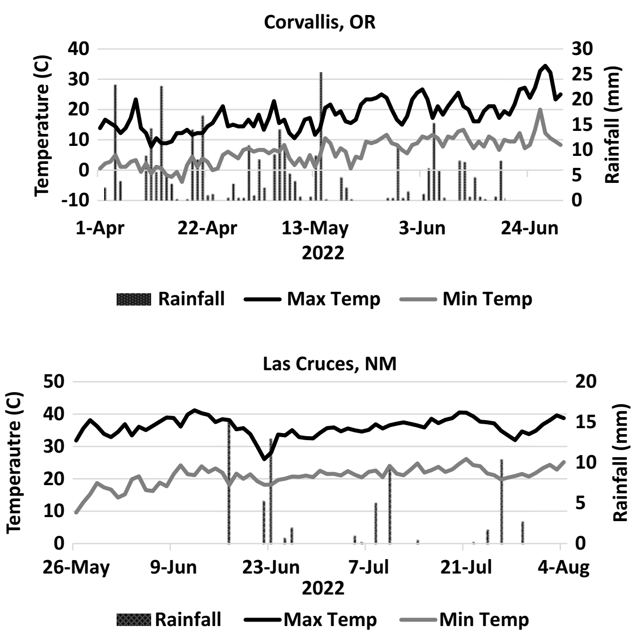

Figure 1. High and low temperatures in degrees Celsius and rainfall in millimeters during the 2022 experimental period in Corvallis, OR, and Las Cruces, NM.

both temperature zones. High and low temperatures, as well as precipitation over the course of the experiment, were recorded at both sites (Figure 1).

Dependent variables in this experiment included area under percent green cover progress curves (AUPGCPC), percent green cover on the final rating date, and change in monocot and dicot densities over the course of the experiment. These variables were derived from images collected using a battery-powered photo light box that was placed in the same location throughout the experiment. In Corvallis, two images were collected twice a week using a Sony DSC-H9 (Tokyo, Japan) camera, and the light box covered an area of 0.31 m^2 for each image. In Las Cruces, one image was collected twice a week using a Canon SX 700HS (Tokyo, Japan) camera, and the light box covered 1.00 m^2.

Percent green cover data were collected for each rating date by analyzing light box images using Sigma Scan Pro version 5.0 software (Grafiti, Palo Alto, CA, USA). These data were used to build AUPGCPCs calculated using the trapezoidal method (Shaner and Finney 1977). Monocot and dicot percentages were assessed using stratified sampling (Laycock and Canaway 1980; Richardson et al. 2001) by overlaying a digital grid onto images collected from each plot using Sigma Scan Pro. When the grid lines crossed in an image, the plant was identified as either monocot, dicot, or no plant. In Corvallis, the changes in monocot and dicot densities were calculated using images from the beginning of the study (April 15, 2022) to the last rating date (June 10, 2022) for a total period of 56 d after initial treatment (DAIT). Images from Corvallis were overlaid with a 121-point digital grid per image (242 data points 0.62 m^{-2}). In Las Cruces, the changes in monocot and dicot densities were calculated using images from the beginning of the study (May 25, 2022) to 2 wk after the fourth herbicide application (July 21, 2022) for a total period of 57 DAIT. Images from Las Cruces were overlain with a 225-point digital grid per image (225 data points 1.00 m^{-2}). These data were used to calculate the changes in monocot and dicot densities over the course of the trial in both locations by subtracting the initial percentage from the final percentage and dividing by the final percentage [(Final − Initial)/Final]. All dependent variables in the experiment in both locations satisfactorily met the assumptions of ANOVA and were analyzed in R (R Core Team, 2022). When significant differences were observed, pairwise comparisons were assessed using Tukey's HSD at a 0.05 level of significance.

Results and Discussion

Area Under Percent Green Cover Progress Curve

This research demonstrated that all treatments, with the exception of the mint oil + sodium lauryl sulfate + potassium sorbate combination, reduced the AUPGCPC compared to water, indicating nonselective herbicide effects. Treatments with the lowest AUPGCPC, or the greatest nonselective herbicide effect, included the acetic acid treatment in Corvallis and d-limonene and pelargonic acid in Las Cruces (Table 2). In Corvallis, acetic acid was more effective than 5 of the 10 alternative herbicide treatments, and in Las Cruces, d-limonene and pelargonic acid were more effective than 4 of the 10 treatments. In the experiment by Reiter and Windbiel-Rojas (2020), d-limonene and acetic acid had a lower normalized difference vegetation index (NDVI) on all rating dates after initial application up to 21 d, and it was also observed that a lower NDVI resulted from 22% ammoniated soap of fatty acids applied in a 10% v/v solution, supporting findings in this research. A study in Norway focusing on desiccation of white

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Table 2. Area under percent green cover progress curves and percent green cover on the final rating date in Corvallis, OR, and Las Cruces, NM.[a,b]

		AUPGCPC		Green cover	
Herbicide	Rate	Corvallis	Las Cruces	Corvallis	Las Cruces
	g ai ha^{-1}			%	
Clove oil	2,669	3,439 b	3,747 bc	86 a	78 a–c
Caprylic acid	20,200	2,075 c	3,041 c–e	58 b–e	78 a–c
Capric acid	16,527				
Ammonium nonanoate	41,844	1,732 c–e	3,104 c–e	60 b–d	71 a–c
d-Limonene	121,652	1,843 cd	2,046 e	64 bc	56 bc
Sodium chloride	64,591	1,695 c–e	2,411 de	53 c–e	56 bc
Ammoniated soap of fatty acids	29,984	1,635 c–e	3,143 c–e	47 e	65 a–c
Maleic hydrazide	4,068				
Cinnamon oil	18,435	3,016 b	3,634 b–d	68 b	74 a–c
Clove oil	18,435				
Mint oil	3,007	4,929 a	4,632 ab	88 a	85 ab
Sodium lauryl sulfate	3,007				
Potassium sorbate	3,007				
Acetic acid	166,870	1,289 e	2,732 c–e	51 de	75 a–c
Pelargonic acid	40,966	1,341 de	2,041 e	54 c–e	45 c
Water	—	5,102 a	5,079 a	90 a	93 a

[a]Abbreviation: AUPGCPC, area under percent green cover progress curve.
[b]Values followed by the same letter are not significantly different according to Tukey's HSD ($P < 0.05$).

clover seed crops observed a decrease in green color when treatments of acetic acid, sodium chloride, or pelargonic acid were applied one or two times preharvest (Havstad et al. 2022), also supporting observations in this experiment.

While clove oil and cinnamon oil + clove oil were more effective than water, all other treatments were more effective at reducing the AUPGCPC than these two treatments in Corvallis. In Las Cruces, clove oil and cinnamon oil + clove oil performed similarly to the combination of mint oil + sodium lauryl sulfate + potassium sorbate, which did not decrease the AUPGCPC compared to water. These results indicate that these treatments are not likely the best product choice if vegetation suppression efficacy is the most important criterion for landscape managers. Previous research exploring the herbicidal effects of a variety of essential oils found that among 25 oils tested, cinnamon, clove, summer savory and red thyme caused visible injury to dandelion leaf disks (Tworkoski 2002). When applied to johnsongrass [*Sorghum halepense* (L.) Pers.], common lambsquarters (*Chenopodium album* L.), or common ragweed (*Ambrosia artemisiifolia* L.) 25 to 30 cm in height, a 1% concentration of cinnamon or clove oil injured these plants, and a 5% and 10% concentration killed most plants 7 d after treatment (Tworkoski 2002). Boyd and Brennan (2006) observed control of nettle (*Urtica urens* L.) at a 10% concentration and common purslane (*Portulaca oleracea* L.) at a 20% concentration of clove oil. In the present study, clove oil was diluted to a concentration of 0.33% (as per the product label rate directions), and when a combination of cinnamon oil and clove oil was applied (as per product label directions), the final concentration was 2.3% for each oil. These low rates would suggest that the oil concentrations were insufficient to expect results similar to those observed by Tworkoski (2002). Reiter and Windbiel-Rojas (2020) observed a decrease in NDVI when the combination of 47% caprylic acid and 32% capric acid was applied in a 9% v/v solution to 'TifSport' hybrid bermudagrass [*Cynodon dactylon* (L.) Pers. × *C. transvaalensis* Burtt Davy]. The same study did not observe a decrease in NDVI when the combination of 8% citric acid + 2% clove oil was applied in a 25% v/v solution.

Percent Green Cover on Final Rating Date

In Corvallis, a combination of ammoniated soap of fatty acids + maleic hydrazide resulted in the lowest percent green cover on the final rating date (47%) and was similar to the acetic acid (51%), sodium chloride (53%), pelargonic acid (54%), and a combination of caprylic + capric acid (58%) treatments (Table 2). In Las Cruces, the pelargonic acid treatment averaged 45% green cover on the final rating date and was similar to all other treatments, except the combination of mint oil + sodium lauryl sulfate + potassium sorbate and water. Even though these results are not encouraging for landscape managers desiring to apply a single alternative nonselective application for effective weed control, they do demonstrate that there was substantial suppression of the plant species present during the study. However, after four treatments over 56 d in Corvallis and four treatments over 57 d in Las Cruces, it is unlikely that these products are viable options for terminating vegetation in well-established sites, such as for lawn renovations or overgrown landscape beds or in hardscapes, because the vegetation quickly recovered following termination of the study (data not shown). Further research is required to determine if complete termination of vegetation could be achieved if applications were to continue over long periods, or several successive seasons, until the plant's vegetative nutrient reserves have been exhausted.

Change in Monocot and Dicot Density over Time

Suppression of either monocots or dicots was explored using the same light box images in both Corvallis and Las Cruces. In Corvallis, the clove oil treatment increased monocot cover compared to water only (Table 3). The combination of ammoniated soap of fatty acids + maleic hydrazide was the only treatment that reduced the monocot population to an extent that was greater than the water control (Table 3). In Las Cruces, no differences in monocot density were observed compared to water only. These differences between the observations in Corvallis and Las Cruces may be a function of the environment and more vigorous growth and survivability of stressors such as herbicide injury of bermudagrass, which has a stoloniferous and

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Table 3. Change in monocot and dicot density in Corvallis, OR, and Las Cruces, NM.[a]

Herbicide	Rate	Change in monocot density		Change in dicot density	
		Corvallis	Las Cruces	Corvallis	Las Cruces
	g ai ha^{-1}	%		%	
Clove oil	2,669	+2 a	+36 a	−32 bc	−87 bc
Caprylic acid	20,200	−35 b	+7 ab	−53 b–d	−71 bc
Capric acid	16,527				
Ammonium nonanoate	41,844	−39 bc	+18 ab	−26 b	−80 bc
d-Limonene	121,652	−20 ab	+12 ab	−52 b–d	−82 bc
Sodium chloride	64,591	−27 b	−3 ab	−75 cd	−92 bc
Ammoniated soap of fatty acids	29,984	−61 c	+5 ab	−39 b–d	−86 bc
Maleic hydrazide	4,068				
Cinnamon oil	18,435	−18 ab	+15 ab	−50 b–d	−89 bc
Clove oil	18,435				
Mint oil	3,007	−32 b	+45 a	+35 a	−18 ab
Sodium lauryl sulfate	3,007				
Potassium sorbate	3,007				
Acetic acid	166,870	−33 b	+14 ab	−80 d	−97 c
Pelargonic acid	40,966	−26 b	−32 b	−67 b–d	−97 c
Water	—	−31 b	+20 ab	+38 a	+45 a

[a]Values followed by the same letter are not significantly different according to Tukey's HSD ($P < 0.05$).

rhizomatous growth habit compared to bunch-type grasses like the perennial ryegrass and annual bluegrass at Corvallis.

Except for the combination of mint oil + sodium lauryl sulfate + potassium sorbate, all herbicides reduced the density of dicots in both Corvallis and Las Cruces. This observation, along with the AUPGCPC and monocot density data, suggests that some treatments may provide opportunities for future research into how to use alternative nonselective products as selective dicot weed controls in a landscape setting. For instance, clove oil was applied at 1% (as per product label directions) and resulted in a decrease in dicot density in Corvallis of 32% and in Las Cruces of 87%, while resulting in a numerical increase in monocot density in both locations. In research by Boyd and Brennan (2006), clove oil applied at 10% and 20% v/v controlled nettle and common purslane but had no effect on rye (*Secale cereale* L.). The dynamics of the ecology of the lawn are complex and will depend on the dominant monocot species and the season when the applications are applied, although these results support future research in the use of alternative nonselective herbicides as selective contact dicot control products in a lawn setting.

The motivation behind pesticide restrictions and complete bans on pesticides is often unclear; however, public health and safety are likely primary factors, especially on school grounds. The more efficacious a treatment is regarding suppression of vegetation, the less frequently applications will need to be made, thus reducing exposure to pesticides of applicators and potentially others. This study's results indicate that more than four applications would be necessary to suppress vegetation under similar conditions in both locations and in both types of turfgrass. Such an approach could increase public exposure to herbicides compared to standard nonselective chemistries and might limit the practicality of their use. If alternative herbicides are not adopted, lawn renovation can still be achieved by mechanical removal using machines like sod cutters or fraise mowers. For landscape beds, mulching remains an option, with applications of alternative herbicides perhaps being more successful when vegetation is smaller and, especially, younger (Kudsk and Streibig 2023). For hardscapes, vegetation size will likely be a factor in suppression, and other weed management techniques, such as heat or steam, may be options in these settings (Kolberg and Wiles 2017; Peerzada and Chauhan 2018). Cost is also likely a concern. At the time of publication, cost for all treatments (except for the combination of mint oil + sodium lauryl sulfate + potassium sorbate, which had no effect on green cover reduction) would be at least 9 times greater per hectare than one application of glyphosate.

Practical Implications

When it becomes necessary to renovate a lawn, nonselective herbicides are often used to terminate the existing vegetation, with glyphosate as a common choice for this purpose. When legislation or other pressures oblige landscape managers to choose alternatives to glyphosate, little research is available on the efficacy of products sold as nonselective herbicides. In this experiment, none of the treatments successfully terminated an established lawn in either Corvallis, OR, or Las Cruces, NM. These findings suggest that the application rates, frequencies, or timings tested in this research will not satisfactorily terminate a lawn under similar circumstances. One interesting finding, however, was that grasses and broadleafs exposed to the herbicides expressed different sensitivities, suggesting that future studies focusing on selective control are warranted. Specifically, the data suggest that some alternative herbicide treatments were more impactful in injuring dicot plants than monocots, especially in New Mexico, where the dominant monocot was bermudagrass. This may indicate the possibility of spot-spraying dicot-specific weeds within a desirable turfgrass landscape with minimal and temporary discoloration of the turfgrass, especially stoloniferous and rhizomatous grass varieties like bermudagrass. Finally, even though none of the treatments successfully terminated the vegetation after four applications, that does not mean that they would be ineffective on less mature plants, with more applications, or in the late summer or early fall; however, future research is needed to answer these questions.

Acknowledgments. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does

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Competing interests. The authors declare no conflicts of interest.

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