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Managing Canada Thistle (*Cirsium arvense*) in a Constructed Grassland with Aminopyralid and Prescribed Fire

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Green spaces such as golf courses that intermingle within or exist on fringes of urban landscapes can provide opportunities for increasing the ecological value of urban areas. To that end, more naturalistic and less input-intensive "links"-style golf courses have recently gained favor over input-intensive parkland courses. The Osgood Public Golf Course in Fargo, ND is a links-style golf course set adjacent to suburban housing developments. This course incorporated large areas of prairie plantings, or "constructed grasslands," which over time became dominated by fescue species and infested with Canada thistle. Our objective was to explore the efficacy of using prescribed fire combined with aminopyralid herbicide to control Canada thistle and promote a more diverse mix of warm-season C_4 and cool-season C_3 grasses. Aminopyralid was applied during fall 2010 and prescribed fire was applied during spring 2011. We found that aminopyralid provided excellent control of Canada thistle 1 and 2 yr post-treatment. Open niches created from Canada thistle control were readily filled by C_3 grasses, primarily fescue species, which were the dominant species on the constructed grasslands prior to treatment. Fire intensity was variable within and across plots and was associated with reductions of litter and C_3 grasses, but was not associated with increases of C_4 grasses within the time frame of this study. Our results demonstrate the effectiveness of aminopyralid for Canada thistle control in constructed grasslands. Prescribed fire maintained C_3 grass dominance while removing litter, but C_4 grass response was variable and appeared dependent on pretreatment C_4 species abundance. Reduction of litter in constructed grasslands dominated by fescue could potentially lead to microsite conditions that would favor C_4 and other C_3 species, especially if short-term management promoted additional facilitation efforts, such as repeat spring fire treatments and seeding.

Nomenclature: Aminopyralid; Canada thistle, *Cirsium arvense* (L.) Scop. CIRAR.

Key words: Cool-season grasses, golf course, grassland restoration, prescribed fire, urban grassland, warm-season grasses.

Increasing urban and suburban development continues to fragment natural landscapes, leading to degradation of wildlife habitat and often ecosystem services (Goddard et al. 2009; McKinney 2002, 2006). Urbanization reduces biodiversity and promotes establishment of nonnative species (McKinney 2006). However, when properly managed, urban landscapes can provide enhancement of biodiversity and ecosystem services such as water and nutrient cycling (Jansson 2013). In particular, green spaces such as parks, gardens, and golf courses that intermingle within or exist on fringes of urban landscapes can provide opportunities for increasing the ecological value of urban areas (Andersson et al. 2014; Goddard et al. 2009).

Of the approximately 908,322 ha (2,244,512 ac) area occupied by golf course facilities in the United States, 609,000 ha are maintained turfgrass areas and 140,000 ha are naturalized or nonturf areas (Lyman et al. 2007). Although they occupy a relatively small percentage of the total land area in the United States, golf courses are usually located on the fringes of urban areas and thus can contribute significantly (either positively or negatively) to the ecological attributes of urban areas. Negative environmental consequences have been associated with golf course construction and maintenance, such as loss of native habitat and therefore biodiversity, contamination of soil and water with pesticides and excess nutrients, depletion of water resources, and soil erosion (Terman 1997; Wheeler and Nauright 2006). However, the impact of golf courses

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on biodiversity is highly contingent upon what sort of land use the golf course construction replaces. For example, previous case studies have indicated that golf courses are associated with greater ecological value than human-modified urban landscapes or agricultural landscapes (Colding and Folke 2009).

Due to heightened public environmental awareness, trends in golf course design have evolved away from highly manicured and input-intensive "parkland"-style courses toward more naturalistic and less input intensive "links"-style courses, modeled on the original golf courses developed in Scotland during the 13th century (Bartlett and James 2011; Tanner and Gange 2005). The Osgood Public Golf Course in Fargo, ND, is a unique nine-hole links-style golf course that was designed by Kevin Atkinson of Phelps-Atkinson Golf Course Design (Arvada, CO); construction was finished in 2004. Constructed on former farmland and set adjacent to a new suburban housing development on the southern edge of Fargo, the Osgood course includes prairie plantings that we refer to as "constructed grasslands." These constructed grasslands were established by seeding a mix of native and introduced C_3 and C_4 grasses, which included crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.], fescue (*Festuca* spp.), blue wildrye (*Elymus glaucus* Buckley), sideoats gramma [*Bouteloua curtipendula* (Michx.) Torr.], switchgrass (*Panicum virgatum* L.), and little bluestem [*Schizachyrium scoparium* (Michx.) Nash]. During 6 yr of initial establishment, these constructed grasslands became dominated by fescue species (*Festuca* spp.) and heavily infested with Canada thistle [*Cirsium arvense* (L.) Scop].

To address the Canada thistle infestation, the Osgood course superintendent implemented a chemical weed management strategy that consisted of applying 2.9 L ha^{-1} (0.31 gal ac^{-1}) Millennium Ultra 2 (37.32% 2,4-D + 2.54% clopyralid + 4.65% dicamba, NuFarm Americas, Alsip, IL) in June and September from 2005 to 2009. Based on initial surveys of the site during early spring 2010, this approach was deemed ineffective because many of the constructed grasslands contained high densities of Canada thistle and contained few of the C_3 and C_4 grasses that had been seeded originally.

Our objective was to test a new constructed grassland management approach combining aminopyralid application for Canada thistle control and prescribed fire to increase the structural diversity of the grass community. Specifically, we aimed to increase C_4 grasses (primarily switchgrass, sideoats gramma, and little bluestem) and decrease C_3 grasses, which were dominated by mat-forming perennial grasses with high rates of lodging (e.g., primarily fescue and, to a lesser extent, Kentucky bluegrass, *Poa pratensis* L.). Aminopyralid is an auxinic herbicide that is applied at low-use rates (reducing environmental impact and cost) and has been shown to provide equal or better control of Canada thistle when compared with 2,4-D, clopyralid, and dicamba (Enloe et al. 2007). Prescribed fire in the northern Great Plains is frequently applied to improve grassland productivity and reduce introduced C_3 perennial grasses such as Kentucky bluegrass and smooth brome (*Bromus inermus* Leyss.) (Bahm et al. 2011) in favor of native C_3 and C_4 species (Diboll 1986; Kilde 2000). Our hypotheses were that aminopyralid application would reduce Canada thistle density and that prescribed fire would reduce C_3 perennial grasses while stimulating C_4 grasses.

Materials and Methods

Site Description and Experimental Design. This study was conducted from 2010 to 2012 on constructed grasslands located within the Osgood Golf Course in Fargo, ND (46°48′49.4″N 96°53′28.3″W, elevation 272 m [892 ft]). Based on sampling we conducted prior to this experiment, we determined that the constructed grasslands had slopes ranging from 14 to 29%, and clayey soils (11.5% sand, 31.5% silt, 57.1% clay), with 5.8% organic matter (OM), 10.3 kg ha^{-1} (9.2 lb ac^{-1}) nitrogen (N), 12 mg ha^{-1} (0.01 lb ac^{-1}) phosphorus (P), 382 mg ha^{-1} potassium (K), and pH 7.8. The study was conducted within a completely randomized design with three treatments (control, herbicide only, and herbicide + prescribed fire) assigned randomly among 12, 9.14 by 9.14 m (30 by 30 ft) plots located within the constructed grasslands, resulting in four replications for each treatment.

Herbicide and Prescribed Fire Application. On October 21, 2010, aminopyralid (Milestone, Dow Agrosciences, Indianapolis, IN) was applied at 0.09 kg ai ha^{-1} (1.3 oz ae ac^{-1}) + 0.25% v/v nonionic surfactant (NIS) with a CO_2-pressurized backpack boom sprayer using 140 L ha^{-1} spray volume at 276 kPa (40 psi). This herbicide application was timed to occur after the first light frost; air temperature at application ranged from 3 to 6 C (37.4 to 42.8 F) and mean windspeed ranged from 1.6 to 9.7 km hr^{-1} (1 to 6 mph). Prescribed fire was applied April 28, 2011, using ring ignition techniques (Wright and Bailey 1982). Ambient air temperature was 11 C, relative humidity was 49%, and mean windspeed was 6.8 km hr^{-1}. Relative cover assessments made during late fall 2010 identified that fine fuel was made up mostly fescue species, which occupied on average 88.2% of the cover. Mean fine fuel moisture was 40.8 ± 2.7% and mean fuel load was 2,267 ± 71 kg ha^{-1} (63 lb ac^{-1}) and were determined immediately prior to burning by clipping four, 0.25-m^2 quadrats of live and dead plant material per plot and drying them to a constant weight at 105 C. Temperature data was recorded using HOBO® U12 J, K, S, T Thermocouple Data Loggers (Onset Computer Corporation, Bourne,

Table 1. Mean and range of thermocouple observations for aminopyralid-treated plots[a] in constructed grasslands infested with Canada thistle during spring prescribed fires in Fargo, ND.

	Spring fire		
Thermocouple measurements	Mean	Maximum	Minimum
Maximum temperature (C)	104	126	87
Heat duration (s)	120	153	90
Heat dosage (C-s)	2,886	3,886	2,111

[a] Each plot had four thermocouples placed 1 cm above the soil surface.

MA) and K-type Thermocouples (Omega Engineering, Inc., Stanford, CT) at 1-s intervals to create time–temperature profiles at the plot level. Four thermocouples were located 2 m diagonally in from each corner of each plot. Maximum temperature was defined as the greatest value for each time–temperature profile. Heat duration was defined as the number of seconds measuring greater than 60 C and heat dosage (degree-seconds [C-s])was calculated by summing degrees greater than 60 C over the heat duration. These measurements were used to derive the mean maximum temperature, heat duration, and heat dosage to which treatment plots were subjected (Table 1).

Vegetation Assessment. At peak summer biomass in 2011 and 2012, Canada thistle stem density and canopy cover for all species were assessed within 18, 0.25-m^2 quadrats $plot^{-1}$ using a stratified random sampling approach. To place quadrats, three permanent transects were established along the upslope and downslope sides of each plots at 1.52 m, 4.57 m, and 7.62 m. Permanent transects were used to establish long-term monitoring of Canada thistle density and species abundance. A random-number generator was used to randomly locate six quadrats along each transect. Within each quadrat, we estimated understory canopy cover by species for every species rooted within a quadrat as 0 to 0.5%, >0.5 to 1%, >1 to 5%, >5 to 10%, >10 to 25%, >25 to 50%, >50 to 75%, >75 to 95%, and >95 to 100%; cover class midpoints were used for analysis. Canada thistle stems were counted in each quadrat for density assessments. For analysis, grass species data were aggregated into two functional groups: C_3 grasses and C_4 grasses. Crested wheatgrass, smooth brome, fescue spp., slender wheatgrass [*Elymus trachycaulus* (Link) Gould ex Shinners], western wheatgrass [*Pascopyrum smithii* (Rydb.) Á. Löve], and Kentucky bluegrass comprised the C_3 grasses. Switchgrass, yellow foxtail [*Setaria pumila* (Poir.) Roemer and J. A. Schultes], lovegrass (*Eragrostis* spp.), witchgrass (*Panicum capillare* L.), sideoats grama, big bluestem (*Andropogon gerardii* Vitman), and little bluestem comprised the C_4 grasses. Herbaceous forbs (excluding Canada thistle) were aggregated, and included Flodman thistle [*Cirsium flodmanii* (Rydb.) Arthur], hedge bindweed [*Calystegia sepium* (L.) R. Br.], perennial sowthistle (*Sonchus arvensis* L.), sweetclover, (*Melilotus* spp.), white clover (*Trifolium repens* L.), dandelion (*Taraxacum officinale* G. H. Weber ex Wiggers), black medic (*Medicago lupulina* L.), and showy milkweed (*Asclepias speciosa* Torr.). Absolute cover was converted to relative cover for data analysis. At the end of the second growing season, biomass was assessed by clipping six 0.25-m^2 quadrats in each plot, two per transect. Biomass from the current growing season was clipped at ground level and sorted by Canada thistle, other forbs, C_4 grasses, and C_3 grasses. Residual biomass (i.e., standing dead and dislodged littler) from previous growing seasons was combined and hereafter referred to as litter. All of the biomass samples were dried to a constant weight at 70 C.

Statistical Analyses. Analysis of variance (ANOVA) was conducted to assess treatment effects on biomass of Canada thistle, C_3 grasses, and C_4 grasses using the MIXED procedure (SAS 9.3; SAS Inc., Cary, NC) with maximum likelihood estimation. Means separations for multiple comparisons were made using Tukey's HSD test to control for Type I experiment-wise error rate ($P < 0.05$). Multivariate analysis of variance (MANOVA) was conducted to control for experiment-wise Type 1 error rate for univariate comparisons among mean cover estimates for Canada thistle, C_3 grasses, and C_4 grasses. Wilks' Lambda statistic was highly significant. Subsequently, univariate repeated measures ANOVAs were performed to assess treatment effects on Canada thistle density and cover, C_3 grass cover, and C_4 grass cover. Specific preplanned contrasts were used to compare treatment effects on mean cover within each year. Prior to conducting ANOVA tests, Levene's test was performed to assess variance homogeneity, and the Shapiro-Wilk test was performed to assess normality. When necessary, Box-Cox transformations were used to find power transformations that improved the normality and variance homogeneity of the data. Data were subsequently back-transformed for presentation.

Results and Discussion

Herbicide and Prescribed Fire Effects on Canada Thistle. Aminopyralid application effectively reduced Canada thistle relative cover and stem density in 2011 and 2012 (Figures 1 and 2A) as well as Canada thistle biomass in 2012 (Figure 3A). In 2011, compared with control plots, Canada thistle stem density was reduced by 99.7 and 98.8% in plots treated with aminopyralid and aminopyralid + prescribed fire, respectively. In 2012, stem density was reduced by 94.1 and 83.9% in plots treated with aminopyralid and aminopyralid + prescribed fire, respectively (Figure 1). Similarly, compared with control

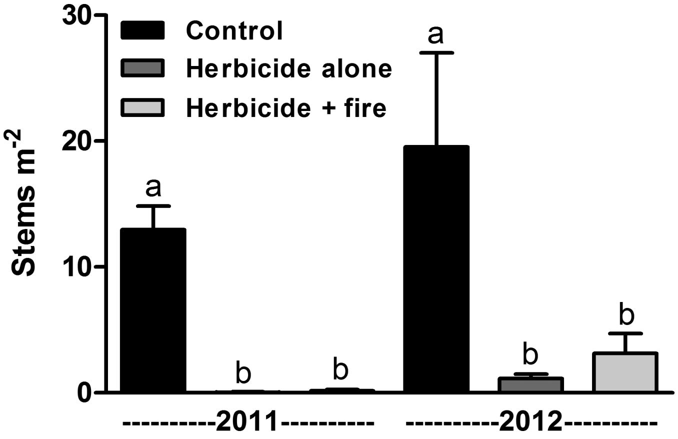

Figure 1. Mean Canada thistle stem density (stems m^{-2}) ± SE as influenced by herbicide (aminopyralid) and herbicide + prescribed fire in 2011 and 2012. Means within a year followed by the same lowercase letter are not significantly different ($P < 0.05$).

plots, relative cover of Canada thistle decreased in the aminopyralid and aminopyralid + prescribed fire plots by 98.6 and 95.7%, respectively (2011), and by 92.7 and 78.7 %, respectively (2012) (Figure 2A). Canada thistle aboveground biomass was reduced compared with the control by 99.4 and 87.7% by aminopyralid and aminopyralid + prescribed fire, respectively. However, stem density, cover, and biomass did not differ between the aminopyralid-only and aminopyralid + prescribed fire treatments during either year (Figures 1, 2A, and 3A).

Previous studies have shown that aminopyralid provides good to excellent Canada thistle control. For example, aminopyralid provided 90% or better control of Canada thistle 1 yr after treatment at rates ranging from 0.08 to 0.11 kg ai ha^{-1} when applied in the spring (at bolting) or in the fall (Enloe et al. 2007). Canada thistle control with 0.11 kg ai ha^{-1} aminopyralid was effective 22 mo after treatment, with 62% reductions following 84% reductions 10 mo after treatment (Samuel and Lym 2008). We also found that aminopyralid provided excellent Canada thistle control in the 2 yr following treatment. Although we did not see an increase in cover or biomass of Canada thistle with integrated aminopyralid and prescribed fire treatments, the potential for Canada thistle to respond favorably over time could be linked to heat-induced degradation of herbicide residual effects following the prescribed fire (Lesica and Martin 2003).

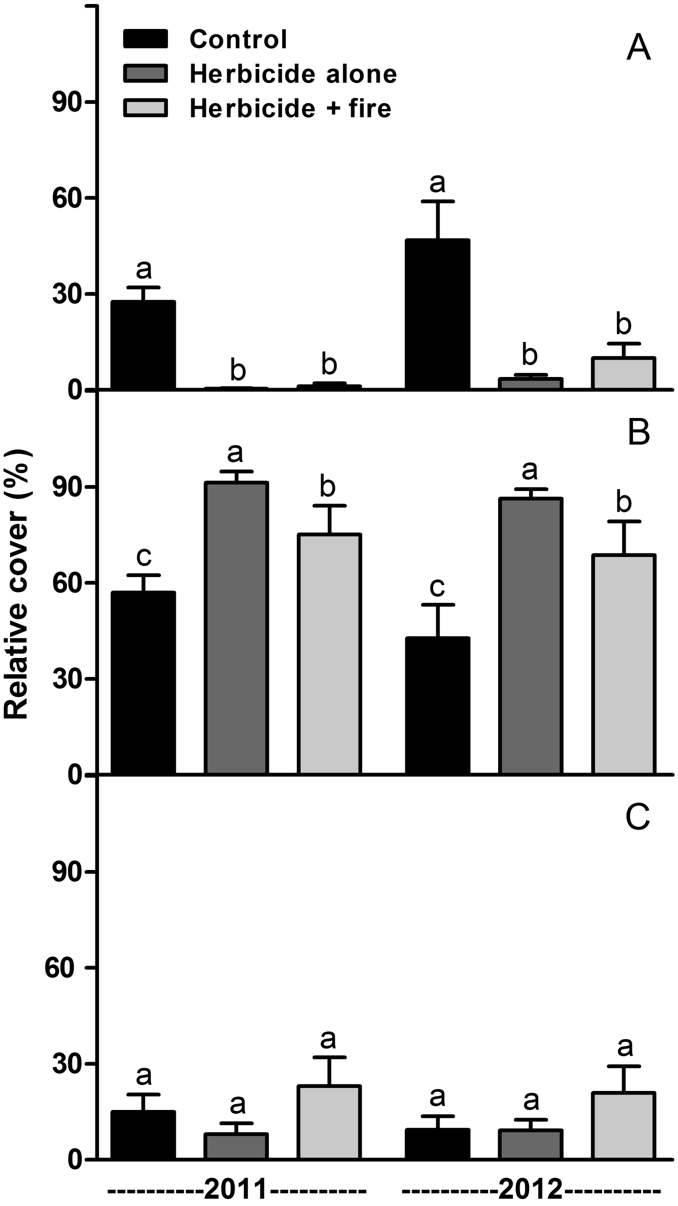

Figure 2. Mean relative cover ± SE for (A) Canada thistle, (B) C_3 grasses, and (C) C_4 grasses as influenced by herbicide (aminopyralid) and herbicide + prescribed fire measured during 2011 and 2012. Means within a vegetation type and year followed by the same lowercase letter are not significantly different ($P < 0.05$).

In this study, spring prescribed fire was intended to suppress C_3 perennial grasses and promote C_4 perennial grasses, not control Canada thistle. However, one concern was that fire could stimulate Canada thistle, because fire often promotes perennial forbs (DiTomaso et al. 2006; Jacobs and Sheley 2003). Previous studies have shown variable responses of Canada thistle to fire (Grace et al. 2002). Wildfire was associated with Canada thistle increase over several years in Yellowstone National Park (Turner et al. 1997). Conversely, fall prescribed burns can cause an initial increase in Canada thistle density, presumably because Canada thistle might emerge earlier than in nonburned areas. However, in one previous study, this initial increase did not translate into long-term increases in Canada thistle (Travnicek et al. 2005). In our study, we did not find Canada thistle increasing in plots treated with fire compared to plots treated only with herbicide (Figures 1–3).

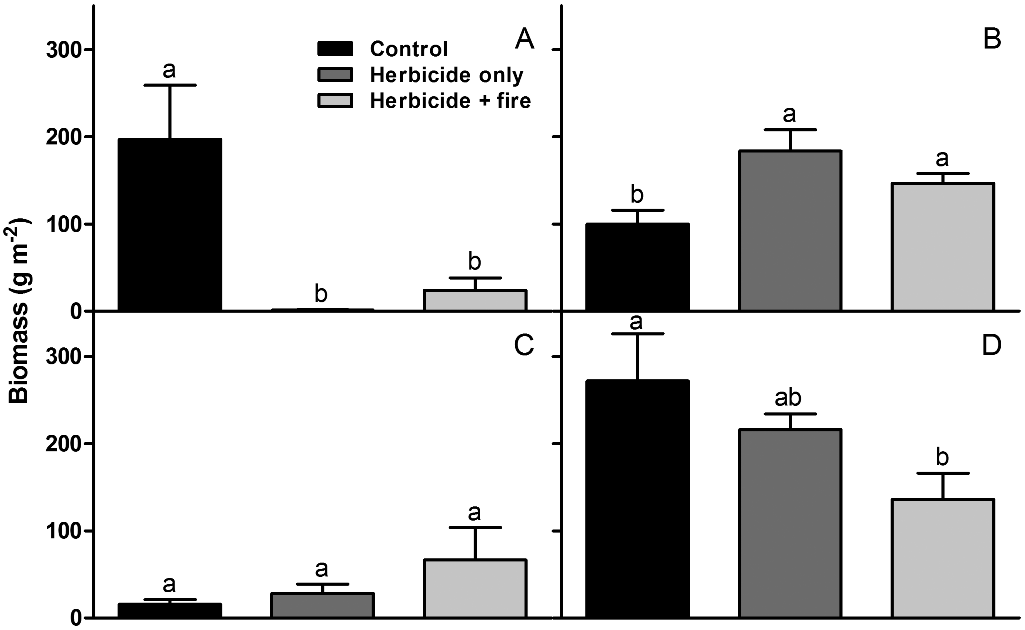

Figure 3. Mean aboveground biomass (g m^{-2}) ± SE for (A) Canada thistle, (B) C_3 grasses, (C) C_4 grasses, and (D) plant litter as influenced by herbicide (aminopyralid) alone and herbicide + prescribed fire and measured during 2012. Means within a vegetation type followed by the same lowercase letter are not significantly different ($P < 0.05$).

Prescribed Fire Effects on the Grass Community. Following treatment, vegetation measurements conducted in 2011 and 2012 showed that C_3 grass cover was greatest in control plots and least in plots treated with aminopyralid + fire, whereas plots treated with herbicide only contained an intermediate amount of cool-season grass cover (Figure 2B). Biomass assessments, which were conducted only during 2012, indicated that C_3 grass biomass in plots treated with aminopyralid alone and aminopyralid + fire was greater than C_3 grass biomass in control plots (Figure 3B). Many C_4 grass species respond positively to prescribed burns conducted during the dormant period (Simmons et al. 2007). However, C_3 grasses such as Kentucky bluegrass and smooth brome are often inhibited by early spring burns conducted when these species are elongating (Grace et al. 2002). Therefore, early spring burns are often employed to shift grass community species composition in favor of C_4 grasses (Grace et al. 2002; Lesica and Martin 2003). The results of our study indicate that effective Canada thistle control via herbicide opened a niche that was subsequently filled by C_3 grasses, but plots that were also burned experienced somewhat reduced resurgence of C_3 grasses (at least in terms of cover) compared to plots treated with herbicide only (Figure 2B). Presumably, this result was due to prescribed fire having a suppressive effect on the C_3 grasses.

We hoped to see stimulation of C_4 grass species following suppression of C_3 grasses caused by early spring prescribed fire, but relative cover and biomass of these grasses did not increase in plots treated with herbicide + fire compared to control plots (Figures 2C and 3C). However, relative cover and biomass for C_4 grasses were highly variable (Figures 2C and 3C). The reason for this variability could be natural patchiness of the grass populations, but fire behavior characteristics could also have played a substantial role. Examination of the data showed one plot in the herbicide + fire treatment had much greater presence of C_4 grasses measured post-treatment than the other three plots (data not shown). This particular plot experienced the greatest mean duration of time above 60 C and also had the least variability among sensors for maximum temperature and heat dosage, indicating that the heating effects of the burn were more intense and even across this plot than the other plots. The prescribed burns were conducted in early spring under somewhat less-than-ideal conditions (i.e., high relative humidity and high fuel moisture content). Large amounts of moist plant litter or living plant tissue above the soil surface might also have prevented the fires from reaching ideal intensity and duration in many of the plots (McGranahan et al. 2012), possibly leading to within-plot variability of warm-season grass species' response to fire that was not adequately captured by our sampling regime. Another possibility is that initial densities of C_4 grasses were insufficient to provide adequate competitive pressure against the C_3 grasses (Willson and Stubbendieck 2000).

Fire is thought to increase C_4 grasses by removing surface litter, thereby resulting in greater soil warming earlier in the season that might improve nitrogen availability during early growth (Hulbert 1988). Litter biomass measured during 2012 decreased by approximately 50% in plots treated with herbicide + prescribed fire compared to control plots (Figure 3D), but this reduction in litter did not result in the increase of the C_4 grass community. One reason for this is that patchiness in fire intensity might not have provided consistent stimulation of C_4 grasses, as discussed above. Another reason could be that sufficient propagules were lacking to regenerate these species, because we did not reseed after treatment. This possibility serves to stress the idea that restoration efforts depend not only on controlling invasive species, but ensuring the regeneration of native or desired species (Alexander and D'Antonio 2003).

Restoration strategies such as prescribed fire or herbicide application aim to avoid harm to nontarget species that have been deemed desirable, such as perennial or annual forbs in the case of many grassland restorations. However, removal of invasive weeds via herbicide application might also provide niches within which native forbs can regenerate. For instance, Samuel and Lym (2008) found that for areas invaded by Canada thistle, aminopyralid application did not affect species richness compared with untreated plots. But in areas consisting of only native species, aminopyralid application resulted in a decline in species richness compared with untreated control areas. The constructed grasslands at Osgood golf course contained very few herbaceous forbs at the start of the experiment. During 2010, initial measurements showed that no plot contained more than 0.6% relative cover of forbs, and these consisted mostly of sweetclover, white clover, hedge bindweed, and common dandelion (data not shown), none of which are highly desirable forbs in a grassland restoration. The general absence of desirable forbs was likely due to years of Canada thistle management using broadleaf herbicides. Also, herbaceous forbs were not seeded when the constructed grasslands were first constructed, so forbs could only have been produced from the pre-existing seed bank. Because the golf course was built on land that was formerly in agricultural production for a long period of time, few propagules of desirable forbs likely exist in the seed bank. Because forb relative cover was consistently less than 0.7% of the relative cover, we do not present results of that analysis. In summary, aminopyralid provided excellent control of Canada thistle, even 2 yr after treatment, but seems to be associated with declines in the already almost nonexistent forb community.

Oftentimes, removal of one unwanted plant species results in replacement with another equally undesirable species, instead of restoration of a desired native community (Samuel and Lym 2008). Our results showed that the niche left open by treatment with aminopyralid alone was readily filled with C_3 grasses, primarily fescue species. Adding prescribed fire to the herbicide treatment reduced the abundance of C_3 grasses, but less-than-ideal environmental conditions during the burn and reduced oxygen flow due to the lodged nature of the fescue species likely caused low fire intensities and burn patchiness. Prescribed fire effectively removed large amounts of standing dead and dislodged litter, which presumably altered site conditions that could favor C_4 grasses. We speculate that additional prescribed fire treatments could further promote site characteristics that favor C_4 grasses; however, in situations of low C_4 propagule availability, seeding should also be considered.

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Literature Cited

Alexander JM, D'Antonio CM (2003) Seedbank dynamics of French broom in coastal California grasslands: effects of stand age and prescribed burning on control and restoration. Restor Ecol 11: 185–197

Andersson E, Barthel S, Borgström S, Colding J, Elmqvist T, Folke C, Gren Å (2014) Reconnecting cities to the biosphere: stewardship of green infrastructure and urban ecosystem services. Ambio 43: 445–453

Bahm MA, Barnes TG, and Jensen KC (2011) Herbicide and fire effects on smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) in invaded prairie remnants. Invasive Plant Sci Manag 4: 189–197

Bartlett MD, James LT (2011) A model of greenhouse gas emissions from the management of turf on two golf courses. Sci Total Environ 409:1357–1367

Colding J, Folke C (2009) The role of golf courses in biodiversity conservation and ecosystem management. Ecosystems 12:191–206

Diboll N (1986) Mowing as an alternative to spring burning for control of cool-season exotic grasses in prairie grass plantings. Pages 204–209 *in*. Proceedings of the Ninth North American Prairie Conference, Moorhead MN: University of Wisconsin Digital Collections

DiTomaso JM, Brooks ML, Allen EB, Minnich R, Rice PM, Kyser GB (2006) Control of invasive weeds with prescribed burning. Weed Technol 20:535–548

Enloe SF, Lym RG, Wilson R, Westra P, Nissen S, Beck G, Moechnig M, Peterson V, Masters RA, Halstvedt M (2007) Canada thistle (*Cirsium arvense*) control with aminopyralid in range, pasture, and noncrop areas. Weed Technol 21:890–894

Goddard MA, Dougill AJ, Benton TG (2009) Scaling up from gardens: biodiversity conservation in urban environments. Trends Ecol Evol 25:90–98

Grace JB, Smith MD, Grace SL, Collins SL, Stohlgren TJ (2002) Interactions between fire and invasive plants in temperate grasslands of North America. Pages 40–65 *in* Galley KEM, Wilson TP, eds Proceedings of the Invasive Species Workshop: the Role of Fire in the Control and Spread of Invasive Species. Fire Conference 2000: the First National Congress on Fire Ecology, Prevention, and Management. Miscellaneous Publication No. 11. Tallahassee, FL: Tall Timbers Research Station

Hulbert LC. (1988) Causes of fire effects in tallgrass prairie. Ecology 69: 46–58

Jacobs JS, Sheley RL (2003) Prescribed fire effects on Dalmation toadflax. J Range Manag 56:193–197

Jansson Å. (2013) Reaching for a sustainable, resilient urban future using the lens of ecosystem services. Ecol Econ 86:285–291

Kilde R. (2000) Going Native: A Prairie Restoration Handbook for Minnesota Landowners. Minnesota Department of Natural Resources, Section of Ecological Services, Scientific and Natural Areas Program. http://files.dnr.state.mn.us/assistance/backyard/prairierestoration/goingnative.pdf. Accessed May 9, 2014

Lesica P, Martin B (2003) Effects of prescribed fire and season of burn on recruitment of the invasive exotic plant, *Potentilla recta*, in a semiarid grassland. Restor Ecol 11:516–523

Lyman GT, Throssell CS, Johnson ME, Stacey GA (2007) Golf course profile describes turfgrass, landscape, and environmental stewardship features. Appl Turfgrass Sci DOI: 10.1094/ATS-2007-1107-01-RS

McGranahan DA, Engel DM, Fuhlendorf SD, Miller JR, Debinski DM (2012) An invasive cool-season grass complicates prescribed fire management in a native warm-season grassland. Nat Area J 32:208–214

McKinney ML (2002) Urbanization, biodiversity, and conservation. BioScience 52:883–890

McKinney ML (2006) Urbanization as a major cause of biotic homogenization. Biol Conserv 127:247–260

Samuel LW, Lym RG (2008) Aminopyralid effects on Canada thistle (*Cirsium arvense*) and native plant species. Invasive Plant Sci Manag 1: 265–268

Simmons MT, Windhager S, Power P, Lott J, Lyons RK Schwope C (2007) Selective and non-selective control of invasive plants: the short-term effects of growing-season prescribed fire, herbicide, and mowing in two Texas prairies. Restor Ecol 15:662–669

Tanner RA, Gange AC (2005) Effects of golf courses on local biodiversity. Landsc Urban Plann 71:137–146

Terman MR. (1997) Natural links: naturalistic golf courses as wildlife habitat. Landsc Urban Plann 38:183–197

Travnicek AJ, Lym RG, Prosser C (2005) Fall-prescribed burn and spring-applied herbicide effects on Canada thistle control and soil seedbank in a northern mixed-grass prairie. Rangeland Ecol Manag 58:413–422

Turner MG, Romme WH, Gardner RH, Hargrove WH (1997) Effects of fire size and pattern on early succession in Yellowstone National Park. Ecol Monogr 67:411–433

Wheeler K, Nauright J (2006) A global perspective on the environmental impact of golf. Sport Soc 9:427–443

Willson GD, Stubbendieck J (2000) A provisional model for smooth brome management in degraded tallgrass prairie. Ecol Restor 18:34–38

Wright HA, Bailey AW (1982) Fire ecology: United States and Southern Canada. New York: Wiley. 528 p

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