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Effectiveness of Burning, Herbicide, and Seeding Toward Restoring Rangelands in Southeastern North Dakota

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ABSTRACT

Many rangelands in southeastern North Dakota are invaded by Kentucky bluegrass (*Poa pratensis* L.) and/or smooth brome (*Bromus inermis* Leyss.). It may be especially difficult for native species to reestablish in rangelands dominated by Kentucky bluegrass and/or smooth brome due to these species' competitive advantages. Relatively few studies have specifically compared the effectiveness of methods intended to reduce competition from Kentucky bluegrass and/or smooth brome before seeding with native species in southeastern North Dakota. In our current study, we evaluated the effects of five restoration treatments: 1) control (no seeding or competition-reduction treatments), 2) interseed (native seeds drilled into the existing plant community), 3) spring burn before drill seeding native species, 4) glyphosate application before drill seeding native species, and 5) spring burn plus glyphosate application before drill seeding native species on a degraded rangeland plant community. We installed the five treatments in fifteen 40 × 100 m plots in 2010. In 2015, we sampled the vegetation within each plot to determine whether the restoration methods increased total and/or native warm-season grass biomass, reduced Kentucky bluegrass and/or smooth brome biomass, or increased grass species richness. Although none of our restoration treatments impacted Kentucky bluegrass biomass, each of our restoration treatments increased grass species richness over the control. Including a glyphosate application before seeding with natives also increased total biomass, reduced smooth brome biomass, and increased native warm-season grass species richness. Thus, we suggest that the glyphosate application was a worthwhile addition at this location because it resulted in additional improvements to the invasive-dominated plant community.

Introduction

Kentucky bluegrass and smooth brome are both highly competitive species, possessing many characteristics that prove advantageous over the native grasses of the Northern Great Plains (DeKeyser et al., 2013, 2015; Grant et al., 2009). Kentucky bluegrass and smooth brome disrupt ecosystem function through altering nitrogen cycling and/or carbon storage, reducing plant diversity, and/or shifting seasonal forage production (Vinton and Goergen, 2006; Toledo et al., 2014). Kentucky bluegrass and smooth brome both increase in the absence of herbivory and/or fire and may occur together or form dense monocultures (Murphy and Grant, 2005; Grant et al., 2009). Both species are now ubiquitous throughout the Northern Great Plains, occurring on native prairie remnants and restored prairies (Murphy and Grant, 2005; Toledo et al., 2014).

As Kentucky bluegrass and smooth brome have spread across the Northern Great Plains, researchers have proposed a variety of techniques intended to ameliorate the impacts to native ecosystems, including the reinstallation of fire and/or grazing regimes, herbicide applications, and/or the restoration of native species (Murphy and Grant, 2005; Grant et al., 2009; DeKeyser et al., 2013). However, it is important to note that it may be especially difficult for new species to establish in invasive-dominated plant communities because the ecological processes necessary to maintain diverse plant communities may have been altered in a manner that favors invasive species (Sheley et al., 2006; Vinton and Goergen, 2006). Thus, researchers have proposed selecting management techniques that address underlying ecological principles and processes during restoration as a means to improve restoration outcomes (i.e., through the manipulation of competitive dynamics and/or the principles of ecological succession during restoration) (Sheley et al., 2006, 2010; Hobbs and Cramer, 2008).

One method to improve plant community composition in an invasive-dominated grassland is to supply seeds from native species

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that may be underproducing or completely absent from the invaded plant community. Interseeding native species (by drilling or broadcasting seeds into an established plant community) is often used to increase the abundance of certain species during rangeland restoration (Rossiter et al., 2016). One of the main benefits of interseeding is that it does not disturb the soil or existing plant community to the same extent as tilling, which is especially advantageous when the existing plant community contains certain desirable species (Bailey and Martin, 2007). Additional benefits include the relative ease with which species may be restored and the potential for improvement in site quality (Bailey and Martin, 2007; Rossiter et al., 2016). However, a potential disadvantage is that it may take 4 − 5 years for new species to establish due to competition from the existing plant community (Bailey and Martin, 2007). Thus, managers often attempt to shorten the time it takes for newly seeded species to establish through the use of herbicides, tillage, burning, mowing, and/or grazing in order to reduce competition before seeding with native species (Endress et al., 2012; Taylor et al., 2013; Martin and Wilsey, 2014).

Because ecological restoration is dependent on complex, site-specific factors, the use of individual competition-reduction methods before seeding has met with varying degrees of success (Endress et al., 2012; Martin and Wilsey, 2014). Interestingly, research suggests that incorporating multiple competition-reduction treatments may be more effective than applying the same treatments individually (Sheley et al., 2006). For example, Collins et al. (1998) found that frequent burning alone produced a plant community dominated by warm-season grasses, while burning and grazing promoted greater plant species diversity. Similarly, Taylor et al. (2013) determined grazing before a herbicide application enhanced the establishment of certain native species more than the grazing or herbicide treatments, individually. In our current study, we examined whether the synergistic effect observed by other researchers was at work in an invasive-dominated grassland in southeastern North Dakota.

To date, relatively little research has specifically evaluated whether the inclusion of competition-reduction methods before seeding with native species impacts invasive species in southeastern North Dakota, thereby fostering the restoration of native species. In this study, we compared the effectiveness of seeding native species into a southeastern North Dakota grassland dominated by Kentucky bluegrass and smooth brome, with and without the inclusion of competition-reduction methods (before seeding). We implemented a herbicide (glyphosate) application and a prescribed burn, individually and in combination, before seeding with native species in 2010. In 2015, we estimated biomass and grass species richness to evaluate whether the different treatments produced differences in total biomass, Kentucky bluegrass biomass, smooth brome biomass, native warm-season grass biomass, and/or grass species richness at our study site. We predicted that the glyphosate and burning combination (before seeding) would be the most effective restoration method at this location, resulting in the highest total biomass by reducing Kentucky bluegrass and smooth brome biomass. In addition, we predicted that the combination of glyphosate and burning would increase species richness, as this combination was expected to result in the greatest reduction of competition from Kentucky bluegrass and smooth brome.

Methods

Our study was conducted on approximately 6 hectares of grassland invaded by Kentucky bluegrass and smooth brome located in Richland County, North Dakota (46°32'31.31"N and 97°8'34.92"W). The area was cultivated before the 1970s when it was reseeded to grass and grazed with cattle (unfortunately, we have been unable to obtain more detailed information about the management history at this site). In summer 2010, we installed five treatments: 1) control (no seeding or competition reduction), 2) interseed (native seeds were drilled into the existing plant community, 3) spring burn before drill seeding native species, 4) glyphosate application before drill seeding native species, and 5) spring burn and glyphosate application before drill seeding native species in three replications, for a total of fifteen 40 × 100 m plots. We applied glyphosate using a boom sprayer 3 weeks before seeding.

We seeded in July 2010 (due to a wet spring) using a rangeland drill set a depth of 0.25 − 1.25 cm (20-cm spacing). The soils at this site are primarily sandy, having originated on sandy delta plains and outwash plains (USDA-NRCS, 2014a). Mean annual precipitation is 538 mm (Biondini et al., 2011), and mean annual temperature is 5.4°C (NDAWN, 2014). Before the installation of our competition-reduction and seeding treatments, the vegetation was dominated by Kentucky bluegrass and smooth brome (unpublished data)—many native warm-season grasses typically associated with North Dakota rangelands (based on Ecological Site Descriptions (USDA-NRCS, 2014b)) were not present (e.g., big bluestem [*Andropogon gerardii* Vitman], little bluestem [*Schizachyrium scoparium* Michx.], Indiangrass [*Sorghastrum nutans* {L.} Nash], and switchgrass [*Panicum virgatum* L.]). We based our seed mixture on Ecological Site Descriptions (Major Land Resource Area 56) and seeded at rates intended to reflect the composition of reference condition plant communities (Table 1).

In August 2015, we estimated aboveground biomass and grass species richness using eight 0.25-m^2 quadrats per plot. Biomass samples were separated by species and oven-dried at 60°C before weighing. We used analysis of variance (ANOVA) to determine whether total biomass, Kentucky bluegrass biomass, smooth brome biomass, native-warm-season grass biomass, and/or grass species richness responded to our treatments: 1) control, 2) interseed into existing plant community, 3) spring burn before seeding, 4) glyphosate application before seeding, and 5) spring burn and glyphosate application before seeding. In addition, we used Tukey's (honestly significant difference) test to make comparisons between treatment populations.

3. Results

Total biomass ($P = 0.026$), smooth brome biomass ($P = 0.008$), native warm-season grass biomass ($P = 0.047$), and grass species richness ($P = 0.013$) responded to rangeland restoration methods: 1) control, 2) interseed into existing plant community, 3) spring burn before seeding, 4) glyphosate application before seeding, and 5) spring burn and glyphosate application before seeding while Kentucky bluegrass biomass ($P = 0.767$) did not (Table 2). Total biomass (mean = 337.35 g/m^2; SE = 31.46) was greater ($P < 0.05$) in plots that were treated with herbicide before seeding than in control plots (mean = 203.13 g/m^2; SE = 14.00) (Fig. 1A). In contrast, smooth brome biomass was greater in control plots (mean = 83.67 g/m^2; SE = 20.29) than plots treated with glyphosate before seeding (mean = 22.12 g/m^2; SE = 4.20) and plots treated with glyphosate in addition to a spring burn (mean = 29.20 g/m^2; SE = 7.89) (Fig. 1B). Smooth brome biomass was also greater in plots that were burned before seeding (mean = 83.02 g/m^2; SE = 5.65) than plots treated with glyphosate (mean = 22.12 g/m^2; SE = 4.20) (see Fig. 1B). In addition, native warm-season grass biomass was greater in plots treated with glyphosate (mean = 286.82 g/m^2; SE = 37.96) than control plots (mean = 146.58 g/m^2; SE = 31.48) (Fig. 1C).

Mean grass species richness in control plots was 2.54 species (SE = 0.07). Each rangeland restoration treatment yielded greater mean grass species richness after 5 years (Fig. 1D). However, grass species richness in all of the seeded plots was approximately equal, regardless of glyphosate application and/or burning. Plots that were interseeded only (without a glyphosate application or a spring burn) had a mean grass species richness of 4.83 species (SE = 0.85). Applying glyphosate, burning, and the combination of glyphosate and burning yielded mean grass species richness values of 4.71 species (SE = 0.11), 4.50 species (SE = 0.13), and 4.75 species (SE = 0.31), respectively (Fig. 1D).

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