Thatch Removal: A New Method for Managing Kentucky Bluegrass in the Northern Great Plains

Hayley Hilfer and Ryan Limb
North Dakota State University, School of Natural Resource Sciences, Fargo, N.D.

Summary

Kentucky bluegrass (<u>Poa</u> <u>pratensis</u> L.) engineers its environment to promote its success through the production of thatch, a tightly woven mat of roots, partially decomposed plant material, senesced stems and leaves, and live plants. Thatch suppresses the growth and establishment of native species through alterations in soil surface light availability and hydrology, posing a threat to grassland biodiversity and forage sustainability.

We conducted an experiment utilizing new methodology to remove Kentucky bluegrass thatch. We evaluated plant community composition in areas with historic thatch accumulation and in response to thatch removal using a skid-steer equipped with an angle broom attachment.

We found that thatch removal significantly reduced thatch depth and Kentucky bluegrass cover. Thatch removal also increased species evenness and diversity. This research provides insight about the effects of Kentucky bluegrass thatch on plant community composition and the role it plays in successful invasion.

Introduction

Inhibiting the expansion of invasive plant species worldwide is of great importance in an era of human-induced global change. Globally, invasion by one or two regionally non-native "ecosystem engineers" creates homogenous landscapes that no longer support historical biodiversity (Ehrenfeld, 2010; Richardson et al., 2000).

Ecosystem engineers utilize mechanisms to facilitate their spread and dominance while replacing local native species (Hobbs et al., 2006; Olden et al., 2004). Invasion by an ecosystem engineer triggers threshold development, and ecosystems can transition into an entirely new state where reversal to a pre-invaded condition may be difficult or impossible to achieve (Hobbs et al., 2006). Managing the spread of invasive species is of increasing importance to preserve ecosystem integrity, yet the effects of the mechanisms they utilize are not fully understood within a species- and scenario-specific context (Gong et al., 2020).

Kentucky bluegrass (*Poa pratensis* L.) is an ecosystem engineer whose dominance is facilitated by the presence of thatch, a tightly woven mat of roots, partially decomposed plant material, senesced stems and leaves, and live plants (Dornbusch et al., 2020; Ellis-Felege et al., 2013; Nouwakpo et al., 2019). Kentucky bluegrass (KBG) thatch reduces light availability and daily temperature fluctuations (Bosy and Reader, 1995; Gasch et al., 2019), the two primary mechanisms involved in germination cueing (Rice, 1985).

The ability of thatch to decrease light availability is the primary mechanism through which KBG suppresses the germination and growth of native species. Thatch also is associated with changes in soil surface hydrology (Gasch et al., 2019; Liang et al., 2017; Nouwakpo et al., 2019) and nutrient cycling (Chuan et al., 2020; Sanderson et al., 2017). These three mechanisms interact to create a positive feedback loop that favors the persistence of KBG while squandering the performance of native species.

KBG is a prolific invader in the Northern Great Plains (NGP). The temperate grasslands of the NGP historically were dominated by cool-season C_3 grasses (Toledo et al., 2014) and evolved with the interacting disturbances of periodic fire and grazing, processes which were altered upon European settlement (Fuhlendorf and Engle, 2001, 2004). Historic management practices, such as infrequent burning and grazing (Murphy and Grant, 2005; Printz and Hendrickson, 2015) or prolonged periods of rest (Kobiela et al., 2017), have further promoted homogeneity and increased the abundance of KBG (DeKeyser et al., 2013; Miles and Knops, 2009).

More recent management efforts aimed at controlling KBG spread, such as grazing, burning or chemical application, have mixed results. KBG's functional similarity as a C_3 grass makes it difficult to manage chemically without damaging the remaining native population (Kral et al., 2018). The location of KBG's apical meristems near the soil surface and below the thatch layer make it a grazing-tolerant grass (Hendrickson and Lund, 2010).

In addition, the tendency of thatch to hold excessive moisture also may decrease its susceptibility to fire as a viable management strategy (Czarniecka-Wiera et al., 2020; Kral et al., 2018). KBG invasion in the NGP provides an excellent example of an ecosystem engineer within the context of a human-modified landscape. New management strategies are required to address the creation of this novel ecosystem.

We propose that thatch is the primary mechanism utilized by KBG to facilitate its dominance. The goal of this research is to investigate the effects of removal of KBG thatch on a northern Great Plains grassland system.

Here we evaluate changes in plant community composition following removal of the thatch layer using an angle-broom attachment on a skid-steer for one growing season. Complete removal of the thatch layer in this way will provide insight about its role in KBG invasion and plant community composition, and will better inform future development of management methodologies aimed at preventing the spread of KBG.

Methods

Site Description

This experiment was conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC). This center is positioned within the Missouri Coteau ecoregion, which is composed primarily of small glacial lakes and irregular rolling hills formed by the collapse of supraglacial sediment (U.S. Department of Agriculture - Soil Conservation Service [USDA-SCS], 1981).

The climate of the region is described as continental (USDA-SCS, 1981), with average temperatures ranging from minus 11 C in January to 21 C in July (North Dakota Agricultural Weather Network [NDAWN], 2020). Average annual precipitation is 407 millimeters, with 73% of the rainfall occurring between May and September, primarily during heavy thunderstorm events (NDAWN, 2020; USDA-SCS, 1981).

The vegetation of central North Dakota is typical of mixed-grass prairie, historically dominated by cool-season and warm-season native grasses such as green needlegrass (*Nasella viridula)*, western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*) and little bluestem (*Schizachyrium scoparium*), as well as a variety of sedges (*Carex* spp.) and forbs (Limb et al., 2018). Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*), two non-native cool-season grasses, have come to dominate this region within the past half century and are responsible for many recent changes in biodiversity (Limb et al., 2018).

Experimental Design

We initiated a split-plot design in four approximately 16-hectare (ha) bluegrass-invaded pastures with two treatments (thatch removal and control), each replicated 10 times in April 2020. These pastures are part of a modified twice-over rest-rotation grazing system in which fencing is utilized to direct cattle distribution to increase habitat heterogeneity. For the purposes of this experiment, all four pastures will be subjected to the same grazing treatments each year across the three-year study period.

Plots are placed in one intensity grazing treatment only to reduce any potential grazing effects, and in pastures that were idle the previous year to maximize thatch cover and treatment effect. No other intentional treatments will be implemented in these plots during the study period.

Pastures were stocked with calf-cow pairs to achieve moderate use (20% to 40% disappearance of graminoid species) in 2020. A full-use grazing treatment (40% to 60% disappearance of graminoid species) will be used in 2021 and a heavy use treatment (60% to 80% disappearance of graminoid species) will be applied in 2022 (Table 1).

Table 1. Grazing treatments applied to the four pastures during the three-year period, with the number of grazing days utilized to achieve the respective degrees of disappearance.

Year	Grazing Treatment	Degree of Disappearance	Grazing Days
2020	Moderate use	20%-40%	54
2021	Full use	40%-60%	108
2022	Heavy use	60%-80%	155

To investigate the effects of thatch removal, a paired design with stratified random sampling was employed. Prior to treatment initiation, a visual survey of all four pastures was conducted to determine areas that were dominated by KBG and contained thick layers of thatch (100% litter cover). Areas of interest were dominated by grasses and still had some native vegetation component.

Ten 10- by 20-meter (m) plots then were placed in areas that had minimal topographical and vegetative variation. Each plot was further divided into two 10- by 10-m plots, which were assigned randomly to one of two treatments: thatch removal or control.

Edge effects were reduced by nesting a 5- by 5-m sampling plot within each treatment plot, creating a 2.5-m buffer zone around the measurement area (Figure 1). This size was chosen to be large enough to capture a plant community (Dornbusch et al., 2020), yet small enough to avoid attracting grazers.

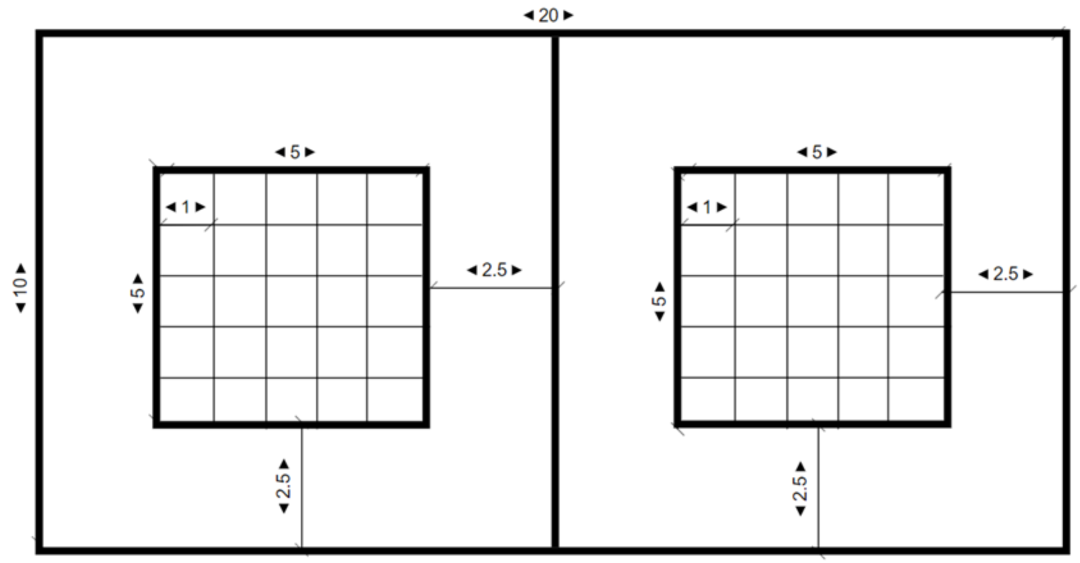

Figure 1. 10- by 20-m split-plot design, with each 10 m^2 half randomly assigned to treatment or control. For vegetation sampling, 25 m^2 plots are nested within each half and further gridded into the 1 m^2 subsamples utilized for Daubenmire cover class collection.

Thatch removal treatment was applied on May 20-21, 2020, using an 82-inch Titan Implement X-treme Skid-Steer Angle Broom Attachment connected to a SSV75 Kubota Skid-Steer (Figure 2a). Each treatment plot was brushed until the root-mat layer was clearly visible (Figure 2b).

Figure 2a. 82-inch Titan Implement X-treme Skid-Steer Angle Broom Attachment connected to a SSV75 Kubota Skid-Steer.

Figure 2b. Result of thatch removal split-plot, with thatch removal treatment on the left and control treatment on the right.

Photos by Hayley Hilfer

Data Collection and Analysis

Plant community composition data was collected the first two weeks in July during the peak growing season and will continue in 2021. Identification and canopy cover of each species of the entire 25 m^2 sampling plot was recorded within 1- by 1-m^2 frames using a modified Daubenmire cover class system (1 = trace-1%, 2 = 1%-2%, 3 = 2%-5%, 4 = 5%-10%, 5 = 10%-20%, 6 = 20%-30%, 7 = 30%-40%, 8 = 40%-50%, 9 = 50%-60%, 10 = 60%-70%, 11 = 70%-80%, 12 = 80%-90%, 13 = 90%-95%, 14 = 95%-98%, 15 = 98%-99%, 16 = 99%-100%) (Daubenmire, 1959).

All values were converted to midpoints and averaged across the 25 subsamples in each plot. Plant species richness, evenness and Simpson's diversity index were calculated using PC-ORD 7.0.

The effectiveness of the thatch removal treatment was determined by measuring thatch layer depth in the buffer zone of each treatment plot. Litter depth was measured at 10 locations within the buffer zones of each treatment plot in the week following treatment initiation.

A sod hole cutter with a 4.25-inch diameter was used at each location to remove a sample down to bare soil. The depth of the root mat and decomposing material was measured with a ruler. These measurements were combined for total depth and averaged within treatment and control plots for analysis. Additional depth measurements will be collected in May of the following years to assess changes in depth through time.

Data Analysis

The treatment effect was assessed by creating a distance matrix in PC-ORD 7.0 and comparing the similarity values for each treatment-control pair. The statistical analysis of plant community metrics (richness, evenness and diversity) consisted of the mean difference between treatment and control values.

We utilized one-tailed t-tests with a specified value of zero to investigate how univariate data responded to thatch-removal (SPSS Version 27; IBM Corp., 2020). Results were considered significant at $p \leq 0.05$.

Results

In the first year of our experiment, thatch removal treatment significantly reduced thatch depth by an average of 9.16 centimeters. We identified a total of 88 plant species across all plots in 2020, with an average of 30 species across all 10 plots.

The difference between treatment and control plots indicated a significant reduction in KBG cover (Figure 3). No effect of treatment ($p > 0.05$) was observed in smooth brome and native grass cover, with a slightly positive trend found in native forb cover ($p = 0.17$). Evenness and Simpson's diversity increased ($p \leq 0.05$) with thatch removal (Figure 4).

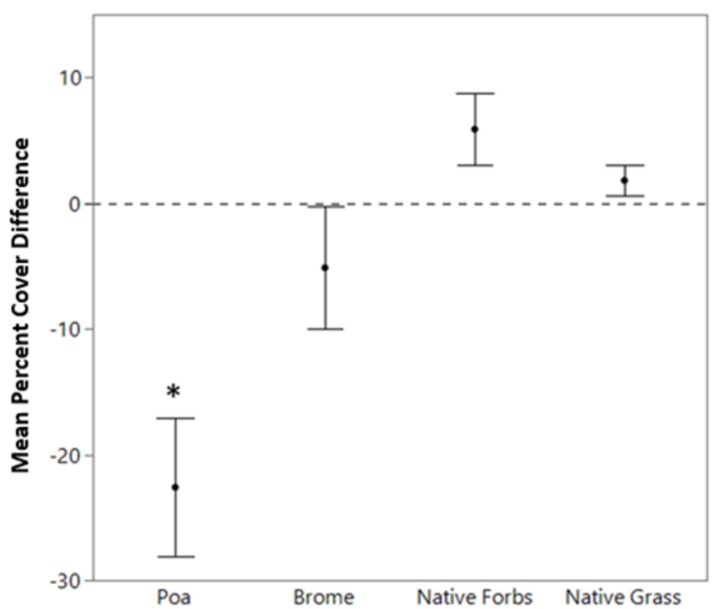

Figure 3. Mean percent cover differences due to thatch removal of Kentucky bluegrass (Poa), smooth brome (Brome), native forbs and native grasses between paired treatment and control plots (n = 10) in 2020. No difference between treatment and control is represented by the dashed line. The asterisk represents a statistical difference from the control plot average ($p < 0.05$). Error bars represent standard error of the mean.

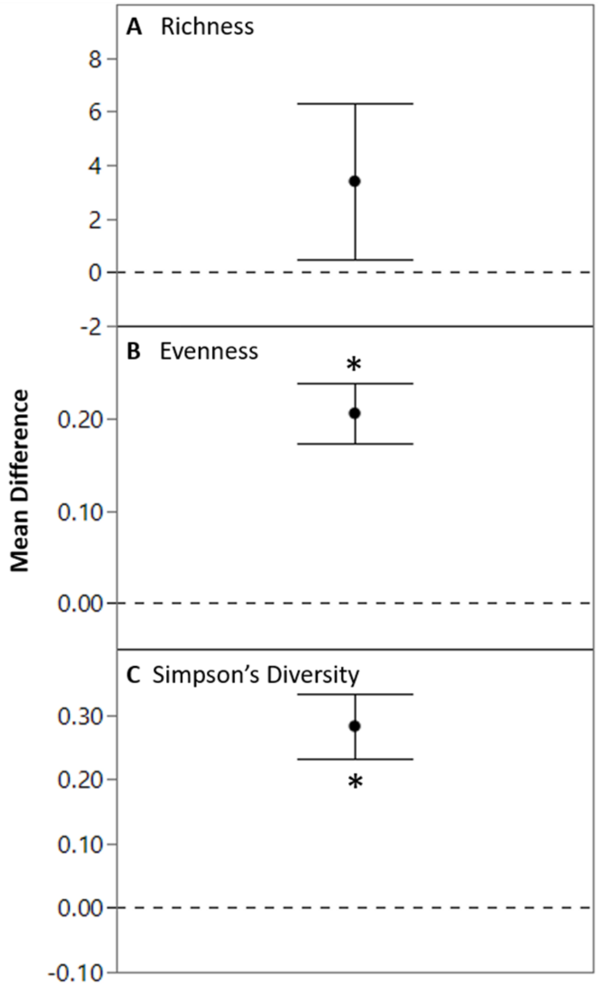

Figure 4. Mean differences due to thatch removal between paired treatment and control plots in plant species richness (A), evenness (B) and Simpson's diversity index (C) in 2020 (n = 10). No difference between treatment and control is represented by the dashed line. Asterisks represent a statistical difference from the control plot average ($p < 0.05$). Error bars represent standard error of the mean.

Discussion

Our data show significant differences in thatch depth and KBG cover immediately following treatment initiation. Alternative management strategies, such as alternative grazing management and burning, have proven successful at preventing increases in KBG cover but unsuccessful at producing any meaningful declines through time (Dornbusch et al., 2020; Kobiela et al., 2017).

The nature of our methodology specifically targets the thatch layer and likely disrupts the positive feedback loop to a greater extent than these strategies. Although performance of native species did not improve within the first year, we saw a slightly positive increase in native forb performance. We also observed significant increases in species evenness and Simpson's diversity, indicating that removal of the thatch layer provided adequate conditions for improved performance of already established species. Data collection one-year post-treatment application may provide more time for the establishment of newly dispersed species or allow those already present in the seedbank to respond to the new environmental conditions (Bosy and Reader, 1995; Molinari and D'Antonio, 2020; Nouwakpo et al., 2019).

The consequences of KBG in the northern Great Plains are severe, with impacts on local biodiversity eventually impacting ecosystem services such as pollinator populations and livestock forage production (Toledo et al., 2014). KBG has been found to have poor digestibility overall and tends to go dormant quickly during the hot, dry summers typical of the NGP (Hockensmith et al., 1997; Toledo et al., 2014).

Higher species richness produces increased forage quality (French, 2017) and greater forage resistance to environmental stress. The propensity of KBG to create monocultures not only creates vast areas of poor forage, but also reduces forage sustainability. We anticipate that the outcomes of this species- and scenario-specific research will better inform management decisions directed at the reduction of KBG and foster the development of new methodologies targeted at reducing the spread of ecosystem engineers more broadly.

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