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Restoring Native Plant Species in Crested Wheatgrass Rangelands Using Glyphosate and No-Till Reseeding

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Abstract

The objectives of this study were to evaluate the effects of spring application of glyphosate (1.1 kg/ha) on 1) crested wheatgrass (Agropyron cristatum (L.) Gaertn) phytomass, 2) seedling establishment of native grasses and forbs using no-till reseeding and 3) non-target plant species responses. Field trials were conducted at five sites in central and eastern Montana in 2002 and 2003. Each site contained sixteen 36x36 m plots to test four treatments. The treatments included control, glyphosate only, glyphosate plus cool season plants no-till seeded in the fall, and glyphosate plus spring no-till seeding of cool season plants in 2002. In 2003, one half of the plots were sprayed a second time with glyphosate to control crested wheatgrass growth. Five 0.25 m2 quadrats per plot sampled in August were used to estimate crested wheatgrass, seeding and non-target phytomass. Split plot error was the testing term for glyphosate treatment differences, and the whole plot error was the testing term for planting treatments. Data that was not normally distributed was rank-transformed. Data was analyzed by site due to site by treatment interactions. Application of glyphosate for two consecutive years reduced crested wheatgrass phytomass 91% compared to controls. Application for one year reduced phytomass 56% across all sites but two sites showed no reduction in phytomass one year after application. No-till seeding failed on four of five sites due to lack of adequate moisture and did not influence seedling phytomass a year after planting. Non-target plant species biomass was increased by glyphosate application on four of five sites. Application of glyphosate did not increase seedling establishment planted under low moisture conditions, but it increased biomass of non-seeded plants.

Keywords: *Agropyron cristatum*, Phytomass, Seedling establishment, Non-Target species

1. Introduction

One of the most widespread alien perennial forage crops of the Northern Mixedgrass Prairie is crested wheatgrass (Agropyron cristatum (L.) Gaertn) (Henderson & Naeth 2005). The invasion of this plant species into adjacent grasslands and loss of wildlife habitat associated with its cultivation has raised concerns among ecologists (Klement, Heitschmidt & Kay 2001). Henderson and Naeth (2005) found that native C3 mid-grasses and forbs were less abundant in invaded areas. They concluded that invasions of crested wheatgrass lowered plant diversity and appeared to simplify the composition of mixed-grass prairies. Crested wheatgrass stands are also characterized by low root mass and lower C and N (Christian & Wilson 1999).

Several studies have attempted to control crested wheatgrass stands with herbicides. Bakker, Christian, Wilson and Waddington (1997) found that crested wheatgrass phytomass was reduced by approximately one third by the end of the growing season. Hansen and Wilson (2006) reported growth rates for crested wheatgrass varied greatly with water availability in a

two year study.

Restoring native species to areas planted with crested wheatgrass usually involve some form of tillage combined with herbicide application to remove vegetation which is one of the major obstacles to seedling establishment. Wilson and Gerry (1995) found that treating introduced grasses with herbicides resulted in a 20-fold increase in density of native seedlings. Tilling without herbicide application resulted in very low establishment of native seedlings. Although this study examined different levels of tillage, it did not examine the effects of no-till seeding and herbicide use. No-till seeding has been suggested as a method to reestablish native plant species into crested wheatgrass stands.

The objectives of this study were to 1) examine the effects of spring applications of 1.1 kg/ha glyphosate on crested wheatgrass phytomass 2) examine the effectiveness of using no-till seeding and glyphosate to establish native plants and 3) examine the effects of glyphosate on non-target plant species.

2. Methods and Materials

Experimental sites were established at five locations in eastern and central Montana to test treatment effects on a variety of soil, climate, and vegetation types. Conditions at these sites are representative of many crested wheatgrass fields the Bureau of Land Management (BLM) manages in Montana.

2.1 Sites

Four former homestead sites near Christina, Jens, Keltner, and Whitney, MT were planted with crested wheatgrass and returned to the BLM under the Bankhead-Jones Land Utilization Act during the drought of the 1930s. These sites were also part of large grazing allotments prior to and during this study. The characteristic vegetation for these sites is western (Pascopyrum smithii (Rydb.) Löve) and bluebunch (Pseudoroegneria spicata (Pursh) Scribn. & Smith) wheatgrasses, green needlegrass (Nassella viridula (Trin.) Barkworth), and needle-and-thread grass (Stipa comata Trin. & Rupr.) (United States Department of Agriculture – Natural Resource Conservation Service (USDA-NRCS) 1988 and USDA-NRCS 1996).

Christina (47° 24’ N, 109° 17’ W; elev. 1125m) is located 10 km northeast of Christina, Montana on a level terrace above Arnell Creek. This is part of a summer use pasture and is surrounded by native vegetation. The soil type is Linnet clay loam, 2 to 8% slope (fine-montmorillonitic Usteric Argiboroll, USDA-NRCS 1988). The resident vegetation is crested wheatgrass with bluegrasses (Poa spp. L.), western wheatgrass, junegrass (Koeleria macrantha (Ledeb.) J. A. Schultes), and a variety of other grasses and forbs; clubmoss (Selaginella densa Rydb.) forms a dense groundcover in places. This site received 195 mm of precipitation in 2002 and 2003 which was 1% lower than the 50 year average.

Jens (46° 40’ N, 105° 15’ W; elev. 790m) is located 13 km south of Terry, Montana, near the Jens Ranch on a flat terrace above the Powder River. Plots are approximately 100 m from dryland grain fields. The soil type is Degrand loam 0 to 4% slope (fine-loamy over

sandy-skeletal, mixed Aridic Argiboroll, USDA-NRCS 1996). The resident vegetation is dominated by crested wheatgrass with sand dropseed (Sporobolus cryptandrus (Torrey) A. Gray), Japanese brome (Bromus japonicus Thunb.), and green sagewort (Artemisia dracunculus L.). The Jens site averaged 152 mm precipitation per year in 2002 and 2003, which was 30% above the 50 year average.

Keltner (47° 00' N, 105° 37' W; elev. 855m) is located 30 km northwest of Terry, near the Keltner Ranch on a flat bench over the Homestead reservoir. This site is part of a 5,500 ha pasture and is surrounded by native prairie. The soil type is Subwell-Peerless loam, 0 to 4% slope (loamy-skeletal, mixed Typic Haploboroll). The resident vegetation is crested wheatgrass with needle-and-thread grass and silver sagebrush (Artemisia cana ssp. cana Pursh). The fifty year annual precipitation average for this area is 163 mm (United States Department of Commerce 2003). In 2002 and 2003, this site averaged 169 mm of precipitation per year in 2002 and 2003.

Loma (47° 53' N, 110° 32' W; elev. 825 m) is located 3 km southeast of Loma, Montana on a level terrace overlooking the Missouri River. This site is approximately 1 km downwind of dryland grain fields. The soil type is Fortbenton – Chinook fine sandy loam, 0 to 6% slope (fine-loamy, mixed Aridic Haploboroll). Characteristic vegetation for this soil type is prairie sandreed (Calamovilfa longifolia (Hook.) Scribn.), needle-and-thread grass, western wheatgrass and Indian ricegrass (Achnatherum hymenoides (Roemer & J.A. Schultes) Barkworth) (USDA-NRCS 2001). The resident vegetation is crested wheatgrass and alfalfa with annual weeds such as cheatgrass (Bromus tectorum L.), kochia (Kochia scoparia (L.) Schrad.), Russian thistle (Salsola iberica Sennen), and sunflower (Helianthus annuus L.). The stand at this site is much younger than the other sites. It was not grazed, but it was burned by the BLM in 1996 to remove accumulated fuels. From 2002 to 2003, this site averaged 118 mm of precipitation per year. This was 27% below the 50 year average.

Whitney (46° 44' N, 105° 01' W; elev. 780m) is located 22 km south of Fallon, Montana, in rolling hills between Whitney and O'Fallon Creeks, approximately 200 m from dryland grain fields. The soil type is Flowree silt loam, 0 to 6% slope (fine-silty, mixed Aridic Haploboroll, USDA-NRCS 1996). The resident vegetation is crested wheatgrass with a large component of mixed blue grama (Bouteloua gracilis (H.B.K.) Lag. Ex stuud.) and buffalograss (Buchloe dactyloides (Nutt.) Engelm.), which covers approximately 50-60% of the site, bluegrasses, junegrass, needle-and-thread grass, and a variety of forbs. Whitney averaged 162 mm precipitation per year in 2002 and 2003. This was 8% above the 150 mm per year average for the past 50 years.

2.2 Experimental Design

The initial experimental design at all sites was a randomized complete block with four treatments and four replications. The dimensions of each plot were 36 m x 36 m, surrounded by a 2 m wide buffer strip. Individual plots were experimental units.

The treatments were: (1) control, (2) application of glyphosate in spring 2002 only, (3) spring application of glyphosate and planted with native cool-season grass and forb mixtures in

spring 2002, and (4) spring application of glyphosate and planted with native cool-season grass and forb mixtures in fall 2002.

Site by treatment interactions for crested wheatgrass biomass and seeded species biomass were tested with two-way ANOVA and found to be significant (P>0.10). Therefore, data are presented by site for all variables. Within each site the following model was used for crested wheatgrass biomass and seedling biomass: Y = general mean + planting treatment + replication + residual error. Residual error (12 d.f.) was used as the testing term. Mean separations were tested using the Student-Newman-Keuls test at P=0.10 when treatment differences were indicated by ANOVA.

2.3 Spray Treatments

All plots except the control were treated with Roundup Ultra® (glyphosate) applied at 1.1 kg active ingredient (a.i.) ha-1 in early spring 2002 when the crested wheatgrass was 8 to 10 cm tall and most native species had not yet emerged. The glyphosate was applied by spray truck in 100 L of water ha-1. An inert blue dye was used to mark treated areas and no site received precipitation within two days after treatment. Dates of treatment varied from 30 April to 30 May.

In 2003, the glyphosate-treated plots were each split into two 18 x 36 m halves and herbicide was applied to one half again in April 2003, using the same method as in 2002, to control any crested wheatgrass regrowth or emergence. Following this treatment, the 18 x 36 m split-plot was used as the experimental unit except for control plots, since they were not sprayed. Split-plot data is referred to as treated once (1X) for split-plots treated only in 2002 and treated twice (2X) for split-plots treated in 2002 and 2003.

2.4 Planting Treatments

The spring-planted mixes were planted 14 to 21 days after the first glyphosate application, at a depth of 2 cm, with a Truax™ no-till drill designed for native seed mixes. All sites were fenced with barbed wire to exclude cattle for the duration of the trials. The cool season seed mix contained 100% cool season species. Each seed mix contained eight grasses and one or two forbs. Selected species were either characteristic vegetation for tested soil types or fast-growing, adaptable species that could compete well with crested wheatgrass in a variety of climate conditions. The large number of species included reflects different soil and climate types between sites.

The fall-planted cool season-mix was planted after air temperatures dropped below freezing during the day but before the ground froze. Planting dates ranged from 8 October through 7 November 2002.

2.5 Sampling

In August 2003, biomass samples of each species were collected. Five 0.25 m ^{2}quadrats were clipped in each 18 x 36 m plot or in 36 x 36m in control plots. All samples were oven dried for a minimum of 48 hrs. at 50 ° C and weighed. Biomass of crested wheatgrass, seeded species, and non-target species samples were totaled for each plot and converted to g m-2.

3. Results and Discussion

Application of 1.1 kg/ha of glyphosate once in the spring (1x) reduced crested wheatgrass biomass on four of five sites. Application of glyphosate for a second year (2X), at the same rate within site, reduced (P=0.10) biomass (Table 1) across all sites compared to controls, but only reduced phytomass on two sites compared to 1X treatments.. These results are consistent with Gobin (1994), who found a 77% reduction and Bakker, Christian, Wilson and Waddington (1997) who reported a 26 to 70% reduction.

Table 1. Crested wheatgrass phytomass (g/m2) response to no glyphosate application (Control), glyphosate applied once (1X/2002) and glyphosate applied for two consecutive years (2X/2002 and 2003) from five locations in Montana.

	Site				
Treatment/year	Christina	Jens	Keltner	Loma	Whitney
Control/2003	34[a]	65[a]	116[a]	92[a]	78[a]
Spray (1X)/2002	2[b]	9[b]	81[b]	96[a]	7[b]
Spray (2X)/2002 & 2003	0[b]	1[b]	7[c]	1[b]	1[b]

Spray treatments compared to Controls within site due to site x treatment interaction (P=0.04)

Numbers with different letters in the same column differ (P=0.10).

Seeded species biomass, recorded one year after planting, was very low due to poor soil moisture (Table 2). There were no differences between 1X or 2X glyphosate applications on all sites. This supports the theory that moisture was the limiting factor to seedling establishment on four of five sites. May precipitation was 25 to 50% below the 50 year average at all sites.

Table 2. Phytomass (g/m^2) of spring planted cool season plantings with glyphosate applied season seedlings for one year (1X) and two years (2X) at five locations in Montana, USA.

	Christina		Jens		Keltner		Loma		Whitney	
	1X	2X	1X	2X	1X	2X	1X	2X	1X	2X
Spring Cool Season	0	0	0	0	24	16	0	0	0	0
Fall Cool Season	2	0	0	0	1	3	0	0	0	0

No differences (P=0.10) between seeding mixes or spray treatments (1X or 2X) were detected.

Non-target plant species biomass was increased (P=0.10) with the spring applications of glyphosate in 2002 on two of five sites (Table 3). Spraying for a second year (2X) failed to increase non-target production above the 1X level on any site. Consecutive year application (2X) damaged C3 native grasses at Christina, Jens and Keltner. One application of glyphosate could do more to increase plant species composition during low moisture conditions than no-till reseeding. Glyphosate application shifted species dominance in crested wheatgrass stands toward C4 native grasses such as blue grama or weedy species depending on initial stand composition. Stands prone to weed infestation should not be treated with glyphosate.

Table 3. 2003 non-target species biomass (g/m^2) after spring application of glyphosate in 2002 (1X) or 2002 and 2003 (2X) in Montana.

	Site				
Treatment/year	Christina	Jens	Keltner	Loma	Whitney
Control	61	9[a]	6[a]	11	69
Spray (1X)	188	95[b]	167[b]	30	123
Spray (2X)	111	88[b]	59[b]	-	117

Values with different letters within the same columns differ (P=0.10).

4. Conclusions and Implications

Applying glyphosate was effective at reducing the phytomass of crested wheatgrass and increasing the biomass of native species if applied at the correct stage of crested wheatgrass growth. Application should be done before desirable species emerge for most effective treatment. Additional glyphosate application one year after planting damaged cool season planted species. Glyphosate application shifted the dominance in the stands toward native species or weedy species, depending on the plant and seedbank composition, by releasing those species from competition with the crested wheatgrass. The success of glyphosate application is dependent on the initial composition of the stand and the timing of application.

No-till seeding was not successful, due to lack of moisture. This method of seeding is not recommended unless there is sufficient moisture (>60 cm moist soil) in the soil at the time of seeding to support seedling growth. Application of glyphosate to remove competition of crested wheatgrass with seedlings was not successful when moisture was limiting. Seeding can be avoided when native species comprise a portion of the stand, weed infestation potential is low, and glyphosate is applied to rapidly growing crested wheatgrass while native species are dormant.

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