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Western Snowberry Response to Fire and Goat Browsing[1,2]

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Summary

Managers of pastures in the northern tallgrass prairie region are faced with incomplete control of aggressive woody plant species, such as western snowberry (*Symphoricarpus occidentalis* Hook.) due to its high sprouting ability after fire or mowing and the reluctance of managers to use herbicides, which may harm desirable plant species. The objective of this study was to compare western snowberry response to fire and browsing by goats. The study was conducted from 2002 through 2006 at South Dakota State University's Oak Lake Field Station in eastern South Dakota. Small, fenced plots of native-prairie vegetation infested with western snowberry were established on burned (fall 2001) and unburned (>30 years) sites and grazed by goats for three to five days in late June. Western snowberry foliar cover, plant height, stem density and seed production were measured each year. Annual goat browsing in late June reduced western snowberry plant height and seed production in burned and unburned sites, but did not change foliar cover. Fire also reduced plant height and seed production. Stem density remained unchanged after four years of annual goat browsing or five years post fire and was unchanged in controls. Reducing nuisance, resprouting, woody species, such as western snowberry, in grasslands is difficult, but annual goat browsing and/or combination with frequent fire (<4 years) can alter canopy structure and seed production.

Key words: Browse, Goats, Prescribed Fire, Weeds, Woody Plants

Introduction

Western snowberry (*Symphoricarpos occidentalis* Hook.) is widely distributed from Ontario to western Provinces in Canada, south to northern Missouri and west through Okalahoma, New Mexico, Utah and Washington in the United States (Johnson and Larson, 1999; Pelton, 1953). Pastureland and native prairie in the eastern Great Plains can be invaded by western snowberry, a perennial woody shrub with an expansive root system that forms dense colonies up to 200 m in diameter (Pelton, 1953). High density western snowberry infestations can severely limit grass understory growth by reducing nitrogen availability (Wilson, 2000). Weaver and Fitzpatrick (1934) found that Kentucky bluegrass (*Poa pratensis L.*) was one of the last species to die out under its canopy. Reports of local, high-density infestations, as a result of cattle not being effective in controlling western snowberry, gave rise to suggested alternative control strategies, such as the use of herbicides, mowing or browsing (Bailey et al., 1990). Our observations from the Oak Lake Field Station in eastern South Dakota and others elsewhere (Aldous, 1934; Anderson and Bailey, 1979; Fitzgerald and Bailey, 1984; Pelton, 1953) have shown that western snowberry readily resprouts after mowing or prescribed burning.

The use of grazing animals in providing biological control of unwanted vegetation has been shown to be favored over the use of herbicides, biological control by insects or pathogens, and prescribed burning (Wagner et al., 1998). Costs of herbicides and concerns over environmental safety have made biological control by grazing of some unwanted woody species an attractive alternative (Magadlela et al., 1995). Cattle have generally not been effective in reducing western snowberry stem density (Bailey et al., 1990; Fitzgerald and Bailey, 1984). Goat browsing has been an effective, low-cost alternative to herbicides for controlling multiflora rose (*Rosa multiflora* Thumb.) in hill land pasture of the Appalachian region (Luginbuhl et al., 1999) and in reducing brush regrowth in fuelbreaks in California chaparral (Green and Newell, 1982). In Kansas, goats have been successful in reducing stem density and biomass of sericea lespedeza [*Lespedeza cuneata* (Dum.-Cours.) Don], an aggressive herbaceous to near-woody perennial plant that invades disturbed sites (Mayo, 2002). Previous research has shown that goats will readily browse western snowberry (Smart et al., 2006). However, research is lacking on the combined effects of prescribed burning and goat browsing on western snowberry in the tallgrass prairie. The objective of this study was to evaluate the effects of fire and goat browsing on western snowberry cover, plant height, stem density and seed production.

Materials and Methods

Study site

The study was conducted from 2002 through 2006 at the South Dakota State University Oak Lake Field Station (230 ha), approximately 5.5 km south of Astoria, South Dakota, in the northern tallgrass prairie. Climate is continental with cold, dry winters and wet, hot summers. Average annual precipitation is 582 mm (1995-2004) (USDC, 2006). Soils are of the Buse-Laghei complex (Fine-loamy, mixed udic calciborolls). Dominant vegetation is composed of cool-season grasses, such as Kentucky bluegrass, smooth bromegrass (*Bromus inermis* Leyss.), and green needlegrass [*Nassella viridula* (Trin.) Barkworth]; warm-season grasses such as big bluestem (*Andropogon gerardii* Vitman), sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], and prairie dropseed (*Sporobolus heterolepis* A. Gray); and forbs such as goldenrod (*Solidago* spp.) species, wild bergamot (*Monarda fistulosa* L.), aster species (*Aster* spp.), and minor amounts of thistle species (*Cirsium* spp.). In September 2001, a prescribed burn was conducted on upland prairie sites infested with western snowberry. The Oak Lake Field Station generally uses a fire return interval of two to four years as part of their prairie management strategy. Plots established on unburned sites had not been burned for > 30 years.

Experimental design

In April 2002, five experimental paddocks, 89 m^2, were established on upland prairie sites infested with western snowberry. Two paddocks were allotted to sites that were unburned and three paddocks were allotted to the sites that were burned the previous fall. Fifteen mature 'Spanish' female goats weighing approximately 45 kg each were randomly assigned to the five paddocks, three goats in each paddock. Paddocks were constructed using two 5 m cattle panels on each side. Browsing was conducted for three to five days in late June of 2002, 2003, 2004 and 2005 at the time of flowering. The browsing period was based on an appropriate stocking rate that would achieve approximately 50 percent utilization of herbaceous and current years' growth of woody vegetation. Removal of goats from experimental paddocks was contingent on visual inspection of the targeted utilization. Prior to the allotment of experimental paddocks, goats were pastured where they had access to grass and brush vegetation. Stocking rate ranged from 4.5 to 5.6 animal unit months (AUM) ha^{-1}. One AUM equals the amount of oven-dry forage required by one animal unit (454 kg) for a standardized period of 30 days (Bedell, 1998). Stocking rates used in this study were typical of those suggested for eastern South Dakota (Albee et al., 1948). Three control plots, 25 m^2, were established on each site adjacent to experimental paddocks. The experimental design was a completely randomized design with pasture considered the experimental unit. The treatment design was a 2 x 2 factorial with two sites (unburned vs burned) and two browsing treatments (browse vs control).

Vegetation measurements

Foliar cover of western snowberry was visually estimated in 0.25 m^2 quadrats from four to five quadrats approximately 1 m apart along three to five 9-m long transects for a total of 15 to 20 samples in each paddock before each grazing period. Visual estimates were made by a single observer each year. Western snowberry plant height measured from the soil surface to the last extended leaf was estimated from 75 to 100 samples by randomly choosing five plants within each 0.25 m^2 quadrat. Stem density of western snowberry was estimated by counting the number of living stems in each quadrat. Cover of western snowberry plants with seed set was visually estimated in October 2002 and October 2003 using the same procedure to estimate foliar cover.

Statistical analysis

The analyses were computed using PROC MIXED (SAS, 2006) with site and treatment as a 2 x 2 factorial and

Table 1. Western snowberry cover, height, and stem density followed by standard deviations in parenthesis measured in late June 2002 prior to goat browsing at the Oak Lake Field Station near Astoria, SD.

Site	Treatment	Cover	Height	Stem density
		--- % ---	--- cm ---	--- No. m^{-2} ---
Unburn	Browse	29 (2.7)	54 (10.7)	62 (7.2)
Unburn	Control	21 (2.8)	47 (4.1)	37 (8.6)
Burn	Browse	12 (5.5)	29 (1.5)	37 (17.1)
Burn	Control	12 (5.7)	34 (1.7)	33 (17.1)

years as a repeated measure. Western snowberry cover, height, and stem density means were calculated for each site and treatment by year and were standardized by subtracting the means calculated in 2002 (Table 1). The autoregressive 1 model (SAS, 2006) was used to adequately account for error correlation among years for western snowberry cover, height, and stem density. Percentage cover of western snowberry plants with seed means were calculated for site and treatment in 2002 and 2003. The compound symmetry model (SAS, 2006) was used to adequately account for error correlation among years. Least squares means were separated using the PDIFF option (SAS, 2006) and considered statistically significant at the 0.10 probability level.

Results and Discussion

Cover

Goat browsing or no browsing (control) in late June 2002, 2003, 2004 and 2005 on sites differing in burn history, unburned (>30 years) or burned (fall 2001), resulted in no significant differences ($P = 0.902$) in western snowberry cover. There was a significant ($P = 0.006$) quadratic response in cover between years (Fig. 1) which indicates that climatic influences (Table 2) are important drivers in foliar cover expression. Since western snowberry is a cool-season shrub, cool temperatures and above normal precipitation would favor leaf and twig growth in May and June. This was the case in 2003 and 2004 compared with 2005 and 2006 (Table 2) and is consistent with foliar cover responses in Figure 1. Similar cover resulting from browsing in the burned and unburned sites may be related to stimulated changes in canopy structure (stem density, plant height, and stem branching). Pelton (1953) described the age distribution of stems from two western snowberry colonies in Minnesota that were recently burned (<6 years) and unburned (>13 years). The recently burned colony had a high proportion of stems that were > 4 years old, while the unburned colony had a skewed distribution of younger stems to fewer, older stems up to 13 years old (Pelton, 1953). We observed older western snowberry plants from the unburned sites to have leaf foliage concentrated in the upper branches of the plant. Perhaps, goats stimulated "leafing out" from buds lower in the canopy by their browsing of the upper portions. Xu (1998) demonstrated this effect through moderate and heavy clipping of planeleaf willow (Salix planifolia var. planifolia Prush), which produced more leaf and twig biomass than unclipped or lightly clipped plants.

Plant height

Western snowberry plant height was inconsistent over years between site and treatment as indicated by a significant ($P = 0.099$) year x site x treatment interaction (Fig. 2). Western snowberry plant height in burned-control plots linearly increased ($P = 0.086$) over years compared to annual goat browsing, which maintained a lower plant height (Fig. 2A). The opposite occurred in the unburned site, where plant height in control plots remained unchanged compared to a significant linear decrease ($P = 0.045$) in the browsed plots (Fig. 2B). This was most likely a result of the older, unburned-controls being at a long-term equilibrium, since it had not been disturbed for >30 years compared to the burned-controls (Fig. 2C). Goat browsing reduced plant height in unburned sites because they removed the upper portion of the plant canopy, while in the burned sites, stems were younger and actively recovering from the 2001 fire (Fig. 2D). Our results (Fig. 2A) support observations by Pelton (1953) and Anderson and Bailey (1979) that western snowberry plant height returns to control levels after a few years following a disturbance, such as burning. Pelton (1953) observed an average stem height of 75 cm for 20 locations in Minnesota, which ranged from 40 to 110 cm. Our sites tended to be closer to 40 cm (Table 1). In Canada, Bailey et al. (1990) reported after five seasons of cattle grazing in early to mid-June, plant height was reduced by 30 cm in grazed treatments. Their greater reduction (30 cm vs 11 cm in our study) could be related to larger grazing animals (cattle vs goats) causing more trampling and stem breakage at similar stocking rates.

Figure 1. Western snowberry cover difference from 2002 with standard errors bars averaged across site and treatment for 2003-2006 ($P = 0.005$) at the Oak Lake Field Station near Astoria, SD.

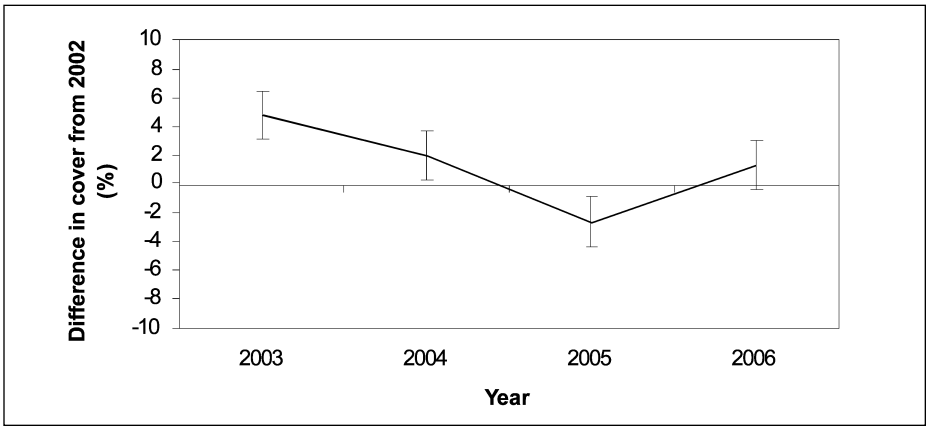


Table 2. Mean monthly temperature (°C) and total monthly precipitation (mm) for the Oak Lake Field Station during April through August 2003-2006 (USDC, 2006).

	Year				
Month	2003	2004	2005	2006	30-yr mean
		Mean Monthly Temperature			
		°C			
Apr	8	8	9	9	7
May	12	12	12	14	14
Jun	17	16	20	19	19
Jul	21	20	22	23	22
Aug	22	17	20	21	20
Sep	14	17	18	13	15
		Precipitation			
		mm			
Apr	38	40	44	73	68
May	124	162	125	53	92
Jun	85	109	160	60	109
Jul	80	65	76	4	99
Aug	27	58	66	177	85
Sep	105	125	208	153	53
Annual	492	635	833	572	685

Stem density

Stem density of western snowberry was inconsistent over years between site and treatment as indicated by a significant (P=0.047) year x site x treatment interaction (Fig. 3). Changes in stem density between the browse and control treatments in burned sites were consistent and not significant over time (Fig. 3A), while the browse and control treatments in the unburned sites often had opposite responses or inconsistent changes in magnitude in stem density over years (Fig. 3B). In the absence of goat browsing, the stem density was significantly greater in unburned than in burned sites (Fig. 3C) and most likely was related to the difference in past disturbance history (years since last fire). After four years with goat browsing, with or without recent burning, stem density was higher in the unburned sites compared to the burned sites (Fig. 3D). Several researchers have demonstrated that western snowberry stems are easily killed by fire but that it resprouts readily (Anderson and Bailey, 1979, Anderson and Bailey, 1980; Pelton, 1953). In addition, the stem density after a single fire usually increases two to three times that of controls (Anderson and Bailey, 1979; Pelton, 1953). In our study, we were not able to assess the direct difference between stem density prior to the burn and one year after the burn. However, the unburned control sites had a higher stem density over time (Fig. 3C) than the burned control sites which indicates that the burn indirectly had a negative impact on stem recruitment.

Seed production

Goat browsing reduced the cover of western snowberry plants with seed similarly between burned and unburned sites, whereas the control in the unburned sites had twice ($P < 0.01$) the cover of plants with seed than the control in the burn sites (Fig. 4). Burning in fall 2001 killed the stems and in spring of 2002 the height of new stems was significantly less than the unburned sites (Fig. 3B). Therefore, the difference in seed production was probably caused by a reallocation of carbohydrates toward stem development at the expense of seed production in the burned sites. Our data supports the direct relationship between plant height and the number of fruits per stem discovered by Pelton (1953). Browsing was successful in reducing seed production because the grazing period was at the time when western snowberry

Figure 2. Western snowberry plant height difference from 2002 with standard error bars for year x site x treatment interaction (P = 0.099); A) comparison of control and browse treatments in the burned sites , B) comparison of control and browse treatments in the unburned sites, C) comparison of controls, and D) comparison of browsing at the Oak Lake Field Station near Astoria, SD.

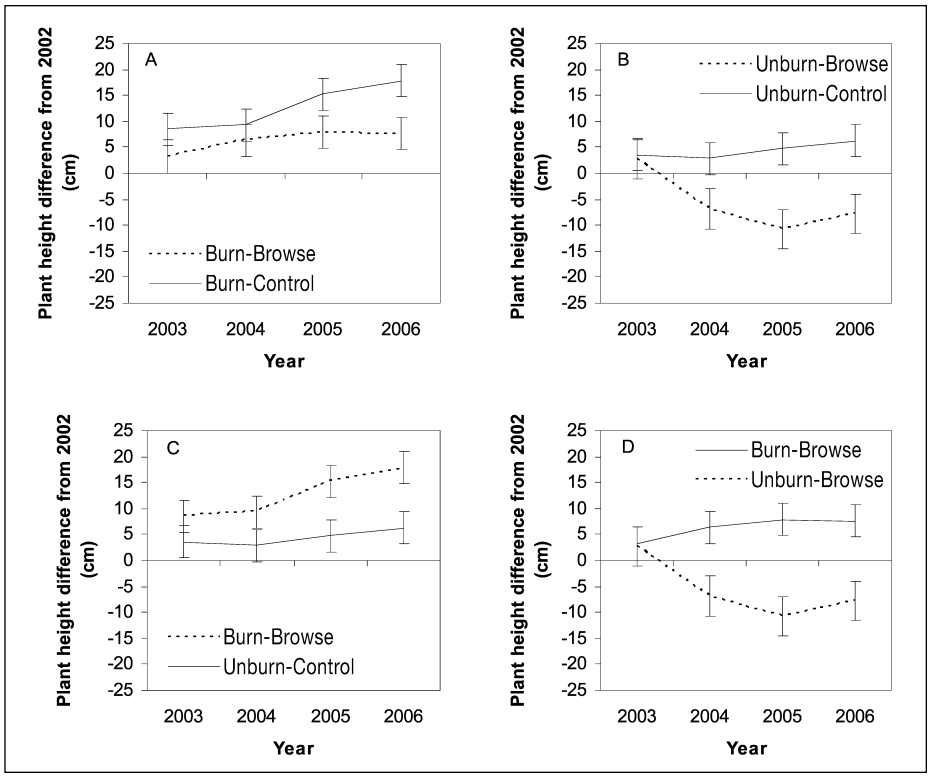
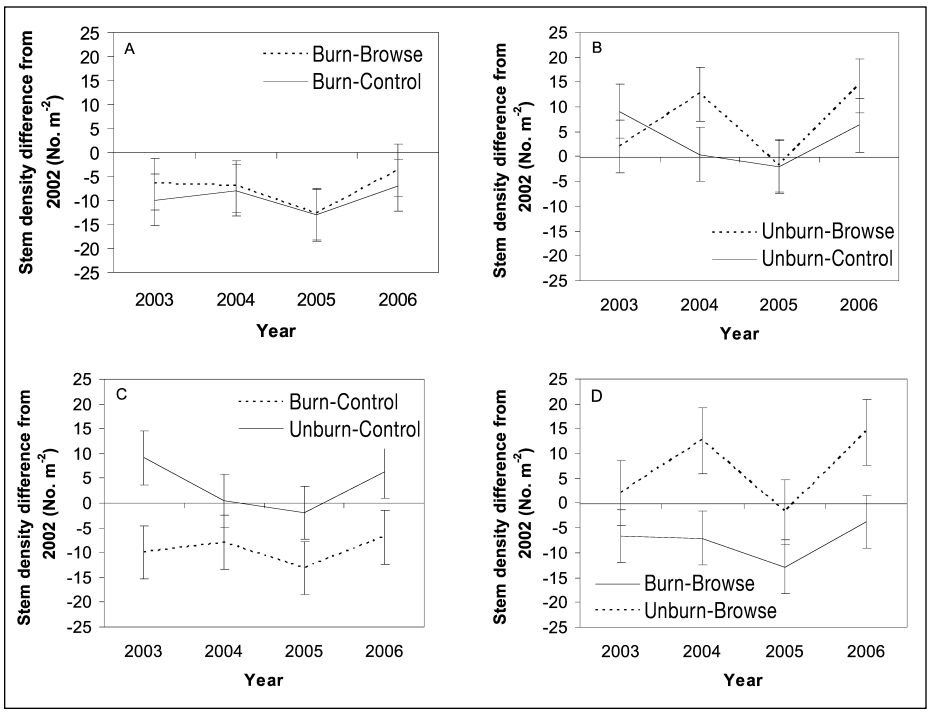


Figure 3. Western snowberry stem density difference from 2002 with standard error bars for year x site x treatment interaction ($P = 0.047$); A) comparison of control and browse treatments in the burned sites, B) comparison of control and browse treatments in the unburned sites, C) comparison of controls, and D) comparison of browsing at the Oak Lake Field Station near Astoria, SD.



was flowering and regrowth after browsing was directed toward its leaf canopy. The significance of stopping seed development probably has little direct influence on new recruitment of plants within the colony as vegetative propagation is its primary way of sustaining stem density and foliar cover (Pelton, 1953). However, stopping seed production would prevent the spread of seed by wildlife to uninfested areas.

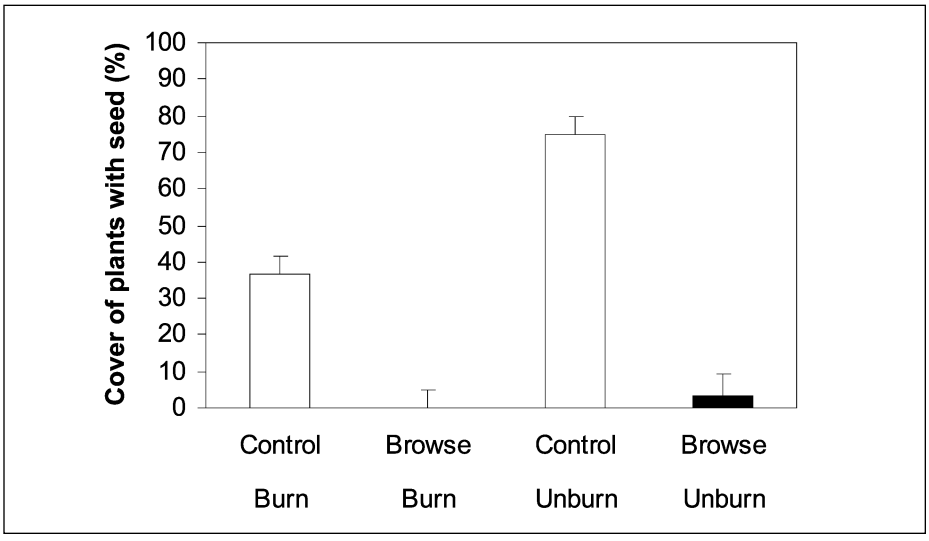
Historical perspective

In the early 1830s, explorer Joseph Nicolet documented that this region had abundant grazers, such as Bison (*Bison Bison*) and Elk (*Cervus canadensis*) and browsers, such as mule deer (*Odocoileus hemionus*), white tailed deer (*Odocoileus virginianus*) and Pronghorn (*Antilocapra americana*) (Bray and Bray, 1993). Coupled with abundant and diverse herbivores, Native Americans used burning to alter their environment to enhance the vegetation for food, basketry, weapons and wildlife manipulation (Anderson, 2005; Higgins, 1986). Since the time of settlement, fire in the northern tallgrass prairie has been suppressed and wildlife populations of browse species such as mule deer and pronghorn are virtually nonexistent. In addition, there is general consensus that western snowberry increases under overgrazing (Pelton 1953). Our data supports that reintroducing a disturbance (fire or browsing) can alter canopy structure (cover, height, density) of western snowberry. Without a disturbance, older western snowberry colonies reach an equilibrium characterized by taller, denser structure. We contend that historically (prior to European settlement) western snowberry colonies in the northern tallgrass prairie would have resembled a more shorter, less dense canopy structure like the burned-browsed paddocks.

Conclusions

Annual goat browsing in late June reduced western snowberry plant height and seed production, but resulted in no change in foliar cover. Stem density was altered by fire and browsing, with lower density reported in burned-browsed sites. Fire also reduced the plant height and seed production. Anderson and Bailey (1980) demonstrated that annual burning severely reduced western snowberry canopy cover and biomass but minimally reduced stem density. Older western snowberry colonies, such as those in our unburned sites, have not burned because of lack of adequate fuel loading to carry a fire. Pretreatments, such as mowing or other disturbance to open up the canopy, may be necessary. We conclude that single browsing events during the growing season were enough of a disturbance to reduce western snowberry plant height and seed production. Stem density was reduced by a combination of fire and grazing, however single grazing events alone actually stimulated western snowberry stem density in infested grasslands.

Figure 4. Cover of western snowberry plants with seed and standard error bars for site x treatment interaction ($P = 0.013$) averaged over fall 2002 and 2003 at the Oak Lake Field Station near Astoria, SD.



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