2004

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BEEF 2004 – 18

Summary

The occurrence of naturalized yellow-flowered alfalfa on private and adjacent public rangeland in northwestern South Dakota presents a dilemma. Its ability to reproduce naturally in native rangeland demonstrates its value for rehabilitating severely depleted rangelands and increasing forage production and quality, soil carbon and soil nitrogen levels. On the other hand, the spread of alfalfa into native rangeland potentially threatens native biological diversity and may result in changes in ecological processes and functions (e.g., alteration of pools and flows of energy and nutrients). A study was initiated on the Grand River National Grassland in 2003 to determine the effects of yellow-flowered alfalfa on species richness and biomass production of native plant communities. In each of two sites, two permanent transects were established. At 2-m intervals along each transect, cover for each species was recorded in 2 x 1 m quadrats. Distinctive plant communities were identified along each permanent transect. In each, three 1.45 x 0.3 m quadrats were clipped for aboveground biomass of alfalfa and other species. Naturalized yellow-flowered alfalfa significantly decreased total species richness, native species richness, and non-alfalfa biomass, but increased introduced species richness and total biomass production when alfalfa cover exceeded 50%. Species composition of major species (frequency ≥ 50%) changed with increased alfalfa cover. The percentage of total biomass from non-alfalfa species declined from 100% to 30% when alfalfa cover increased from 0% to over 50%. Our results clearly suggest that naturalized alfalfa strongly competes with native species in suitable areas of semiarid rangelands.

Introduction

Alfalfa (*Medicago sativa* L.) is a major component of feed for dairy and beef cattle and one of the most productive forage species in North America. Introducing alfalfa through interseeding has been shown to be an efficient approach to increase forage production and animal output in semiarid regions (Lorenz 1982, Smith 1997). Alfalfa is indigenous to the Middle East and Central Asia. It evolved in continental climates with cold winters and hot, dry summers. Although alfalfa has been planted on millions of acres and more than 100 varieties have been developed over the past 100 years in North America since its introduction, incidences of alfalfa becoming naturalized in North American rangelands are extremely rare (Rumbaugh 1982). However, recently Smith (1997) described substantial benefits to animal production in response to the natural spread of a population of yellow-flowered alfalfa (*Medicago sativa ssp. falcata*) on his ranch in northwestern South Dakota. Yellow-flowered alfalfa has a natural range of adaptation up to 64º N in Siberia where climatic conditions are comparable to the northern Great Plains of the United States of America (Hansen 1909). It is more winter-hardy, more drought tolerant, and grazing tolerant than other alfalfas due to its deep-set crown and fibrous root systems (Hansen 1909, Oakley and Garver 1917, Berdahl et al. 1989). It also has a slow regrowth mechanism when grazed (Smith 1997). The occurrence of naturalized yellow-flowered alfalfa on some private lands has resulted in dramatic and welcome increases in alfalfa plant density, which has increased the production and quality of the forage, improved soil condition by increasing soil carbon and nitrogen levels without influencing nitrous oxide emissions (Schuman and Mortenson 2003, Schuman et al. 2004), and has enhanced digestibility of native species (Hess et al. 2004a, b).

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[4] The authors wish to thank the USDA Forest Service and SD Ag Exp. Station for funding this research. We also would like to thank Darla Lenz, USDA Forest Service at Bismarck, ND and the staff of the Grand River National Grasslands Office at Lemmon, SD for providing access to the research site.

Ironically, the same attributes of naturalized yellow-flowered alfalfa that would seem to make it useful for rehabilitating depleted rangelands in semiarid regions may also increase its invasive potential (Pimentel et al. 2000). Evidence for this exists in a pasture of the Grand River National Grassland (GRNG) which lies adjacent to a ranch on which yellow-flowered alfalfa has been planted, the Smith Ranch. Within about 20 years, yellow-flowered alfalfa has become naturalized on over 600 acres in the GRNG. While there is a well-developed body of knowledge to demonstrate the forage value of yellow-flowered alfalfa (Smith 1997, Boe et al. 1998), the impact of this naturalized alfalfa population on native plant communities, and its potential threat to native biological diversity are presently unknown. This lack of understanding about how naturalized alfalfa populations spread in relation to native plant communities is a critical deficiency. Until this information becomes available, it will be difficult to properly utilize and manage yellow-flowered alfalfa from the standpoint of environmental, ecological, and economic considerations. The objective of this study was to determine effects of naturalized alfalfa on species richness and biomass production of native plant communities in mixed-grass prairie.

Materials and Methods

The study was conducted on the Grand River National Grasslands in northwestern South Dakota. The grasslands of the GRNG comprise more than 161,000 acres of public lands interspersed with private lands. The topography is characterized by rolling hills, riverbreaks, and scattered buttes and badlands (Lowe 1975). The climate is semiarid with high interannual variation in precipitation and high drought frequency. Mean annual precipitation is 15.2 inches and mean annual temperature is 43 ºF. Extreme daily high and low temperature records (1916 – 1999) are 113 ºF and - 47 ºF, respectively. Vegetation is dominated by mixed-grass prairie with a variety of native species such as western wheatgrass (*Pascopyrum smithii* [Rydb.] A. Love), green needlegrass (*Stipa viridula* Trin.), threadleaf sedge (*Carex filifolia* Nutt.), blue grama (*Bouteloua gracilis* [H.B.K.] lag.ex Steud), and buffalograss (*Buchloe dactyloides* [Nutt.] Engelm). Soil types range from sandy loam on slopes and uplands to clay loam in swales and drainage areas. The densest naturalized yellow-flowered alfalfa populations were found in swales, but plants also occur frequently on slopes and infrequently on uplands. Most of the GRNG is leased to ranchers who graze cattle through the Grand River Cooperative Grazing Association.

We initiated this study in summer 2003. In June and July two sites where yellow-flowered alfalfa has been naturalized were selected and sampled. Two permanent transects were established on each site. Each transect traversed a site from the top of a side-shoulder through the swale to the top of the opposite side-shoulder. Transect lengths ranged from 108-130 m. Along each transect, the cover of each species was recorded in 2 x 1 m quadrats (cover quadrats) placed at 2 meter intervals. Distinctive plant communities along each transect were identified. Three cover quadrats within each plant community were randomly chosen and a single corresponding biomass quadrat (1.45 x 0.3 m) was established 2 m west of each of three cover quadrats. Aboveground vegetation within each biomass quadrat was clipped and sorted into two categories: alfalfa and other species. Three soil cores were collected on each clipped quadrat, separated into 0 – 6” and 6 – 12” depths, and evaluated for soil moisture and texture. Alfalfa cover values for cover quadrats were assigned to corresponding biomass quadrats.

All quadrats (n=148 cover quadrats and n=56 biomass quadrats) were assigned to one of three classes based on alfalfa cover, where Class I alfalfa cover = 0% (n=72), Class II had 0% < alfalfa cover < 50% (n=42), and Class III alfalfa cover ≥ 50% (n=34). Species richness for all plants, grass and grass-likes, forbs, native species, introduced species, perennial species, and annual species were determined for each quadrat. Data were analyzed using one-way analysis of variance with the LSMEAN procedure applied to determine significant differences between means at $P \leq 0.05$ (SAS 1990).

Results and Discussion

A total of 69 species were found in the 148 cover quadrats, including 15 grasses and grass-likes (11 cool-season species, 4 warm-season species), 51 forbs, and 3 shrubs. Total number of species was 68 in Class I, 58 in Class II, and 35 in Class III quadrats. A similar pattern (36 species for Class I, 26 for Class II, 13 for Class

III) occurred for common species (frequency of at least 10%) (Table 1). Not only did the number of species decrease but major species (defined as having a frequency of at least 50%) composition also changed with increased alfalfa cover. For example, needlegrasses, a major component in Classes I and II, were missing in Class III from the major species list. In Class III quadrats, Kentucky bluegrass, an introduced cool-season and shade tolerant species, was the primary major species associated with yellow-flowered alfalfa (Table 1).

Total species richness was not different between Classes I and II, but when alfalfa cover was greater than 50%, species richness decreased by 50% (Fig. 1A, $P < 0.0001$). Grass and grass-like, fob, perennial, and annual species richness values showed the same patterns as total species (Figs. 1B, C, F, and G; $P < 0.0001$). Notably, native species richness significantly decreased as alfalfa cover increased (Fig. 1D, $P < 0.0001$). The greatest native species richness was observed in quadrats where alfalfa was absent. When alfalfa cover exceeded 50%, 65 to 70% of the native species evident in Classes I and II were missing. This suggests that yellow-flowered alfalfa is a very strong competitor with native species on rangelands. This is likely due to its proliferating crown and more grass-like fibrous root system, which allow it to compete with native grasses and forbs for limited resources such as light, water, and nutrients. The opposite response was found for introduced species (Fig. 1E, $P < 0.0001$). The lowest introduced species richness appeared in quadrats with an alfalfa cover of 0%. When alfalfa cover increased up to 50%, introduced species richness also increased, but then significantly decreased after alfalfa cover exceeded 50%. One explanation is that improved soil nitrogen associated with nitrogen-fixing alfalfa created a favorable microenvironment for introduced species to invade. However, when alfalfa cover exceeded 50%, other species, including introduced species, were less able to compete with alfalfa for limited light, and moisture, and nutrients. In the field we noticed the most frequent associate with alfalfa was Kentucky bluegrass.

As might be expected, total biomass (all species combined) significantly increased as alfalfa cover increased. Class III total biomass was up to 261% of total biomass for Class I (Fig. 2A, $P < 0.0001$). In contrast, non-alfalfa species biomass greatly decreased (Fig. 2B, P=0.0063) when alfalfa cover was greater than 50%. Again, it is likely that non-alfalfa species were unable to compete with alfalfa when alfalfa cover was high. The non-alfalfa biomass contribution to total biomass declined from 100% to 30% as alfalfa cover increased from 0 to ≥ 50% (Fig. 2C, $P < 0.0001$).

Summary and Implications

Our study clearly demonstrated that naturalized yellow-flowered alfalfa significantly increased total biomass production on semiarid rangelands, but at the expense of species richness and native species production. The value of yellow-flowered alfalfa depends upon a manager's needs and goals, including agricultural and/or conservation perspectives. If the objective is increased forage quality and quantity and animal output, and the presence of introduced species is of little or no concern, yellow-flowered alfalfa has great promise. However, this study shows that 65 to 70% of native species may be lost from areas dominated by yellow-flowered alfalfa. Thus, if the objective is to maintain native plant species, presumably for biodiversity, long-term ecosystem stability, and/or wildlife habitat, yellow-flowered alfalfa would be far less desirable. Producers who want to accomplish both goals for multiple uses should have an appropriate management plan based on yellow-flowered alfalfa's biological characteristics and potential ecological impacts.

We should point out that most of the Class III quadrats were found in swales or drainage areas with fine soil texture and high soil moisture. Generally speaking, these areas have favorable water and nutrient conditions relative to more upland sites and are able to support higher biodiversity. Unfortunately, we do not have baseline data on the distribution and abundance of the original species assemblage in these areas before yellow-flowered alfalfa became dominant. Further work is needed to determine: 1) how yellow-flowered alfalfa spreads; 2) the factors controlling yellow-flowered alfalfa spread and establishment; and 3) how yellow-flowered alfalfa interacts with native species and native plant communities.

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Table 1. Summary of cover[a] and frequency[b] of common plant species (frequency greater than 10%) for 3 alfalfa cover classes on the Grand River National Grasslands, South Dakota

Species		Alfalfa Cover (%)					
Common Name	Scientific Name	Class I[c] (n = 72)		Class II (n = 42)		Class III (n = 34)	
		Frequency[d] (%)	Cover (%)	Frequency (%)	Cover (%)	Frequency (%)	Cover (%)
Yellow-flowered alfalfa	*Medicago sativa ssp. falcata*	0	0	100	14.39	100	78.15
Threadleaf sedge	*Carex filifolia*	**81**	24.59	**55**	5.55	12	0.15
Needlegrasses [e]	*Stipa spp.*	**75**	2.78	**81**	0.99	24	0.08
Western wheatgrass	*Pascopyrum smithii*	**71**	8.30	**62**	5.74	**56**	2.99
Common dandelion	*Taraxacum officinale*	**68**	0.62	38	0.17	24	0.08
Red goosefoot	*Chenopodium rubrum*	**61**	0.34	**76**	0.26	44	0.21
Yellow sweetclover	*Melilotus officinalis*	**51**	1.57	**67**	2.55	44	1.64
Slenderleaf collomia	*Collomia linearis*	**50**	2.42	36	0.69	12	0.07
Littlepod falseflax	*Camelina microcarpa*	44	0.10	**76**	0.25	47	0.11
Blue lettuce	*Lactuca oblongifolia*	43	0.23	21	0.33		
Prairie plantain	*Plantago elongta*	39	0.05	17	0.06	12	0.01
Blue grama	*Bouteloua gracilis*	33	0.99	29	0.52		
Crested wheatgrass	*Agropyron cristatum*	29	5.06	**62**	10.41	**56**	4.42
Desert stickseed	*Lappula occidentalis*	29	0.03	14	0.01		
Kentucky bluegrass	*Poa pratensis*	25	1.23	24	1.20	**62**	3.63
Silverleaf scurfpea	*Psoralea esculenta*	25	0.04	14	0.04		
Scarlet globlemallow	*Sphaeralcea coccinea*	25	0.51	26	0.33		
Scarlet gaura	*Gaura coccinea*	22	0.03	14	0.01		
Western yarrow	*Achillea millefolium*	21	0.90	**50**	0.80	**56**	1.01
Rush skeletonplant	Lygodesmia juncea	21	0.06				
Wavyleaf thistle	*Cirsium undulatum*	19	0.14				
Prairie sandreed	*Calalmovilfa longifolia*	18	0.40				
Lambert crazyweed	*Oxytropis lambertii*	14	0.33				
Hood's phlox	*Phlox hoodii*	14	0.05				
Cudweed sagewort	*Artemisia ludovisiana*	13	1.27				
Rough false pennyroyal	*Hedeoma hispdium*	13	0.01				
Penstemon	*Penstemon spp.*	13	0.02	12	0.03		
Fringed sagewort	*Artemisia frigida*	11	0.28	19	0.24		
Japanese brome	*Bromus japonica*	11	0.06	26	0.05		
Waterpod	*Ellysia nyctelea*	11	0.08				
Sixweeks fescue	*Fescue octoflora*	11	0.02				
Stemless hymenoxys	*Hymenoxys acaulis*	11	0.12				
Fragile pricklypear	*Opuntia fragilis*	11	0.04				
Textile onion	*Allium textile*	10	0.01				
Tansymustard	*Descurainia pinnata*	10	0.08				
Wild buckwheat	*Eriogonum flavum*	10	0.01				
Dotted gayfeather	*Liatris punctata*	10	0.05				
Yellow salsify	*Tragopogon dubius*			19	0.04		
Inland saltgrass	*Distichlis spicata*			12	0.40		
Buffalograss	*Buchloe dactyloides*			12	0.50		
Woolly indianwheat	*Plantago patagonica*			14	0.04		

[a] Cover is the mean percent cover for all quadrats in the same class in which a species occurs.
[b] Frequency is the percent of quadrats in the same class in which a species occurs.
[c] Class I cover = 0%, for Class II 0% < cover < 50%, for Class III cover ≥50%.
[d] Bold number indicates the frequency of non-alfalfa species greater than 50%.
[e] Includes green needlegrass (*Stipa viridula*), needleandthread (*Stipa comata*), and porcupine grass (*Stipa spareta*).

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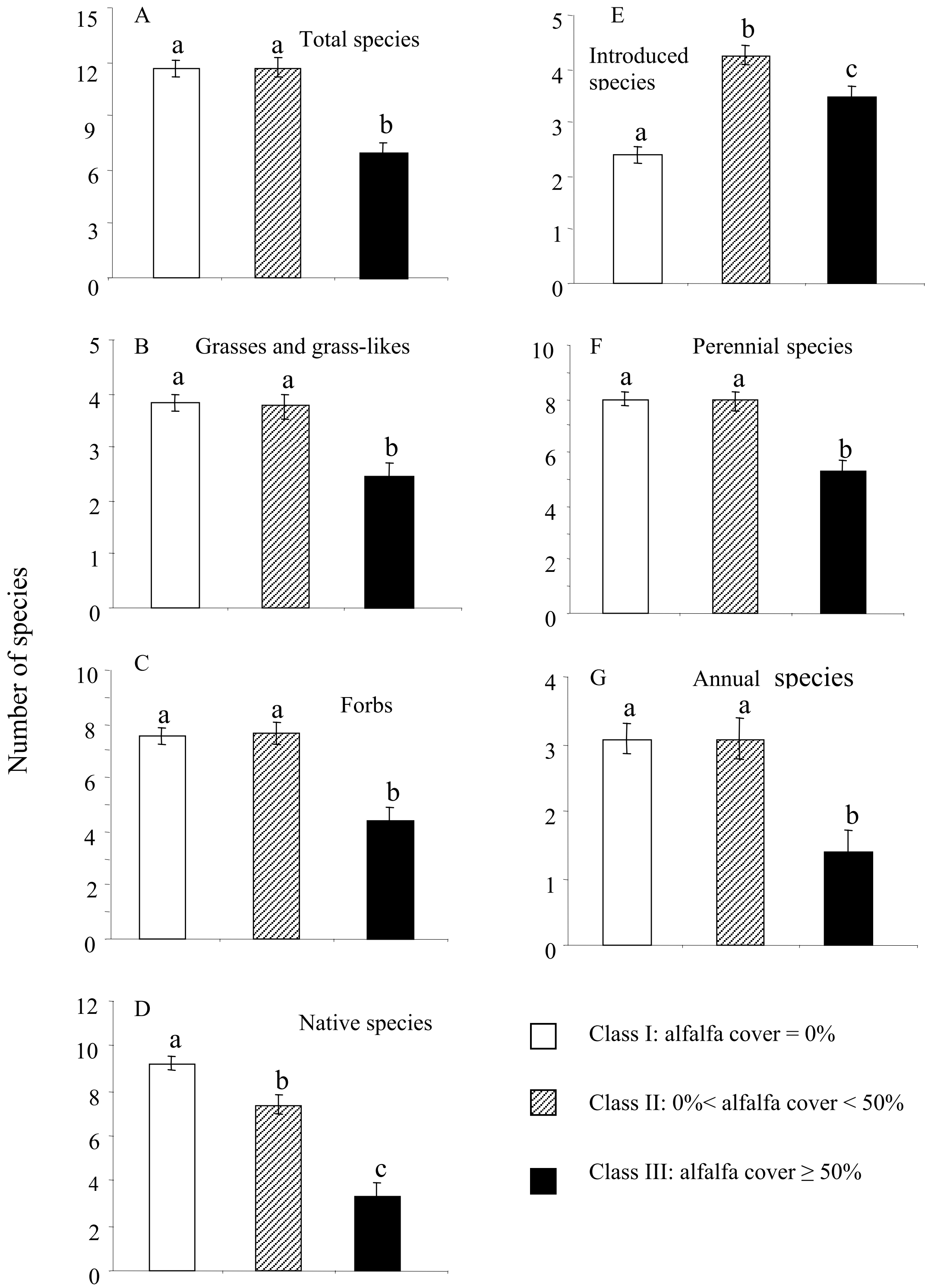

Figure 1. Effects of percentage cover of naturalized yellow-flowered alfalfa on species richness of native plant communities in mixed-grass prairie for A) total species, B) grasses and grass-likes, C) forbs, D) native species, E) introduced species, F) perennial species, and G) annual species. Bars with different letters represent a significant difference at $P \leq 0.05$.

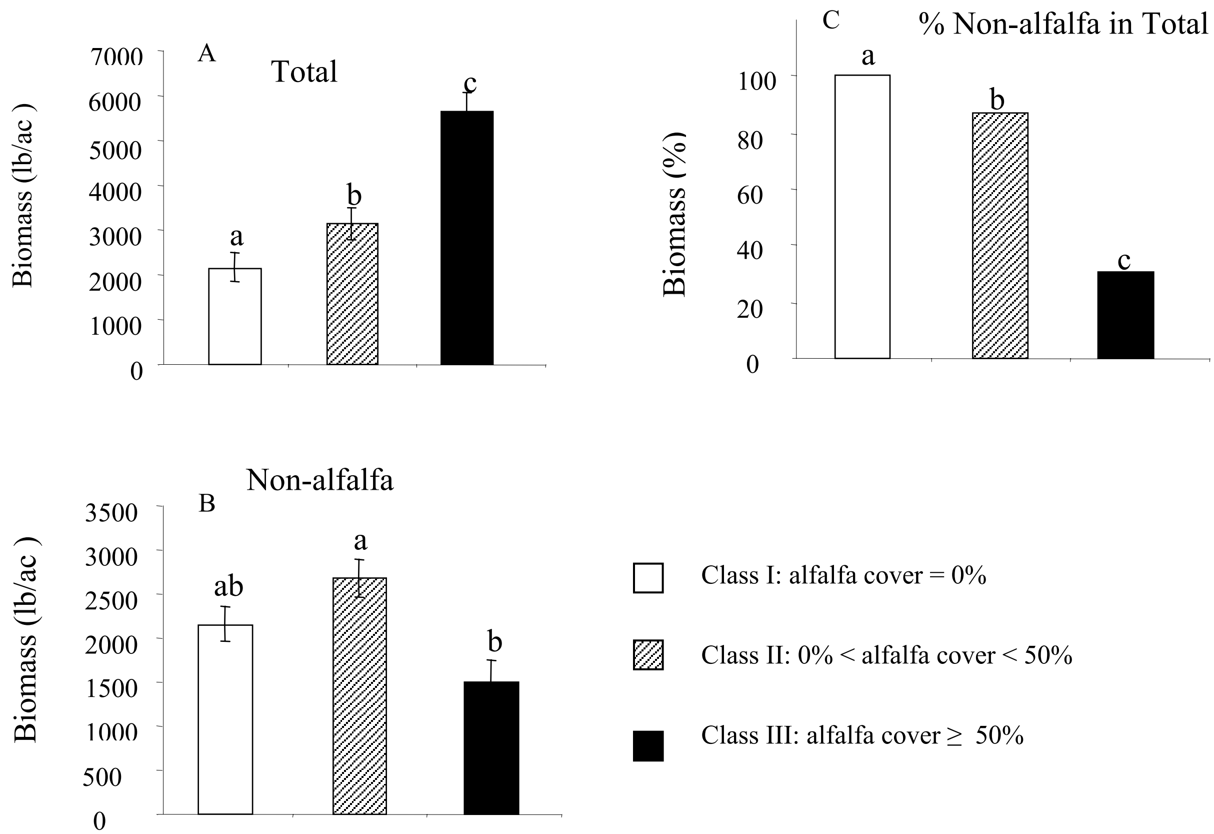

Figure 2. Effects of percentage cover of naturalized yellow-flowered alfalfa on A) total biomass, B) non-alfalfa biomass, and C) percentage of total biomass from non-alfalfa species on the Grand River National Grassland. Bars with different letters represent a significant difference at $P \leq 0.05$.