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Natural Succession Impeded by Smooth Brome (*Bromus inermis*) and Intermediate Wheatgrass (*Agropyron intermedium*) in an Abandoned Agricultural Field

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Abstract

In 1975, an abandoned agricultural field at Rocky Flats Environmental Technology Site (Site) that had been cultivated for more than 38 years, was seeded with smooth brome (*Bromus inermis*) and intermediate wheatgrass (*Agropyron intermedium*). Although these species are commonly planted in reclamation and roadside seed mixtures, few studies have documented their impact on the re-establishment of native plant communities. In 1994, species richness, cover, and biomass were sampled in the agricultural field and compared to the surrounding mixed-grass prairie at the Site. The agricultural field contained only 61 plant species (62% native), compared to 143 species (81% native) in the surrounding mixed-grass prairie. Community similarity based on species presence/absence was 0.47 (Sorensen coefficient of similarity). Basal vegetative cover was 11.2% in the agricultural field and 29.1% in the mixed-grass prairie. Smooth brome and intermediate wheatgrass accounted for 93% of the relative foliar cover and 96% of the biomass in the agricultural field. The aggressive nature of these two planted species has impeded the natural succession of the agricultural field to a more native prairie community. Studies of natural succession on abandoned fields and roads in northeastern Colorado have indicated that if left alone, fields would return to their native climax state in approximately 50 years and would be approaching their native state after 20–25 years. Based on the results of this study, this agricultural field may take more than 100 years to return to a native mixed-grass prairie state and it may never achieve a native state without human intervention.

Key Words: *Bromus inermis*, *Agropyron intermedium*, succession, exotic plant species, reclamation.

Introduction

The loss of native plant communities and biodiversity around the world continues at an alarming rate, with land rapidly being developed and transformed by human needs and desires (ESA, 1997). While much of this loss is a direct result of habitat destruction, the degradation and loss of native plant communities resulting from invasions of aggressive, non-native plant species has become an increasingly important issue for resource managers, ecologists, naturalists, and others involved in the preservation of natural areas (Wilson and Belcher, 1989; Romo and Grilz, 1990; Grilz and Romo, 1994). The planting of non-native graminoid species such as smooth brome (*Bromus inermis*), crested wheatgrass (*Agropyron cristatum*), intermediate wheatgrass (*Agropyron intermedium*), and others, as forage enhancement for overgrazed rangelands and for revegetation of roadsides and disturbed areas, has highly altered the native plant communities once present (Wilson, 1989). Sather (1988) outlined the threats posed by smooth brome being used as a revegetation species, and others have reported on its invasive, aggressive ability to dominate plant communities, often replacing the native species (Wilson, 1989; Blankespoor and Larson, 1994; Grilz and Romo, 1994). While some studies have examined the effect of these non-native species on the native plant communities over a few years (Wilson and Belcher, 1989; Wilson, 1989), few have documented the long-term impact of areas seeded with these non-native species with regard to the re-establishment or successional return of native plant communities. This study examined the differences in species richness, foliar and basal cover, and biomass between a mesic mixed-grass prairie and an abandoned agricultural field that was reseeded approximately 20 years previously with smooth brome and intermediate wheatgrass.

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Methods

Study Site

The study was conducted at the U.S. Department of Energy's (DOE) Rocky Flats Environmental Technology Site (Site). The Site is located on the Colorado Piedmont, east of the Front Range, between Boulder and Golden, approximately 25 km (16 miles) northwest of Denver (39°53'N, 105°11'W, 1810 m). From the early 1950s until 1989, the primary mission of the Site was the production of nuclear weapons components. After production ceased, Site personnel shifted their focus to cleanup and closure. Today the Buffer Zone (the area of open land surrounding the industrial complex in the center of the Site) is one of the few large, relatively undisturbed areas of its kind that remains along the Colorado Piedmont. The topography and proximity of the Site to the mountain front result in an interesting mixture of prairie and mountain plant species. Plant communities on Site include relict xeric tallgrass prairie, mixed-grass prairie, hillside seep wetlands, chokecherry-hawthorn shrublands, and Great Plains riparian woodlands (DOE 1992; DOE 1995; USACE 1995; CNHP 1995; K-H 1997a; K-H 1997b). This paper reports a portion of a larger study conducted under the Ecological Monitoring Program at the Site from 1993 through 1995 (DOE 1995). The purpose of the study was to quantify the differences in species richness, cover, and biomass production among the dominant (in terms of area occupied) plant communities at the Site. Only the portions of the study relevant to this paper are discussed.

Sampling Design

Three study sites characteristic of the mesic mixed-grass prairie and three study sites dominated by introduced species planted in an abandoned agricultural field were located. Locations were chosen to avoid any potential contamination or effects from Site activity. The three mixed-grass prairie sites were located one in each of the three major drainages on Site, and the three agricultural field sites were all located within the one drainage where cultivation had taken place on Site. The total land acreage of the Site is approximately 6500 acres (K-H 1997a). The mixed-grass prairie occupies approximately 2213 acres on Site, and the agricultural field approximately 298 acres (K-H 1997a). The mixed-grass prairie study sites were located on soil types classified as Denver-Kutch-Midway clay loams and Haverson loam (SCS 1980). The agricultural field study sites were located on soil types classified as Standley-Nunn gravelly clay loams and Denver-Kutch clay loams (SCS 1980). Historically, the mixed-grass prairie was heavily grazed until its purchase by DOE in 1974. The agricultural field was cultivated from at least 1937 (based on aerial photographs showing plowed fields) until 1973–74. After the purchase of these lands by DOE as part of an expansion of the Buffer Zone, neither grazing nor farming was allowed. Based on best estimates, the agricultural fields were seeded with the introduced species, smooth brome and intermediate wheatgrass, in 1975 to prevent wind and water erosion. Prior to the initiation of this study, the mixed-grass prairie and agricultural field areas had been left alone with little to no disturbance since the mid 1970s.

Each study site was approximately 2 hectares in size and had 5–50 m transects randomly located in it. Species richness was sampled at each site along the transects in a 2-m x 50-m belt in late May–early June 1994 and again in late August–early September 1994. All species rooted within the belt transect were recorded. Foliar cover and basal cover were sampled at each site along the transects in late August–early September 1994 using a modified point-line intercept method (Bonham 1989). A 2-m-long rod (0.25 inch diameter) was dropped vertically at 50-cm increments along the transect to record a total of 100 intercept points per transect. Two types of hits were recorded. Basal cover hits were recorded based on what was hit by the rod at the ground surface. Hits could be vegetation (live plants), litter (fallen dead material), rock (pebbles and cobbles that were greater than the rod diameter), bare ground, or water—in that order of priority—based on the protection from erosion provided by each type of cover. Basal vegetation hits were recorded only if the rod was touching the stem or crown of the plant where it entered the ground. Foliar vegetation hits were recorded in two categories at the sites, defined by height and growth form. The species of the topmost hit of each growth form was recorded. The growth forms measured were herbaceous and woody <2 m high. No vegetation greater than 2 m in height was present at the sites. A hit was defined as a portion of a plant touching the rod. Data on biomass production were collected at each site along the transects in late August–early September 1994. Five randomly located 0.25-m^2 quadrats were placed 1–5 m outside of each 2-m-wide belt transect, on either side of the transect. A total of 25 quadrats (five per transect) were sampled at each site. All non-woody vegetation within the quadrat was clipped and divided into two classes: current year live and current year dead. Both classes were sorted by species. Litter was also collected from the quadrats. Oven dry weights were determined for each sample.

Species richness was summarized by generating a species list for each study site and total numbers of species per site and per transect. Nomenclature follows the Great Plains Flora Association, 1986. The mean numbers of species per transect were tested for significant variation between the mixed-grass prairie and agricultural fields using a t-test (Fowler and Cohen, 1990). Total mean vegetative basal cover and foliar cover were calculated by transect and community. Basal cover and foliar cover were tested for significant variation between communities using a Mann-Whitney U-test (Fowler and Cohen, 1990). Total relative foliar cover for each species encountered was also calculated by community. Biomass data were reported as total biomass (g/m^2) by site and by individual species. Biomass production was tested for significant variation between communities using a Mann-Whitney U-test (Fowler and Cohen, 1990).

Results

The mixed-grass prairie had 143 species (81% native; all transects per community combined), compared to the agricultural field, which had only 61 species (62% native). By transect, the species richness of the mixed-grass prairie was significantly higher than the agricultural field (63.3 and 19.7 mean species, respectively; $t = 14.42$, $df = 28$, $P < 0.01$). Community similarity based on species presence/absence was 0.47 (Sorensen coefficient of similarity; Brower and Zar, 1977). Mean basal vegetative cover (considered as a measure of soil holding capacity) was significantly higher in the mixed-grass prairie than the agricultural field (29.1% and 11.2%, respectively; two-tailed Mann-Whitney $U = 19.5$, $P < 0.05$). Mean total foliar cover was also significantly higher in the mixed-grass prairie (91.3%) than in the agricultural field (80.2%; two-tailed Mann-Whitney $U = 57$, $P < 0.05$). The percent of relative native foliar cover in the mixed-grass prairie was 52%, compared to only 2% in the agricultural field. Species composition varied considerably between the mixed-grass prairie and agricultural fields. The mixed-grass prairie was dominated by Japanese brome (*Bromus japonicus*), western wheatgrass (*Agropyron smithii*), and blue grama (*Bouteloua gracilis*), and the agricultural field was dominated by smooth brome, intermediate wheatgrass, and alyssum (*Alyssum minus*; Table 1). The mean relative foliar cover values of the ten most abundant species from each community showed an overlap of only three species (Table 1). In the agricultural field, smooth brome and intermediate wheatgrass accounted for 93% of the relative foliar cover (Table 1). Current year production biomass did not differ significantly between the mixed-grass prairie and agricultural field (means of 120.1 g/m^2 and 145.8 g/m^2 respectively; two-tailed Mann-Whitney $U = 68$, $P < 0.05$). Smooth brome and intermediate wheatgrass accounted for 96% of the current year production in the agricultural field (Table 2). Less than 1% of the current year production was from native species in the agricultural field, compared with 63% in the mixed-grass prairie.

Discussion

Comparison of a mixed-grass prairie to an agricultural field reseeded with non-native perennial grasses, smooth brome, and intermediate wheatgrass showed significant differences in species richness, foliar and basal cover, and biomass nearly 20 years after reseeding. The most striking observation was the total domination of the agricultural field community by smooth brome and intermediate wheatgrass. The fact that all the native species combined provided only 2% of the foliar cover and less than 1% of the biomass in the agricultural field after 20 years reveals the continued highly altered state of the community and indicates how aggressive and competitive these species are in relation to the native species in the surrounding mixed-grass prairie. Even along the edges of the agricultural field, where it would be expected that some re-establishment of the native species would take place first, the distinct boundary of the agricultural field is still present. Little to no invasion of the surrounding mixed-grass prairie species has taken place. The successional progression of the agricultural field to a more native mixed-grass prairie has been retarded by the seeded non-native species. Very few native species have been able to re-establish within the community and provide any notable cover or biomass. Additionally, general observations from elsewhere on Site show that satellite, circular patches of smooth brome have become established within the undisturbed mixed-grass prairie, indicating similar total domination by the smooth brome. Similar patches or foci for further invasion have been observed in native grasslands elsewhere (Grilz and Romo, 1994).

The results from this study agree with those of Wilson (1989), who reported that sowing non-native species such as smooth brome, intermediate wheatgrass, crested wheatgrass, and others suppressed the native vegetation. Wilson and Belcher (1989) found that in Manitoba, where introduced species were present, three quarters of the common native species were reduced in cover. This contrasts with Inouye et al. (1987), who found in studying old field succession in Minnesota, that many introduced species may dominate a recently disturbed site but will eventually be replaced by native species. However, this difference may have been due to the fact that the fields in their study were never seeded with non-native species.

Studies examining successional progression on old agricultural fields and abandoned roads on the eastern plains of Colorado suggest that 50 years or more are required for natural successional processes to return an abandoned field to its native state (Shantz 1917; Albertson and Weaver 1944; Costello 1944; Judd 1974; Reichhardt 1982). However, many factors influence the speed at which recovery takes place. Distribution and timing of precipitation, wind movement and drifting soils, the number of years of cultivation, surrounding land use, grazing pressure, type of grazer, rodents, insects, topography, slope, and soil types are all important factors that affect the recovery rates of grasslands in eastern Colorado (Costello 1944).

A series of four to six successional stages were identified for the regeneration of the climax plant community in eastern Colorado (Shantz 1917; Costello 1944; Judd 1974; Table 3). Direct comparison of the agricultural field at the Site to the successional stages described in these studies is complicated by the fact that the agricultural field was seeded, not simply abandoned. The seeded species in the agricultural field have certainly had an influence on what native or non-native species have been able to re-establish. However, observations of the regeneration of the native mixed-grass prairie community on fire-break roads that were abandoned and unreclaimed in the mid 1970s at the Site (roughly the same time the agricultural field was seeded) indicate that the time frame for successional progression on the eastern plains of Colorado is also applicable to grasslands at the Site. Therefore, if the agricultural field on Site had not been reseeded at all, thus allowing natural successional processes to occur, the agricultural field should have been nearing the early stages of a perennial climax mixed prairie community (based on 20 years of growth). Considering the current status of the agricultural field, it could potentially take a century or more, depending on the factors listed above, for it to return to a more native state naturally. In fact, it may never do so without intervention to re-establish the native species and reduce the introduced species.

The agricultural field on Site was reseeded to prevent wind and water erosion, and re-establishment of the mixed-grass prairie was not necessarily a long-term goal. From a resource management standpoint, the long-term implication of this study is that natural succession can be impeded or even prevented in the long term where aggressive, non-native species such as smooth brome and intermediate wheatgrass are present. Proactive management may be (probably will be) required to return such a community to a more native state and/or prevent the loss of native prairie communities from invasion, if aggressive, non-native species are present and beginning to invade from adjacent areas. The current continued use of exotic, aggressive perennial grasses for revegetation of our highway right-of-ways, abandoned agricultural fields, development disturbances, and for rangeland enhancement must be examined in light of the long-term impacts these species have with respect to the biodiversity in our native plant communities. Further study into the long-term impacts of other past projects seeded with non-native species for revegetation and rangeland enhancement will help provide further understanding for preventing future losses of species richness and biodiversity in our native plant communities.

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Table 1. Dominant Species Foliar Cover

Mixed-Grass Prairie	%	Agricultural Field	%
Bromus japonicus	31.9	*Bromus inermis*	55.7
Agropyron smithii	19.9	*Agropyron intermedium*	37.5
Bouteloua gracilis	7.2	*Alyssum minus*	2.0
Carex heliophila	4.5	*Melilotus officinale*	1.3
Bromus tectorum	4.3	*Agropyron smithii*	0.5
Stipa comata	3.4	*Chrysopsis villosa*	0.5
Poa pratensis	2.8	*Convolvulus arvensis*	0.5
Bouteloua curtipendula	2.6	*Agropyron cristatum*	0.5
Psorelea tenuiflora	2.4	*Aristada purpurea*	0.5
Alyssum minus	2.3	*Bromus japonicus*	0.5

Top 10 species listed

Table 2. Current Year Biomass Production

Mixed-Grass Prairie	Biomass (g/m2)	% Total Biomass	Agricultural Field	Biomass (g/m2)	% Total Biomass
Agropyron smithii	26.29	21.9	*Bromus inermis*	85.65	58.8
Bromus japonicus	19.68	16.4	*Agropyron intermedium*	54.81	37.6
Bouteloua gracilis	5.38	4.5	*Alyssum minus*	1.62	1.1
Carduus nutans	4.83	4.0	*Convovulus arvensis*	1.36	0.9
Carex heliophila	4.75	4.0	*Cirsium arvense*	0.59	0.4
Artemesia ludoviciana	4.03	3.4	*Melilotus officinale*	0.51	0.4
Stipa comata	4.02	3.3	*Medicago lupulina*	0.43	0.3
Andropogon gerardii	3.68	3.1	*Poa pratensis*	0.16	0.1
Scorzonera laciniata	3.55	3.0	*Chrysopsis villosa*	0.15	0.1
Poa compressa	3.24	2.7	*Agropyron cristatum*	0.10	0.1

Top 10 species listed.

Table 3. Successional Stages on the Eastern Plains of Colorado

Judd (1974)	Shantz (1917)	Costello (1944)
• Annual weed stage (1–5 years)	• Early weed stage (1–3 years)	• Initial stage (2–5 years)
• Mixed annual-perennial stage (3–7 years)	• Late weed stage (2–5 years)	• Forb stage (3–6 years)
• Perennial stage (5–12 years)	• Short-lived grass stage (4–8 years)	• Short-lived perennial stage (4–10 years)
• Perennial climax grasses (10–50 years)	• Perennial stage (7–14 years)	• Aristida stage (10–20 years)
	• Early short-grass stage (13–25 years	• Climax mixed prairie (20–50 years)
	• Late short-grass stage (20–50 years)	