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Effect of native prairie, crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) and Russian wildrye (*Elymus junceus* Fisch.) on soil chemical properties

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Abstract

Crested wheatgrass and Russian wildrye are used extensively as seeded pastures in the prairie region of western Canada. Their long-term impact on soil quality was studied at 4 sites, each including plant communities of native mixed prairie rangeland and 17- to 27-year-old monocultures of crested wheatgrass and Russian wildrye, in southern Alberta, Canada. Root mass and soil chemical properties were determined on the soil samples collected. Native rangeland had about 7.6 times more root mass than the seeded species from the 0- to 7.5-cm depth and about equivalent mass from the 7.5- to 40-cm depth. For the seeded species, root mass was significantly less between rows than within rows. Soils in the native rangeland community had significantly greater soil organic matter and lower NO_3-N, chemical index, urease activity, and available phosphorus than those in the seeded pastures. Altering the plant community from native mixed prairie to either a sequence of cropping followed by an introduced grass monoculture, or directly to an introduced grass monoculture, resulted in decreased root mass and organic matter, and monosaccharide content of dry aggregates. The seeded grasses could neither return nor maintain the chemical quality of the soils in relation to that of the native rangeland.

Key Words: soil quality, soil organic matter, root mass, mixed prairie, introduced forages, soil sustainability

Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) has been seeded on about 1 million ha in western Canada since the 1930s, especially on eroded areas and abandoned farmland. It has gained general acceptance as excellent early spring pasture for dry areas. Weight gains of yearling ewes on either continuously grazed crested wheatgrass or Russian wildrye pastures on rotation and free-choice systems of grazing were between 2.0 and 3.2 times the gain per hectare on native range (Smoliak 1968). There is, nevertheless, concern in terms of the effect of crested wheatgrass on soil quality in the arid regions of the mixed prairie (Smoliak et al. 1981).

Aboveground, crested wheatgrass out-yields native range by 1.1 to 1.5 times. However, soil under 40- to 49-year-old stands of crested wheatgrass had greater bulk densities, fewer water-stable aggregates, increased chelating-resin extractable carbon, and reduced energy flow into the soil system compared to native prairie (Dormaar et al. 1978). Smoliak et al. (1967) established that root mass in the top 15 cm of native range and crested wheatgrass averaged 10,966 and 7,810 kg ha^{-1}, respectively.

That is, crested wheatgrass is a useful pasture grass but root biomass potentially returns less organic matter to the soil than native rangeland species. Redente et al. (1989) established that crested wheatgrass allocated nearly twice the amount of carbon to photosynthetic tissue than plants in a blue grama ecosystem. Also, crested wheatgrass stands resisted the reintroduction of native species and maintained low species diversity (Dormaar et al. 1978).

Russian wildrye (*Elymus junceus* Fisch.) was recognized as a potential pasture grass in the early 1950s. Because of good curing qualities, it is most useful to graziers during late summer, autumn, or early winter. By the late 1970s, about 100,000 ha in the prairie provinces of Canada and over 300,000 ha in the U.S.A. had been seeded to Russian wildrye (Smoliak and Johnston 1980). In one study (Smoliak and Dormaar 1985), it yielded 47% more forage than did native rangeland. However, 23 years after the Russian wildrye was sown directly into prepared native rangeland, total root mass and carbon in the surface 15-cm layer of soil was greater on native rangeland pasture than on seeded Russian wildrye pasture (Smoliak and Dormaar 1985).

The possible long-term effects of crested wheatgrass on soil (Smoliak et al. 1967, Dormaar et al. 1978, Smoliak and Dormaar 1985) have not generally been recognized. In an elegant article

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(Dwyer 1986), many credentials of crested wheatgrass are given. Yet, the word "soil" is not mentioned once. In the same symposium (Johnson 1986b), Johnson (1986a) discusses soil characteristics but only in relation to growth of crested wheatgrass on saline soils. Management strategies are usually directed at increasing forage production rather than ensuring sustainability of the soil resource. That is, land-management practices have been based almost exclusively on harvestable forage. Fertilizers have been added to forage crops as the fertility of the soil declined. This then resulted in dependence on fertilizer to maintain soil productivity. Adding fertilizers meets the needs of plants for nutrients, but does not fulfill any other functions that the organic component of the soil performs in sustaining the system (Coupland 1979). Many suggestions for future research have been made with respect to crested wheatgrass (Box 1986), yet none are soil-related. Regardless of the importance of forage production, management must concomitantly ensure the sustainability and productivity of the soil resource.

Since the long-term impact of seeded forages for dryland pasture on soil is poorly understood, the present study was initiated to ascertain the effects of altering plant communities by cultivation and seeding on soil quality through the measurement of root mass and various soil chemical properties.

Materials and Methods

Site Descriptions

Four sites, each including adjacent fields of native range and monocultures of crested wheatgrass and Russian wildrye, were selected in the mixed prairie association near Brooks and Hanna, Alberta. The seeded stands within and among the sites varied in area from 100 to 250 ha and had as close to the same agronomic histories as could be found. However, the following noteworthy differences were present:

Site 1. West of Hanna (Lat. N 51° 22', Long. W 112° 26'); Dark Brown Chernozemic (Typic Haploboroll) clay loam to silty clay loam on till (Wyatt et al. 1943). The land was broken in 1918, abandoned in the 1920s, cultivated and crop-fallowed again starting in 1960, partitioned and seeded to crested wheatgrass and Russian wildrye in 1965, and since then grazed by cattle during June and July.

Site 2. East of Hanna (Lat. N 51° 16', Long. W 111° 10'); Hemaruka Brown Solodized Solonetz (Aridic Natriboroll) sandy loam (Kjearsgaard 1988). One field was broken in 1940 and crop-fallowed until 1960, when it was abandoned. In 1964 it was seeded to crested wheatgrass, hayed, then grazed in May and June until 1981, after which it has been grazed by cattle in October only. The other field was broken in 1940, cropped until 1950, seeded to brome until 1960, cropped again until 1971, then seeded to Russian wildrye, and grazed by cattle in October only.

Site 3. West of Brooks (Lat. N 50° 40', Long. W 112° 4'); Halliday Brown Solod (Glossic Natriboroll) silty loam on till (50%)/Hemaruka Brown Solodized Solonetz L (Aridic Natriboroll) on till (40%) (Kjearsgaard et al. 1983); the land was broken and seeded to crested wheatgrass in 1973, but later that year, part of the field was recultivated and seeded to Russian wildrye. The fields were grazed by cattle during July and August.

Site 4. East of Brooks (Lat. N 50° 22', Long. W 111° 22'); Halliday Brown Solod (Glossic Natriboroll) silty loam on till (Kjearsgaard et al. 1983); fields were broken and seeded to crested wheatgrass and Russian wildrye in 1970. The fields were grazed by cattle during July and August.

The crested wheatgrass and Russian wildrye fields of sites 1, 3, and 4 had similar histories within each site. Although the crested wheatgrass and Russian wildrye fields of site 2 had somewhat different histories, the subsequent results indicated that its soil status was similar to that of sites 1, 3, and 4. The native vegetation on sites 1 to 4 is representative of the *Stipa-Agropyron*, *Stipa-Bouteloua*, *Bouteloua-Stipa-Agropyron*, and *Stipa-Bouteloua-Agropyron* communities, respectively (Coupland 1961). Within each site, livestock had equal access to all 3 communities.

Sampling

In April 1992, the soil of each native, crested wheatgrass, and Russian wildrye field was core-sampled (6.5 × 40 cm) in triplicate with samples about 50-m apart. The seeded stands were sampled both between and within rows (row spacings were about 70 cm). Soil analysis for chemical constituents was based on a single core, and for root mass, on 3 cores in each sampling unit. Therefore, at each site, 15 cores [2 seeded (3 between + 3 within rows) + 3 native] were taken for chemical analyses and 45 [2 seeded × 3 cores (3 between + 3 within rows) + (3 cores × 3 native)] for root mass determinations. The samples were partitioned into 2 segments (0-7.5, 7.5–40 cm).

The soil samples were dried and ground to pass a 2.0-mm sieve. At the time of sieving, roots and other debris were removed from the soil and discarded. The soil cores were washed over a series of sieves, the root mass was oven-dried, weighed, and ashed to determine ash-free weight.

Dry aggregates were obtained from the 0- to 7.5-cm segment of an additional 2 cores per sampling unit by passing the whole air-dried sample through a multiple rotary sieve (Chepil 1962). Following preliminary work, the 12.5, 8, 4, 2, and 1 mm aggregates (large) and 0.5 and 0.25 mm aggregates (medium) were grouped. These, together with the 0.1-mm aggregates (small), made for 3 fractions for monosaccharide distribution determinations. The mixtures of the 12.5, 8, 4, 2, and 1 mm aggregates and of the 0.5 and 0.25 mm aggregates were ground to pass a 0.1-mm sieve.

Chemical Analysis

Percent organic matter was determined as per Walkley and Black (1934). Urease activity, which is important as a decomposing agent for urea, was determined at pH 9.0 by incubating 5 g soil with tris(hydroxymethyl) aminomethane(THAM) buffer (0.05M), urea solution, and toluene at 37° C for 2 hours, and measuring the ammonium (NH_4-N) released by steam distillation (Tabatabai and Bremner 1972). Autoclaveable-nitrogen (N), as an index of N availability, was determined as described by Keeney (1982). Kjeldahl-N (total N) was determined as per Association of Official Analytical Chemists (1970), and nitrate-nitrogen (NO_3-N) and NH_4-N by KCl extraction and steam distillation as per Keeney and Nelson (1982), $NaHCO_3$-soluble phosphorus (available P) as per Olsen et al. (1954), and carbohydrates by the phenol-sulfuric acid method of Dubois et al. (1956) as modified by Doutre et al. (1978).

Acid hydrolysis of the 3 dry aggregate fractions was carried out essentially as outlined by Cheshire and Mundie (1966) and Cheshire (1979) except that the samples were first treated with 12

M H_2SO_4 for 16 hours at room temperature, then diluted to 0.5 M H_2SO_4 and held at 100° C for 1 hour (Dormaar 1984). Monosaccharides were reduced and acetylated as described by Blakeney et al. (1983). D-allose was added as the internal standard. The alditol acetates were identified with a Hewlett Packard GC 5840A equipped with a hydrogen flame ionization detector and a 30-m glass capillary column (0.25 mm i.d.) wall-coated with OV-225 (50% cyanopropyl-50% methylphenylpolysiloxane) with helium as the carrier gas at a linear flow rate of 21 cm sec^{-1}. Reference alditol acetates of rhamnose, fucose, ribose, arabinose, xylose, allose, mannose, galactose, and glucose were used as standards and prepared as outlined by Blakeney et al. (1983). Polysaccharides were considered to have a plant origin if they contained substantial quantities of arabinose and xylose and predominantly of microbial origin if they contained mainly galactose and mannose.

Statistical Analysis

The data were analyzed as a randomized complete block design with 4 replicates (sites) and either (a) 2 plant communities (crested wheatgrass or Russian wildrye) and 2 row locations (between and within), or (b) 3 plant communities (2 seeded and native). In the seeded communities of the latter tests, root mass was averaged for row location while all other constituents were only from within row. The design was a split block when aggregate size and sampling depth were included as factors. Paired means were tested using single degree of freedom contrasts (Steel and Torrie 1980).

Results

None of the tests resulted in a significant ($P<0.05$) block by treatment interaction, which supports the assumption that the different agronomic histories of the sites had a negligible effect on the observations (Table 1). Russian wildrye had a greater proportion ($P<0.05$) of the root mass below 7.5 cm than did crested wheatgrass. Root mass was significantly ($P<0.05$) less between than within rows at both depths. Native rangeland had about 2 to 3 times more root mass than the seeded species in the 0- to 7.5-cm depth and about equivalent mass from the 7.5- to 40-cm depth.

The chemical constituents all varied ($P<0.01$) by sampling depth (Table 1). Most constituents were also affected by plant community, sampling location (whether within or between rows), and the interaction of plant community with depth or location of sampling. Soil characteristics were generally similar under crested wheatgrass and Russian wildrye but percent organic matter, NO_3-N, NH_4-N, and available P differed. Soils in the native rangeland community had significantly ($P<0.01$) greater organic matter content and lower NO_3-N, chemical index, urease activity, and available P levels in the upper 7.5 cm of the soil (Table 1). The effects of plant community on these constituents or indices were different below 7.5 cm soil depth. Percent organic matter, total N, NO_3-N, chemical index, and urease activity were greater within than between rows (Table 1). Finally, effects of plant community on the selected indices were affected by depth, hence were not uniform.

Table 1. Some characteristics of soil from native rangeland (NR), crested wheatgrass (CWG) and Russian wildrye (RWR) pastures (root mass average of 36 samples per community, i.e., 4 sites, 3 samples, and 3 cores/sample; remainder average of 12 samples, i.e., 4 sites and 3 samples)

Row[1] (R)	Between			Within				R×C
Community (C)	CWG	RWR	$\bar{x}$	CWG	RWR	$\bar{x}$	NR	(CWG,RWR)
Soil Depth = 0-7.5 cm								
Root mass ($g\ m^{-2}$ core $depth^{-1}$)	172	235	290^a	834^A	550^A	692^b	1717^B	0.134
Organic matter (%)	3.42	3.10	3.26^a	4.46^B	3.68^A	4.07^b	5.27^C	0.122
Total N (%)	0.24	0.25	0.24^a	0.27^A	0.27^A	0.27^a	0.27^A	0.241
NO_3-N ($mg\ kg^{-1}$)	1.0	1.0	1.0^a	0.7^A	2.0^B	1.4^b	0.5^A	0.002
NH_4-N ($mg\ kg^{-1}$)	6.1	4.7	5.4^a	6.2^A	5.7^A	6.0^a	6.3^A	0.202
Chemical index[2]	90.8	95.9	93.4^a	130.3^B	132.9^B	131.6^b	105.3^A	0.482
Urease activity[3]	186.6	171.2	178.9^a	185.5^B	205.3^C	195.4^b	154.8^A	0.018
Available P ($mg\ kg^{-1}$)	5.25	6.93	6.09^a	5.46^B	7.77^C	6.62^a	3.41^A	0.386
Carbohydrates ($mg\ 100\ g^{-1}$)	510	492	501^a	487^A	531^B	509^a	617^B	0.670
Soil Depth = 7.5-40 cm								
Root mass ($g\ m^{-2}$ core $depth^{-1}$)	410	575	492^a	569^{AB}	694^B	632^b	547^A	0.671
Organic matter (%)	1.36	1.47	1.42^a	1.51^B	1.59^B	1.55^b	1.32^A	0.778
Total N (%)	0.13	0.14	0.14^a	0.14^A	0.15^A	0.14^a	0.13^A	0.816
NO_3-N ($mg\ kg^{-1}$)	0.6	0.4	0.5^a	0.7^B	0.4^A	0.6^a	0.3^A	0.293
NH_4-N ($mg\ kg^{-1}$)	4.6	4.0	4.3^a	3.6^A	3.8^A	3.7^a	3.9^A	0.004
Chemical index[2]	27.6	27.6	27.6^a	30.7^A	33.1^A	31.9^b	31.0^A	0.519
Urease activity[3]	122.5	106.8	114.6^a	114.6^B	111.3^{AB}	113.0^a	101.8^A	0.116
Available P ($mg\ kg^{-1}$)	3.03	3.29	3.16^a	2.09^A	3.11^B	2.60^b	2.09^A	0.028
Carbohydrates ($mg\ 100\ g^{-1}$)	205	148	176^a	210^A	211^A	210^b	194^A	0.120

[a-b]Means within a line with the same lower case letter do not differ significantly ($P>0.05$).
[A-B]Means within a line with the same upper case letter do not differ significantly ($P>0.05$).
[1]CWG and RWR were seeded in rows about 70-cm apart.
[2]NH_4-N released on autoclaving (mg kg^{-1} of soil)
[3]NH_4-N released (mg kg-1 of dry soil per 2 h)

Monosaccharides in soils were affected ($P<0.001$) by sampling location and aggregate size (Table 2). However, crested wheatgrass and Russian wildrye had similar effects on monosaccharides. The ratio of galactose plus mannose to arabinose plus xylose was affected by location and aggregate size and not by plant community ($P>0.05$).

Discussion

Plants, and the animals that feed on them, affect the soil and, eventually, determine the level of productivity sustained. Altering the plant community from native mixed prairie first to cropland and then to crested wheatgrass or Russian wildrye significantly reduced the chemical quality of the soils by decreasing root mass and organic matter. Differences in the present study were most evident in the top 7.5 cm of soil which contained 51, 38, and 76% of the total roots sampled from crested wheatgrass, Russian wildrye, and native rangeland, respectively.

We recognize that cultivating the land over a number of years (e.g., Sites 1 and 2) led to a change in soil quality. However, 1) Sites 3 and 4 were directly seeded to crested wheatgrass and Russian wildrye after breaking native rangeland and 2) none of the tests resulted in a significant ($P<0.05$) block by treatment interaction. In other words, the soils of Sites 3 and 4, where crested wheatgrass and Russian wildrye were seeded without cropping, are now similar in quality to those of Sites 1 and 2, where 27 years of crested wheatgrass and Russian wildrye (Site 1) and 28 years of crested wheatgrass and 21 years of Russian wildrye (Site 2) followed a period of annual cropping. All the soils were of different quality than those under the corresponding native range. There is evidence elsewhere that 23 years of crested wheatgrass and Russian wildrye sown into prepared native rangeland in 15-cm row spacings did not restore the soil organic matter to native rangeland levels (Smoliak and Dormaar 1985). Similarly, there is evidence that quality of abandoned cropland, after 10 years of cultivation, recovered faster to native rangeland levels under natural succession than under crested wheatgrass after 49 years (Site 3 of Dormaar et al. 1978).

Blue grama (*Bouteloua gracilis* (HBK.) Lag. ex Steud), an important species on the mixed prairie, has a dense, widely spreading root system with about 84% of its root mass in the upper 15 cm of the soil (Coupland and Johnson 1965). The roots are usually less than 1 mm in diameter at their origin and often diminish to 0.2 mm with depth. Root descriptions in the Halliday and Hemaruka soil series (Kjearsgaard et al. 1983) stress the abundance of fine and very fine, random roots in the Ah horizons. Fine roots contribute most organic matter both as root mass and exudate to the soil (Dormaar and Sauerbeck 1983, Biondini et al. 1988).

Unfortunately, information on the root systems of crested wheatgrass or Russian wildrye is scarce. Even though crested wheatgrass has an extensive, fibrous root system, these roots were generally coarser and longer than those of blue grama, that is, there are less roots, both in number and in mass, in a given soil volume (Unpublished data, Dormaar). Although coarse roots often have greater mass than fibrous roots, the latter often (Dormaar and Sauerbeck 1983) have greater root turnover than the former. Russian wildrye is a deep-rooted bunchgrass with many more coarse roots than under crested wheatgrass and blue grama. Root mass to 15-cm depth has been reported as 1,472, 1,150, and 1,165 g m^{-2} for native range, crested wheatgrass, and Russian wildrye, respectively (Smoliak and Dormaar 1985). Smoliak et al. (1967) established that dry matter weights of roots to a depth of 60 cm from mixed prairie rangeland were significantly higher ($P<0.01$) than weights of roots from crested wheatgrass sites (18,179 vs. 13,878 kg ha^{-1}).

Limited information is available on root-derived organic matter

Table 2. Monosaccharide content (mg 100 g^{-1}) and galactose + mannose/arabinose + xylose ratios of dry soil aggregates to a depth of 7.5 cm in relation to location (between or within rows), aggregate size, and communities of crested wheatgrass (CWG), Russian wildrye (RWR) and native range (NR) (average 8 samples, i.e., 4 sites and 2 samples/site)

			Monosaccharides			Galactose + Mannose/Arabinose + Xylose ratio		
			(Dry aggregates (mm)[1]			(Dry aggregates (mm)[1]		
			12.5-1.0 (L)	0.5-0.25 (M)	0.1 (S)	12.5-1.0 (L)	0.5-0.25 (M)	0.1 (S)
			(mg/100g)					
CWG	Between[2]		512	399	411	0.73	0.80	0.89
	Within		673	620	511	0.64	0.71	0.90
RWR	Between		525	483	448	0.74	0.79	0.96
	Within		654	555	451	0.63	0.77	0.97
NR			788	717	642	0.66	0.78	0.97
		Effects		P			P	
		- Location		<0.001			0.038	
		- Size		<0.001			<0.001	
		Contrasts						
		L vs M		<0.001			<0.001	
		L vs S		<0.001			<0.001	
		M vs S		<0.001			<0.001	
		- Community		>0.05			>0.05	
		Contrasts						
		CWG vs RWR		>0.05			>0.05	
		CWG vs NR		0.005			>0.05	
		RWR vs NR		<0.001			>0.05	

[1]Designation of the 3 composite aggregate sizes used. L = Large; M = Medium; S = Small.
[2]CWG and NR were seeded in rows about 70-cm apart

from crested wheatgrass and none on Russian wildrye. McHenry and Newell (1947) reported on the effects of 10 perennial grasses, after 5 to 7 years of production, on a number of soil properties in the upper 15 cm of a silty clay loam soil. Blue grama maintained higher N content, organic matter, and oxidizable material and imparted greater soil aggregate stability than either crested wheatgrass or Russian wildrye. They concluded that the effects of the grasses must be related to root production although no root measurements were made. Data of Biondini et al. (1988) indicate that crested wheatgrass releases lower amounts of root exudates than blue grama [*Bouteloua gracilis* (HBK.)] Lag. and western wheatgrass (*Agropyron smithii* Rydb.), both important species in the mixed prairie ecosystem. In the present study, the root masses (average of 36 samples = 9 cores/site $\times$ 4 sites) within the rows, to a depth of 7.5 cm, were 17,170, 8,340, and 5,500 kg ha^{-1} for native rangeland, crested wheatgrass, and Russian wildrye, respectively. Therefore, while seeded grass communities may be useful for pasture (Smoliak 1968), they introduce less organic matter into the 0 to 7.5 cm soil environment than does the native community. In addition, there is less potential energy flow to the seeded as compared to the native rangeland soils (Dormaar et al. 1978).

Wide row spacings (55 to 75 cm), recommended to enhance plant productivity (Lawrence and Heinrichs 1977; Knowles and Kilcher 1983), leave a large area of bare ground exposed between rows which may persist for the life of the stand. Bare ground within and between rows was 19 and 44% of field area, respectively, for crested wheatgrass and 25 and 61% for Russian wildrye (Naeth, unpublished data). In sharp contrast, bare ground on native prairie averages <5%. Thus, seeded grass communities with widely spaced rows are at much greater risk of wind and water erosion, especially if rows run upslope or are parallel to the prevailing winds.

Although severe grazing limits colonization of crested wheatgrass by vesicular-arbuscular mycorrhizal fungi (Bethlenfalvay et al. 1985), crested wheatgrass accumulates nutrients effectively in the non-mycorrhizal state (Trent et al. 1993). Considering the root:soil ratio and the aboveground crested wheatgrass:native rangeland growth ratio, this means increased export of nutrients from soil to aboveground vegetation and then to the grazing animal under crested wheatgrass than under native rangeland. Although replacing native range with crested wheatgrass and Russian wildrye has been considered an improvement on some rangelands (Smoliak 1968), this study and others (Smoliak et al. 1967; Dormaar et al. 1978; Smoliak and Dormaar 1985) indicate that these grasses reduce soil quality, due to increased nutrient export and decreased organic matter input, compared with native rangeland soils.

Practically all the N in surface soils is organically combined (Keeney 1982). Mineralization of this soil organic N may make up to 120 kg of N ha^{-1} available for crops. Laboratory indices of N availability are not only a measure of the soil's ability to release N for plant growth, but also allow insight into N-organic matter relationships. The chemical indices suggest the organic matter quality is different and that these differences are related to differences in root mass quality between species (Herman et al. 1977) which affect the humification process. That is, the organic matter of the native rangeland was probably in a more stable stage of humification than that from the crested wheatgrass and Russian wildrye soils. In another study, Klein et al. (1988) detected greater microbial activity in the rhizosphere of blue grama than of crested wheatgrass, indicating more root exudates and a greater potential for soluble organic matter accumulation.

Urease, produced primarily by microbial and fungal organisms (Skujins 1976), is important as a decomposing agent for urea. Although all fields within a site were equally grazed, plant species seemed to affect the activity of urease since it was higher under crested wheatgrass and Russian wildrye than under native range. The more stable organic matter and lower urease activity under native range may indicate greater sustainability of soil quality.

Agricultural production from the mixed prairie was initially increased by replacing the native rangeland with cereal crops, thereby interrupting the self-sustaining processes of the native rangeland. This resulted in a loss of cultural energy and reduced soil stability which subsequently necessitated regrassing some areas. Seed of introduced species is readily available and inexpensive; whereas, seed of native species has generally not been available and certainly not the mix required to simulate a native community. Crested wheatgrass is a cold- and drought-tolerant, highly productive and stable bunchgrass (Johnson 1986b). It establishes readily from seed, which makes it suitable for revegetating disturbed areas, while early growth provides grazing for livestock in spring. However, since crested wheatgrass, and possibly other forage species grown as monocultures, reduce soil quality, it is important to limit their use, since the sustainability of the soil is more important than the possible short-term benefits from forage production. A much better understanding of the interrelationships between soil and plants is required in order to make confident predictions on the sustainability of agronomic systems. Until then, a conservative approach to land management is prudent and one that will benefit future generations the best.

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