Productivity of Russian Wildrye and Crested Wheatgrass and Their Effect on Prairie Soils

S. SMOLIAK AND J.F. DORMAAR

Abstract

Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) and Russian wildrye (*Elymus junceus* Fisch.) are used extensively as seeded pastures in the Prairie Provinces of Canada. Rangeland plowed in 1954 was planted to the 2 grasses in 1955. Herbage was harvested over a 25-year period, root weights were determined in 1977, and soil samples were obtained in 1965 and 1978 from the 2 seeded pastures and from adjacent native rangeland from each of 3 replicates. Forage production from the seeded pastures was greatest 4 years after seeding. Averaged over all years, crested wheatgrass yielded 113% more and Russian wildrye yielded 47% more forage than did native rangeland. Total root weight in the surface 15-cm layer of soil was greater on the native rangeland pasture than on the seeded pastures. Soils from native range pastures generally contained more organic carbon, less sodium, and had lower pH and sodium adsorption ratios than the soils from Russian wildrye pastures seeded 10 and 23 years before the soils were sampled. The organic C and pH's of the soils obtained from crested wheatgrass pastures decreased during the 23-year period while those of soils from the native range did not change.

About 18 million ha of rangeland and 2.5 million ha of seeded pastures are utilized by the beef industry in the Prairie Provinces of Canada. It is estimated that about 1 million ha of crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) and 100,000 ha of Russian wildrye (*Elymus junceus* Fisch.) contribute to the forage supply for livestock production. Stands of the 2 introduced forages, when used to complement native range in spring and fall, have doubled livestock gains per hectare primarily by permitting increased stocking rates (Smoliak 1968, Smoliak and Slen 1974).

The loss of organic matter and N from soils in the Northern Great Plains through long-term wheat cropping has been documented. Such cropping over a 34-year period resulted in a loss of 35% of the N and 41% of the organic matter that was present in the original prairie soil, but conversion of the cropland to seeded pasture resulted in the reduction of the rate of loss of N and organic matter (Norum et al. 1957). Crested wheatgrass has been used to provide a permanent type of pasture and to improve the carrying capacity of grazing lands (Smoliak et al. 1967, Looman and Heinrichs 1973, Dormaar et al. 1978) on much of the abandoned, cultivated land. Early studies (Lehane and Staple 1943) showed that in addition to reducing soil erosion and increasing the grazing capacity of abandoned fields, crested wheatgrass improved the chemical and physical properties of the soil as compared to cultivated soil. In a comparison of 40- to 49-year-old stands of crested wheatgrass with native range soils, Dormaar et al. (1978) showed that pH and bulk densities were higher on crested wheatgrass soils while water-stable aggregates were higher on native range soils. The greater root mass allowed for increased energy flow into the native range soil system compared with the crested wheatgrass soil system. As the crested wheatgrass stands in these studies resulted from seeding into cropland that produced several crops of cereals, it is very likely that the changes of some soil characteristics could have occurred during the cropping period although the data were

compared with native range soils.

Russian wildrye also appears to be capable of providing a long-term pasture with good productivity under grazing (Smoliak and Johnston 1980). However, the influence of Russian wildrye on prairie soils has not been determined. Therefore, this study was initiated to assess the changes in characteristics related to soil organic matter and the productivity of established stands of crested wheatgrass and Russian wildrye sown in 1955 on newly plowed native range.

Materials and Methods

The study was conducted at the Agriculture Canada Research Substation near Manyberries, Alberta. The vegetation of the study site is typical of the *Stipa-Bouteloua* faciation of the Mixed Prairie Association (Coupland 1961). The Orthic Brown Chernozemic (Aridic Ustochrept) soil is of a medium texture. Portions of native rangeland in the study area were plowed to a 10- to 12-cm depth to kill the native vegetation and summer-fallowed in 1954 to accommodate seeding of introduced grasses for a sheep grazing trial (Smoliak 1968). In the spring of 1955, the prepared areas were sown to crested wheatgrass (9.3 ha) and to Russian wildrye (10.9 ha) at 9 kg/ha seeding rate in 15-cm row spacings. The study had 3 replicates. Adjacent areas of 20 ha of virgin rangeland in each of the 3 replicates completed the grazing fields. The fields were grazed by yearling ewes from 1957 through 1966 (Smoliak 1968), and by yearling steers from 1967 through 1972 (Smoliak and Slen 1974). After the grazing study was terminated, all cross fences were removed and the whole area was grazed by cows and calves from 1973 through 1980. None of the fields was fertilized.

Herbage was harvested from 10 caged 0.89-m² areas in each pasture at the end of each grazing season from 1956 to 1980. All herbage was clipped near ground level with a hand-held power mower. The point-quadrat method was used to estimate the percentage ground cover which was reported previously (Smoliak 1968, Smoliak and Slen 1974). Root weights were determined from 5 soil plugs taken at random in each replicate in each pasture type. Plugs were 10.4 cm in diameter and 15 cm deep and were obtained with a golf-cup hole cutter in September 1977. The plugs were washed on a screen and the separated roots were dried at 100°C for 24 hours. Ash content of the roots was determined after ignition at 700°C for 4 hours. Root weights are reported on an ash-free, oven-dry basis for the 15-cm depth.

Composite samples were obtained from the top 10 cm of soil in July 1965 and September 1978 from each replicate and pasture type and air-dried. The roots were screened out, after which the soil was ground to pass a 1-mm screen.

Total organic carbon (C) of the root samples was determined by dry combustion at 900°C for 15 minutes with the evolved CO₂ collected and weighed, total nitrogen (N) was determined using a macrokjeldahl procedure, and solvent-extractable C was obtained by extraction in a Soxhlet apparatus for 72 hours with a mixture of ethanol-benzene (1:1). Lignin was determined as described by Deriaz (1961). Methoxyl groups were determined by a modified Zeisel technique (Tech. Assoc. of the Pulp and Paper Industry 1945). Calorific values on five bulked samples from each pasture were obtained by combustion in a Parr 1241 adiabatic oxygen

Authors are range ecologist and soil scientist, respectively, Agriculture Canada, Research Station, Lethbridge, Alberta T1J 4B1.
Manuscript accepted April 15, 1985.

Table 1. Precipitation and dry matter production on three pasture types, Manyberries, Alberta.

Year	Precipitation (mm)		Dry matter production (kg/ha)		
	April to July	Annual	Native range	Crested wheatgrass	Russian wildrye
1956	208	365	480 ± 104	426 ± 93	235 ± 61
1957	112	350	706 ± 178	843 ± 209	790 ± 154
1958	128	334	664 ± 152	1,361 ± 240	966 ± 188
1959	148	307	529 ± 120	1,448 ± 279	1,020 ± 216
1960	137	285	446 ± 106	702 ± 149	649 ± 171
1961	78	215	272 ± 78	564 ± 140	490 ± 101
1962	167	287	286 ± 72	784 ± 131	530 ± 110
1963	146	266	314 ± 74	786 ± 179	527 ± 131
1964	159	384	299 ± 63	804 ± 202	454 ± 119
1965	419	600	547 ± 151	1,137 ± 251	1,030 ± 296
1966	155	345	338 ± 79	904 ± 237	788 ± 94
1967	178	430	516 ± 129	1,226 ± 217	726 ± 109
1968	126	320	574 ± 147	916 ± 168	682 ± 164
1969	100	243	319 ± 93	761 ± 133	588 ± 120
1970	219	352	238 ± 71	863 ± 234	475 ± 104
1971	157	316	245 ± 62	700 ± 184	424 ± 86
1972	126	334	178 ± 43	610 ± 134	399 ± 95
1973	98	219	188 ± 51	522 ± 149	261 ± 34
1974	215	382	476 ± 127	824 ± 197	544 ± 102
1975	295	572	593 ± 135	1,295 ± 262	758 ± 142
1976	175	300	439 ± 107	1,158 ± 214	690 ± 156
1977	114	286	274 ± 71	520 ± 145	358 ± 66
1978	220	513	493 ± 121	762 ± 87	610 ± 139
1979	168	343	421 ± 104	1,088 ± 248	508 ± 78
1980	162	334	416 ± 98	785 ± 186	523 ± 107
Mean					
-25 years	168	347	410	872	601
52 years	164	324			

bomb calorimeter. All values are expressed on a dry, ash-free basis.

Total organic C of the soil samples was determined by dry combustion at 900°C for 15 minutes with the evolved CO₂ collected and weighed, while total N was determined using a macro-kjeldahl procedure. Soil pH was measured in 0.01M CaCl₂. Since Russian wildrye is a useful grass on saline soils, it was deemed useful for future reference to obtain baseline data of several parameters indicative of saline soils, such as pH, electrical conductivity (EC), sodium adsorption ratio (SAR), and the water soluble Na, Ca, and Mg contents (U.S. Sal. Lab. Staff 1954, Rhodes 1982).

An analysis of variance test with years as a split plot was used to determine if any significant differences existed between the year means. Duncan's multiple range test at the 0.05% level was used to determine significant differences among the 3 pasture types.

Results and Discussion

Dry matter production of the native range and the 2 seeded pastures was measured over a 25-year period (Table 1). Crested wheatgrass pastures produced an average of about 113% more forage than did the native range pastures, while Russian wildrye pastures produced about 47% more. Although the peak forage production of crested wheatgrass was reached 4 years after seeding, both seeded pastures responded to seasonal precipitation as did the native range. Mean precipitation during the 25-year period was greater than the long-term averages. The higher production of herbage on seeded pastures, as compared to native range pastures, could be a result of a greater release of N. Coupland (1973) has suggested that the loosening of the soil and its greater exposure to sunlight increases the rate of decomposition of organic matter and this consequently increases the supply of N.

Total root weight in the surface 15-cm layer of soil was greater on the native range pasture than on the seeded pastures (Table 2). The greater root weight also resulted in a higher kCal/m² of the native range soil. There were no differences in the total C content

Table 2. Characteristics of root material of native range, crested wheatgrass and Russian wildrye sod.

Characteristic measured	Native	Crested wheatgrass	Russian wildrye
Total C (%)	49.8a ¹	49.7a	47.1a
Total N (%)	2.3b	2.7a	2.2b
Solvent extractable C (% of total C)	16.0b	23.3a	17.4b
Lignin (%)	16.4a	16.0a	13.2b
OCH ₃ (meq/g of O.M.)	3.0b	3.4a	2.9b
Calorific value (Cal/g)	4866b	5019a	4585c
Root weight to 15-cm depth (g/m ²)	1472a	1150b	1165b
kCal/m ²	7160a	5771b	5340b

¹ Means within rows followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's multiple range test.

but the crested wheatgrass roots contained more total N, solvent-extractable C, and methoxyl group, and had a higher calorific value than the roots of the native range or Russian wildrye. The roots of native range and crested wheatgrass contained more lignin than those of the Russian wildrye.

Soil from the Russian wildrye pastures contained less organic C in 1965 and 1978, less total N in 1978, and had a lower pH in 1978 than the native range soils (Table 3). Soil from the crested wheatgrass pastures contained less organic C and had a lower pH in 1978 than did the native range soils.

The soils from the Russian wildrye pastures also had higher SAR values and contained more water extractable Na than did the soils from the native range and crested wheatgrass pastures (Table 3). From 1965 to 1978 the values for EC, SAR, and water soluble Na, and Ca + Mg decreased in all pastures. These variables are used

Table 3. Some characteristics of soil from native range, crested wheatgrass and Russian wildrye pastures (average of 3 samples).

Characteristic measured	Native	Crested wheatgrass	Russian wildrye
Total organic C (%)			
1965	1.40a ¹	1.36a	1.27b
1978	1.42a	1.26b	1.21b
Total N (%)			
1965	0.14a	0.14a	0.13a
1978	0.14a	0.13a	0.12b
C/N ratio			
1965	10.0a	9.7a	9.8a
1978	10.1a	9.7a	10.1a
pH CaCl ₂			
1965	6.8a	6.7a	6.6a
1978	6.8a	6.6b	6.2c**
EC (dS/m)			
1965	1.03a	0.86a	1.19a
1978	0.47a**	0.39a**	0.43a**
SAR			
1965	0.60b	0.51b	0.83a
1978	0.29b	0.36b	0.47a
Na (meq/liter)			
1965	1.3b	1.0b	2.0a
1978	0.4b**	0.5b**	0.6a**
Ca + Mg (Meq/liter)			
1965	9.4a	8.3a	10.2a
1978	4.0a**	3.3a**	2.9a**

¹Means within rows followed by the same letter are not significantly different ($P<0.05$) according to Duncan's multiple range test.

**Significantly different ($P<0.01$) from value in 1965.

to measure soil salinity but the change during the 13 years is thought to be in response to the differences in precipitation during the 2 sampling years. Bowman et al. (1984) have shown that changes in Na concentrations in soils supporting Russian wildrye were related to moisture availability.

The results of this study show that, like crested wheatgrass, Russian wildrye is adapted to the study area. The root weight of Russian wildrye in the top 15 cm of soil was similar to that of crested wheatgrass. There was some invasion by native grasses into the Russian wildrye pastures, but none into the crested wheatgrass pastures.

The Russian wildrye root material had a lower lignin content than either the native range or crested wheatgrass root material and lower root weight/m² than the native range sod. It is likely that the lower lignin content of the Russian wildrye root material allowed for a faster turnover initially. In fact, it may have even

primed the native organic matter in the process. Plowing of the soil would have accelerated the breakdown of the organic matter as well. However, as the organic matter level came to a new equilibrium, soil-nutrient cycling would be lower than in crested wheatgrass sod. In 10 years, Russian wildrye reduced ($P<0.05$) the amount of organic C in the soil and, in 23 years, the amount of total N. Reduced amounts of organic C were observed in soils on the crested wheatgrass sites after 23 years. Thus, while both introduced grass species did deplete soil nutrients, the reduction was not as great as that reported under cereal cropping (Lehane and Staple 1943). Although the nutritional requirements of the 2 introduced grasses were not determined, it may well be that they are greater than those of native rangeland grasses, which have evolved on soils with low nutrient levels, and that additional nutrients could be provided through the application of fertilizers.

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