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Seasonal changes of herbage biomass on the fescue prairie

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Abstract

Knowing the amount of herbage on rangeland is basic to management decisions related to livestock grazing. However, the amount of herbage available for grazing changes seasonally. Therefore, changes in herbage biomass were examined in different communities of the fescue prairie. The study was conducted at 2 sites in southwestern Alberta. In the Porcupine Hills near Stavely, changes in herbage biomass components were examined in 3 communities: rough fescue (*Festuca campestris* Rydb.), Parry oat grass (*Danthonia parryi* Scribn.)-Kentucky bluegrass (*Poa pratensis* L.), and Kentucky bluegrass-sedge (*Carex* spp.) by sampling at monthly intervals from April or May to late September. Observed trends among the rough fescue, Parry oatgrass-Kentucky bluegrass, and Kentucky bluegrass-sedge communities were, for peak current year's standing production, 398, 305, and 226 g m^{-2}, respectively; for spring current year's standing production as a percent of its peak, 73, 50, and 35%, respectively; and for percent losses of total herbage biomass, from fall to spring, 24, 43, and 56%, respectively. In the foothills near Pincher Creek, the standing crop of grasses and forbs was sampled using paired subplots. One subplot was harvested in October and the other in April. Dry matter losses over winter averaged 27 and 58% for grasses and forbs, respectively. Of the 3 communities examined, production on the rough fescue community was the greatest, least dependent on precipitation during the growing season, and least susceptible to weathering losses and, therefore, had the greatest forage values. The Kentucky bluegrass-sedge community had the lowest forage values.

Key Words: primary production, litter, disappearance of dry matter, *Poa pratensis, Danthonia parryi, Festuca campestris, Carex* spp.

The fescue prairie, one of the most productive grasslands on the Northern Great Plains, extends from northern Montana through central Alberta and Saskatchewan to south-west Manitoba. In southwestern Alberta, the fescue prairie covers the foothills of the Rocky Mountains (Pavlick and Looman 1984) at elevations between 1,000 and 1,700 m above sea level. The dominant species is normally rough fescue (*Festuca campestris* Rydb.) but Parry oat grass (*Danthonia parryi* Scribn.) may dominate drier sites. Also, at higher elevations near the limits of its distribution, rough fescue may be replaced by Richardson needle grass (*Stipa richardsonii* Link) as the dominant herbaceous species.

Rough fescue is extremely susceptible to grazing during the growing season but tolerates grazing while dormant. This may reflect the historical use of the fescue prairie which is believed to have been winter grazing by bison. Winter grazing of this prairie by cattle is an economically sound management practice (Willms et al. 1993) which conserves the integrity of the grassland. However, dry matter losses over winter, from weathering, trampling, and herbivory, limit the amount of forage available for livestock.

Grazing fescue prairie at moderate and heavy stocking rates resulted in the disappearance of 30.2 ± 1.3 and 25.9 ± 1.5 kg ($\bar{x}$ ± SD), respectively, forage dry matter per animal-unit-day (AUD) (Willms 1988). This represented a grazing efficiency of less than 50%, assuming that forage intake was 12 kg AUD^{-1}. Apparently, more than 50% of available herbage was lost through decomposition, consumed by non-livestock species, or transferred to the litter pool. In a similar environment, dry matter losses over winter from leaves of Altai wildrye (*Elymus angustus* Trin.) were about 45% (Willms 1992).

Available forage, also referred to as standing crop, is a commonly measured attribute of grasslands but its dynamics on the fescue prairie are not well understood. Morris and Brunner (1971) reported that herbage biomass in Montana was greatest in July and varied by 39% over the year. About 83% of aboveground production was achieved by 15 June in Alberta (Willms 1988). However, the study by Morris and Brunner (1971) was for a single year only and neither study estimated weathering losses over winter. The objective of this study was to determine seasonal changes in the biomass of herbage components of major plant communities in the fescue prairie.

Materials and Methods

Site Description

The study was conducted in 2 locations. The Stavely site was 85 km northwest of Lethbridge near Stavely (50° 12', 113° 57'; 1,350 m) in the Porcupine Hills of southwestern Alberta whereas

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the Pincher Creek site was located in the foothills of the Rocky Mountains about 104 km southwest of Lethbridge near Pincher Creek (49° 28', 114° 12'; 1,220 to 1,710 m).

Soils at the Stavely site are classified as thin Orthic Black Chernozemic (Cryoboroll) developed on till overlying sandstone. Precipitation during the growing season averaged 348 mm (Table 1) at nearby sites. In 1949, 2 fields were fenced to enclose areas of 32 and 16 ha and stocked annually from May to November with 13 cows and calves to achieve moderate and high grazing pressures, respectively. The grassland vegetation is representative of the Rough Fescue Association described by Moss and Campbell (1947). Grazing modified the species composition of the plant communities by causing a shift from one dominated by rough fescue to one dominated by Parry oatgrass-Kentucky bluegrass (*Poa pratensis* L.) in the moderately grazed field or Kentucky bluegrass-sedge (*Carex* spp.) in the heavily grazed field (Table 2).

Table 1. Winter (December to March)[1] and monthly precipitation on the fescue prairie near Stavely, Alberta, during the growing season[2].

	Winter	April	May	June	July	August	Total
				(mm)			
1988	70	10	9	63	19	122	293
1989	122	30	29	46	37	55	319
1990	94	52	89	46	99	90	470
30-yr average		64	70	99	55	60	

[1]Based on the average of 2 nearby sites (Claresholm and Pincher Creek, Alberta).
[2]Measured at the study site.

Table 2. Composition of major species at the Stavely, Alberta, site.

Species	Rough fescue	Parry oatgrass-Bluegrass-	Bluegrass-Sedge
		(%[1])	
Grasses and sedges			
Agropyron dasytachyum[2]	1.1	4.4	5.1
Agropyron subsecundum	1.1	2.8	1.6
Agrostis scabra	0.6	2.8	1.6
Bromus inermis	2.6	0.1	0.2
Danthonia parryi	16.7	19.0	15.3
Festuca campestris	41.1	5.1	1.0
Festuca idahoensis	3.9	4.8	5.7
Poa pratensis	2.3	24.4	22.3
Stipa comata/viridula	1.7	10.6	7.9
Carex spp.	4.6	6.8	15.9
Forbs			
Achillea millefolium	2.0	1.4	0.5
Artemisia frigida	0.0	0.1	8.8
Aster ericoides/laevis	5.5	0.6	0.9
Galium boreale	5.2	1.6	1.0
Taraxacum officinale	0.1	2.2	0.8
Thermopsis rhombifolia	0.3	1.6	3.0
Shrubs			
Potentilla fruticosa	1.5	2.3	1.5

[1]Composition is based on basal area determined by point sampling.
[2]Nomenclature follows Looman and Best (1987).

The Pincher Creek site is located in the Montane ecoregion (Strong and Leggat 1981). The area is characterized by open grasslands interspersed with lodgepole pine (*Pinus contorta* Dougl.), Douglas fir [*Pseudotsuga menziessii* (Mirb.) Franco], and limber pine (*Pinus flexilis* James). The dominant herbaceous species is Richardson needle grass and rough fescue with bearberry [*Arctostaphylos uva-ursi* (L.) Spreng.] as the major shrub component (Table 3). The soils vary from Orthic Regosols (*Typic cryorthent*) to Rego Black Chernozemic (*Eutric cryoboroll*) overlying colluvial and till. The area is used as winter range for elk and summer range for cattle.

Table 3. Composition (%[1]) of major species in the Montane ecoregion near Pincher Creek, Alberta.

Grasses and sedges	
	(%)
Bromus ciliatus[2]	2.3
Danthonia parryi	7.6
Danthonia intermedia	1.2
Festuca campestris	10.6
Festuca idahoensis	6.5
Poa pratensis	1.1
Stipa richardsonii	28.3
Carex spp.	2.2
Forbs	
Anemone multifida	2.8
Fragaria virginiana	3.0
Galium boreale	2.2
Lupinus spp.	5.9
Monarda fistulosa	2.3
Vicia spp.	2.5
Shrubs	
Arctostaphylos uva-ursi	16.5
Rosa acicularis	1.6

[1]Composition based on estimates of canopy cover.
[2]Nomenclature follows Looman and Best (1987).

Experimental Approach

In 1988, study sites were selected in each of the grazed fields representing both a Parry oatgrass-Kentucky bluegrass and a Kentucky bluegrass-sedge community. Hereafter, these communities will be referred to as Parry oatgrass-bluegrass and bluegrass-sedge, respectively. Another site was established in a rough fescue community within an exclosure that was established in 1983 on an area that had previously been lightly grazed in the fall. The study sites on the grazed fields were fenced to exclude livestock in the year that the study was initiated. Within each site, 252 plots were arranged in randomized complete block design with 3 years × 7 blocks and with years split into 12 months. Although a plot was assigned for each month, samples were obtained at monthly intervals only from April or May to late September as snow cover and freezing temperatures limited field activities.

Plots were 1-m^2 on the rough fescue site and 0.5-m^2 on the Parry oatgrass-bluegrass and bluegrass-sedge sites. Plots on the rough fescue site were larger to reduce the between-sample variation caused by the large, tufted rough fescue plants. All herbage biomass was harvested near ground level and mulch was removed to the mineral layer. Herbage was dried at 70°C and hand sorted into components of current year's standing production, standing litter representing mostly the previous year's growth, and fallen litter that was fragmented into pieces that were usually less than 10 cm long and included mulch. The fallen litter was screened to separate the coarse and fine components. A subsample of the fine component was ashed to determine organic matter. Current year's standing production and standing litter were combined to form a standing crop component for certain comparisons. The coarse and fine fallen litter components were pooled for statistical analysis.

For each year and site, the seasonal maximum biomass of each component was determined and used as an estimate of peak biomass. Estimates of spring, peak, and fall biomass represented the date factor, which was analyzed, together with plant community and year, using analysis of variance. Single degree of freedom contrasts were used to compare paired means. Individual analyses by a main factor were made where significant ($P<0.05$) interactions were found.

Four study sites were selected at Pincher Creek at least 2 km apart on exposed, rugged ridges with subplots at each site distributed from the mid-slope to the crest of the hill. Changes in herbage biomass over winter were assessed in a randomized complete block design with 3 years and 4 blocks (sites) while years were split into 2 season (fall and spring). In each year, 12 paired subplots (0.25 m^2) were sampled at each site; one subplot was harvested in mid-October and the second was harvested in the first week of April each year from fall, 1987 to spring, 1990. The spring-harvested subplots were protected from grazing over-winter with portable cages (1.5 × 1.5 × 1.5 m) set up the previous fall. Forbs and grasses were separated in the field then oven-dried at 70°C, and weighed. Standing litter was pooled with current year's standing production because they could not be reliably separated. New subplot locations were clipped each year. The data were analyzed as a split block with year tested against the year x site interaction (error 1) while season and the interaction of season and year was tested against the residual error (year × site × season interaction).

Table 4. Herbage biomass components in fall and spring in 3 plant communities on the fescue prairie at Stavely, Alberta, over 3 years (n=21) and associated analyses of variance.

	Standing crop[1]	Fallen litter	Total
	(g m^{-2})		
Rough fescue			
Fall	683b[2]	1,031a	1,714b
Spring	321a	984a	1,305a
SEM	37	120	96
Parry oatgrass Bluegrass			
Fall	468b	94a	562b
Spring	217a	102a	319a
SEM	23	16	25
Bluegrass - Sedge			
Fall	238b	112b	350b
Spring	94a	60a	154a
SEM	10	11	17
Analysis of variance Effect:			
	Probability		
Community (C)	<0.001	<0.001	<0.001
Date (D)	<0.001	0.492	<0.001
Year (Y)	<0.001	0.020	0.996
C×D	<0.001	0.828	0.322
C×Y	0.010	0.009	0.052
D×Y	0.193	<0.001	<0.001

[1]Standing crop in fall includes current year's standing production plus standing litter and, in the spring, only standing litter.
[2]Within community, paired fall and spring means with different letters are significantly ($P<0.05$) different (based on an analysis of variance for each community separately).

Results

Losses of standing crop and total herbage biomass over winter among communities at Stavely were: rough fescue > Parry oatgrass-bluegrass > bluegrass-sedge ($P<0.05$, Table 4). However, as a proportion of their fall estimates, losses over winter from the rough fescue, Parry oatgrass-bluegrass, and bluegrass-sedge communities were 53, 53, and 60%, respectively, for standing crop and 24, 43, and 57%, for total herbage. Fallen litter decreased only in the bluegrass-sedge community (Table 4). Dry matter losses of total herbage over winter (Table 4) were 103, 80, and 87% of peak current year's standing production (Table 5) for the rough fescue, Parry oatgrass-bluegrass, and bluegrass-sedge communities, respectively.

At Pincher Creek, disappearance of total herbage over winter averaged 36% (Table 6). Losses of grasses and forbs averaged 27 and 55%, respectively. Herbage losses between seasons were similar among years.

Plant community, sampling date, and year significantly ($P<0.01$) affected the biomass of most herbage components at the Stavely site (Table 7). Only total litter did not differ ($P>0.05$) among years. The effect of plant community on current year's standing production and litter components were different ($P<0.01$) among years (Table 7). Peak current year's standing production occurred in June 1988, July 1989, and September 1990 in each community. Most herbage components differed significantly ($P<0.01$) among communities in the order: rough fescue > Parry oatgrass- bluegrass > bluegrass-sedge (Tables 6 and 7). The average between-community difference in current year's standing production was about 30% while total litter differed by 75% between the rough fescue and Parry oatgrass-bluegrass communities (Table 8). The peak litter biomass was not chronologically synchronized with peak current year's standing production and varied from May to September.

The trends in biomass estimates across sampling dates were similar ($P>0.05$) among communities for each herbage component (Table 7). However, an individual analysis of each community shows greater similarity among sampling dates in the rough fescue and least in the bluegrass-sedge communities (Table 5). Current year's standing production at the time of sampling in spring was 73, 50, and 35% of its peak on the rough fescue, Parry oatgrass-bluegrass, and bluegrass-sedge communities, respectively (Table 5). The total herbage biomass in spring was 87, 64, and 53% of its peak for the respective communities (Table 5).

The average decrease in estimates of current year's standing production, from the peak to fall was 23%; however, this was modified by year and plant community and varied from 0 to 70% over the study period. In 1990, peak and fall standing crop estimates of current year's production were similar.

Current year's standing production was least variable among years in the rough fescue community and most variable in the bluegrass-sedge community (Table 9). Production was most responsive to precipitation during the growing season (Table 1) in the bluegrass-sedge community. Therefore, in 1988 when precipitation during the growing season was low, the difference in production between the rough fescue and bluegrass-sedge communities was 62% and, in 1990, when precipitation was the greatest, the difference was only 25%.

Discussion

The seasonal accumulation and disappearance of herbage biomass was affected by plant community and modified by growing

Table 5. Biomass of various herbage components on the fescue prairie near Stavely, Alberta, in relation to sampling date when analyzed separately by plant community over 3 years (n=21). Statistical analyses of pooled data are shown in Table 6.

	Current year's standing production (1)	Standing litter (2	Standing crop (1+2)	Fallen litter (3)	Total (1+2+3)[1]
	(g m^{-2})				
Rough fescue					
Spring	291a[2]	297a	588a	1,005a	1,593a
Peak	398b	398b	727b	1,190a	1,828a
Fall	327ab	356ab	683ab	1,031a	1,713a
SEM	24	28	38	84	106
Parry oatgrass - Bluegrass					
Spring	154a	167a	321a	125a	446a
Peak	305c	283b	504b	231b	696c
Fall	224b	244b	468b	94a	556b
SEM	13	20	25	15	28
Bluegrass-Sedge					
Spring	80a	88b	168a	102a	270a
Peak	226c	114c	327c	196b	508c
Fall	175b	63a	238b	112a	350b
SEM	10	8	12	18	23

[1]Totals for peak yields may not be the column totals because peak yields of herbage components were not necessarily synchronized chronologically.
[2]Within columns and communities, means with different letters are significantly ($P<0.05$) different.

Table 7. Statistical analysis of herbage components on the fescue prairie near Stavely, Alberta, in relation to plant community (Rough fescue, Rf; Parry oatgrass-Bluegrass, PB; Bluegrass-Sedge, BS), date, and year.

	Current year's standing production (1)	Standing litter (2)	Standing crop (1+2)	Fallen litter (3)	Total (1+2+3)
Analysis of variance Effects:					
	Probability				
Community (C)	<0.001	<0.001	<0.001	<0.001	<0.001
Date (D)	<0.001	<0.001	<0.001	0.002	<0.001
Year (Y)	<0.001	<0.001	<0.001	0.002	<0.001
C×D	0.384	0.088	0.710	0.861	0.999
C×Y	<0.001	0.002	0.225	<0.001	<0.001
D×Y	<0.001	0.008	0.042	0.082	0.220
Contrasts for main effects					
Community					
Rf vs PB	<0.001	<0.001	<0.001	<0.001	<0.001
Rf vs BS	<0.001	<0.001	<0.001	<0.001	<0.001
PB vs BS	<0.001	<0.001	<0.001	0.740	0.001
Date					
Spr. vs Peak	<0.001	<0.001	<0.001	0.002	<0.001
Spr. vs Fall	<0.001	0.092	<0.001	0.971	0.034
Peak vs Fall	<0.001	0.011	0.012	0.002	0.014
Year					
1988 vs 1989	<0.001	0.002	0.458	0.038	0.048
1988 vs 1990	<0.001	<0.001	<0.001	0.001	<0.001
1989 vs 1990	<0.001	0.005	<0.001	0.140	0.010

conditions. In general, as long-term grazing intensity increased, over winter losses of herbage increased, magnitude and stability of annual production decreased, and growth was delayed in spring. These effects appeared to be associated with shifts in the dominant species of the community from rough fescue to Parry oat grass and, eventually, bluegrass. These shifts corresponded with changes from "hard" to "soft" grasses, from deep to shallow-rooted species, and from species with low regrowth potential to those with high regrowth potential.

The resistance to weathering of rough fescue, a "hard" grass, seems to be derived from a well developed sclerenchymatous layer in the leaves (Coupland and Brayshaw 1953) and, perhaps, from leaf rolling which may contribute to its ability to cure on the stem (Looman 1983). Rough fescue has a greater ($P<0.05$) concentration of acid detergent fibre than Parry oat grass (Willms and Beauchemin 1991). Similar comparisons with the dominant species in the bluegrass-sedge community were not available but other rhizomatous grasses of the fescue prairie have less crude fibre than either rough fescue or Parry oat grass (Johnston and Bezeau 1962). Forbs are also more vulnerable to decomposition than grasses because they have less fibre and shatter readily after senescence (Johnston and Bezeau 1962).

Losses of total herbage biomass over winter were accounted for mostly by the standing crop component in the rough fescue and Parry oatgrass-bluegrass communities (Table 4), suggesting that any input to the fallen litter component was matched by similar losses from standing litter. In the bluegrass-sedge community,

Table 6. Average spring and fall standing crops for grasses and forbs at Pincher Creek, Alberta and associated analyses of variance (n=12).

	Grasses	Forbs	Total
	(g m^{-2})		
Fall	59	26	85
Spring	43	11	54
SEM	3	2	4
Analysis of variance Effect:			
	Probability		
Year (Y)	0.311	0.346	0.248
Date (D)	0.004	<0.001	<0.001
Y×D	0.440	0.052	0.899

Table 8. Biomass of various herbage components on the fescue prairie near Stavely, Alberta, in relation to plant community, date, and year (statistical analyses shown in Table 6; n=63).

	Current year's standing production (1)	Standing litter (2)	Standing crop (1+2)	Fallen litter (3)	Total (1+2+3)
	(g m^{-2})				
Community:					
Rough fescue	338	351	666	1,076	1,709
Parry oatgrass - Bluegrass	228	231	429	150	566
Bluegrass-Sedge	161	88	244	136	384
Date:					
Spring	175	184	359	411	770
Peak	310	265	519	539	1,011
Fall	242	221	463	412	875
Year:					
1988	162	275	405	378	772
1989	218	222	422	462	876
1990	347	173	511	522	1,012
SEM (for each factor)	9	12	16	28	36

Table 9. Estimated annual primary production on the fescue prairie near Stavely, Alberta, in relation to plant community and year (n=21).

	1988	1989	1990	SEM	CV	Year effects (P)
	------- (g m^{-2}) --------					
Rough fescue	316b[1]A[2]	410bA	447aA	21	17	0.165
Parry oatgrass -Bluegrass	246bA	251aA	434aB	15	34	<0.001
Bluegrass - Sedge	121aA	234aB	333aC	14	46	<0.001
SEM	16	11	22			
Community effects (P):	0.004	<0.001	0.101			

[1]Within columns, means with different lowercase letters are significantly (P<0.05) different.
[2]Within rows, means with different uppercase letters are significantly (P<0.05) different.

biomass losses were significant (P<0.05) across each group and resulted in a 56% reduction of total herbage biomass compared with reductions of 23 and 43% in the rough fescue and Parry oatgrass-bluegrass communities, respectively.

The value of the plant community for winter grazing is diminished on overgrazed range as rough fescue decreases and is replaced by less productive, short-statured grasses and forbs (Table 2). Although weathering losses were greatest on the rough fescue community, the proportional decrease was the same as on the Parry oatgrass-bluegrass community resulting in a greater quantity available for grazing. Differences in the weathering rates of the major species were not estimated, but grasses, consisting mostly of rough fescue, lost less than half the proportional biomass that was lost by forbs (Table 6).

Summer losses of standing crops have important implications in determining the carrying capacities of rangeland. In this study, deviations of up to 70% were observed, depending on the growing conditions over the summer. Peak current year's standing production was equivalent to the fall estimates only in 1990 when the production cycle was shifted to later in the year by higher than normal precipitation distributed uniformly over the growing season (Table 1). Peak current year's standing production does not represent total annual production because ongoing losses and growth are not completely accounted for by a single harvest; they are, however, the best approximation from a single harvest.

The greater production stability of the rough fescue community is affected by the deep-rooted rough fescue plants and the large accumulation of litter which traps snow and conserves soil moisture. Furthermore, growth in rough fescue begins early in spring and is completed by the end of June (Stout et al. 1981) which enables it to use spring moisture effectively and avoid moisture stress in summer. Consequently, the rough fescue community was less affected by precipitation during the growing season (Table 5) than were the Parry oatgrass-bluegrass and bluegrass-sedge communities, resulting in greater production stability. On the rough fescue community, 73% of peak current year's standing production had been achieved at the time of sampling in May compared with 50% on the Parry oatgrass-bluegrass and 35% on the bluegrass-sedge communities (Table 5).

Delayed production on the bluegrass-sedge community was likely related to dry soil conditions in spring caused by lack of snow retention. Therefore, the onset of growth and production on the bluegrass-sedge community was dependent on precipitation during the growing season. The shallow-rooted species dominating this community are most productive with frequent showers since moisture conservation is inefficient. Periodic heavy precipitation events, such as those in June, 1988 (Table 1) which produced 68% of monthly rainfall (Willms, unpublished data), are ineffective in promoting production in the bluegrass-sedge community because infiltration is poor (Johnston 1962) and evaporation is high due to low amounts of litter. Forage production in response to precipitation late in the growing season also tends to be low because many species have completed their growth cycle and low temperatures may impede growth.

Conclusions

The dynamics of herbage on the fescue prairie was characterized by large losses of dry matter over winter that were affected by the severity with which the community was modified by grazing. The greatest modification was in the loss of rough fescue and an increase in "soft" grasses that are less productive and are more susceptible to weathering. These changes follow a trend that is related to the degree of over-grazing and is associated with reduced forage values. It is essential to maintain a high proportion of rough fescue on winter range to ensure the best grazing opportunities for either cattle or elk.

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