Seasonal Fluctuations of Blue Grama Roots and Chemical Characteristics

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Abstract

Root collections of blue grama *(Bouteloua gracilis* (H.B.K.) Lag.) were made at intervals near Manyberries, Alberta, over a 3-year period. Root samples, after being weighed, were analyzed for C,N, ethanol/benzene-extractable C, methoxyl groups, lignin, soluble and structural carbohydrates, and calorific value. Significant fluctuations occurred over the seasons for all characteristics. Over 50% of the root mass was lost between October and May. This occurred regardless of soil moisture levels. The relationship of (C:N)(% lignin)/(% carbohydrate$^{-0.5}$) showed significant differences between the roots collected in the fall and those collected in spring and early summer. The chemical composition of the roots in the fall may have to be considered in explaining root mass losses between October and May.

Blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) is a warm-season, short grass that is widely distributed throughout the Great Plains from Alberta to Mexico. It is the most xerophytic grass in the northern portion of the area, dominating in unmodified grasslands only on relatively arid sandy loam soils, but being the major species in overgrazed rangelands (Coupland 1961). Blue grama increases in abundance with grazing and is classed as an Increaser in the northern Great Plains where its dominance indicates fair to poor condition range (Wroe et al. 1979). It has a high density of roots in the surface layers of soil where, by weight, 84% of the root material occurs in the uppermost 15 cm and 93% in the top 30 cm of soil (Coupland and Johnson 1965).

The organic C content of the grassland soils and the amount of roots produced by the grasses have been shown (Lutwick and Dormaar 1976) to increase generally from Brown to Dark Brown to Black Chernozemic soils. However, the production of root material by blue grama in the Brown Chernozemic soil zone equalled that by rough fescue (*Festuca scabrella* Torr.) in the Black Chernozemic soil zone, yet the organic C content of the Brown Chernozemic soil was 2.5% vs 11.1% of the Black Chernozemic soil. The lower C content would indicate that additions of raw organic matter in the Brown Chernozemic soils are mineralized faster than additions in the Black Chernozemic soils.

Dormaar et al. (1977) found that organic matter characteristics of a blue grama-dominated site on Brown Chernozemic soil were closely associated with seasonal fluctuations. Clark and Campion (1976) found that the N content of the root mass of blue grama changed significantly within the growing season. Time of sampling soils or roots is thus of great importance. Herman et al. (1977) noted that decomposition rates of a range of plant residues and changes during decomposition cannot be predicted from properties of the original material such as C:N ratio, lignin content, or carbohydrate content when considered individually. When combined, however, they accurately predicted relative rates of decomposition and changes occurring during decomposition. It was thus possible with the help of this combination, i.e., (C:N)(% lignin)/(% carbohydrate$^{-0.5}$), to relate degree of decomposition to plant composition. It was proposed that this type of quantitative measure of decomposition rates and of probable qualitative changes during decomposition would help to explain the differences in the level of organic matter in soils produced from different plant communities or the differences with time in the same plant community.

The equilibrium, under which the organic matter of the soil of heavily grazed Mixed Prairie forms and exists, is fragile (Dormaar et al. 1977). Since root mass is an important source for soil organic matter, a study was undertaken to follow seasonal fluctuations in root mass of blue grama and in the C, N, solvent-extractable C, methoxyl groups, lignin, carbohydrate, and caloric content of this root mass.

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Materials and Methods

Roots of blue grama were collected from a portion (0.34 ha) of a field that had been heavily grazed (1.7 ha/AUM) for 19 years by sheep (Smoliak 1974). The soil is a member of the Brown Subgroup of the Solod Great Group of the Solonetzic order (Smoliak et al. 1972). The field was divided into three plots of equal size. Within each plot, an area with an almost pure stand of blue grama was selected. Ten samples were taken at random within each blue grama stand with a golfcup-cutter (10.4 cm diam × 13 cm depth) three, four, and two times per year over the 3-year period, 1974 to 1976. After removal of crowns from the soil plugs, the roots were washed essentially as described by Lauenroth and Whitman (1971). The washed roots were dried at 100° C for 24 hours (Ward and Johnston 1960) and weighed; ash content was determined on a portion of each sample by ignition at 700° C for 4 hours. Weight of organic mass was calculated on an ash-free, oven-dry basis and the values converted to kilograms per square meter for the 13-cm depth of sampling. After drying, the 10 root samples from each plot were combined and ground in a Wiley mill to pass through a 100-mesh sieve.

Total organic C of the root samples was determined by dry combustion at 900° C for 15 min with the evolved CO_2 collected and weighed; total N was determined using a macro-Kjeldahl procedure; and solvent-extractable C was obtained by extraction in a Soxhlet apparatus for 72 hr with a mixture of ethanol-benzene (1:1). Methoxyl groups were determined by a modified Zeisel technique (Technical Association of the Pulp and Paper Industry 1945). Lignin, soluble carbohydrates, pentosans, and hexosans were determined as described by Deriaz (1961). Calorific values were obtained by combustion in a Parr 1241 adiabatic oxygen bomb calorimeter. All values are expressed on a dry, ash-free basis.

The relationship established by Herman et al. (1977), (C:N) (% lignin)/(% carbohydrate$^{-0.5}$), was used as an index of decomposibility. Total carbohydrate was estimated by adding soluble and structural carbohydrate values together. Duncan's multiple range test was used to compare means over time for each variable.

Results and Discussion

Mass and chemical characteristics of roots of blue grama showed highly significant changes over the seasons (Table 1). The root mass per unit volume of soil increased from early spring to October, then decreased so that by the next spring it was about the same as in the previous spring. Although the drier year (1974) led to increased root mass, the trend was the same regardless of soil

Table 1. **Mass and chemical characteristics of blue grama root samples and soil moisture of a heavily grazed Mixed Prairie site near Manyberries, Alberta (average of three samples).**

							Carbohydrates					
							Soluble	Structural				
Collection date	Root* mass kg/m²	C (%)	N (%)	Solvent-extractable C as % of total C	OCH_3 (%)	Lignin (%)	(%)	Pentosans (%)	Hexosans (%)	Calorific value (cal/g)	Decom-posability index†	Soil moisture (%)
1974												
April 17	0.71 g	51.8 d	2.32 e	6.71 f	3.11 d	27.0 c	2.16 f	10.1 b	23.2 h	4989 d	102 b	13.3 bc
July 3	1.22 c	48.9 f	1.92 g	7.67 c	2.91 f	26.5 c	2.96 d	11.2 a	25.7 e	4341 f	107 a	2.76 g
October 10	2.54 a	48.0 f	2.60 d	7.00 d	2.73 g	24.6 d	3.69 b	11.2 a	33.2 a	4082 h	65 e	2.75 g
1975												
March 24	1.11 cd	56.4 a	3.22 a	6.56 g	3.41 a	30.3 a	3.37 c	11.3 a	27.0 c	5680 a	81 d	11.5 d
May 21	0.86 fg	55.1 b	2.37 e	6.92 e	3.25 c	27.7 b	2.20 f	10.2 b	24.5 g	5273 c	106 a	18.5 a
July 2	103 de	48.7 g	2.19 f	7.93 a	3.06 de	25.1 d	2.85 d	10.9 a	26.1 d	4488 e	89 c	8.99 e
October 1	1.91 b	50.8 e	2.80 b	7.73 b	2.94 f	23.9 e	4.01 a	11.4 a	32.9 a	4161 g	62 e	8.09 f
1976												
April 9	1.09 cd	55.2 b	2.70 c	6.74 f	3.34 b	29.4 a	3.42 c	11.1 a	29.1 b	5423 b	91 c	14.1 b
May 11	0.91 ef	53.6 c	2.20 f	7.93 a	3.04 e	26.6 c	2.51 e	10.4 b	25.3 f	5012 d	104 ab	12.2 cd

*Average of 30 cores (10.4 cm diam. × 13 cm depth).
†Decomposability index = (C/N)(% lignin)/(% carbohydrates$^{-0.5}$).
a,b Within a column, any two means followed by the same letter do not differ significantly ($P<0.05$).

moisture levels. Over 50% of the root mass was lost between October and May. The present data support those of Sims and Singh (1971) who showed that the root biomass in shortgrass prairie in Colorado had an annual average replacement of 49% of the roots. Dahlman and Kucera (1965), on the other hand, demonstrated that only 24% of the root mass was lost over winter in a tallgrass prairie.

The root mass, as it goes into the winter, represents a potential source of available energy and nutrients. The energy potentially available between October 10, 1974, (i.e., 2.54 kg/m² × 4,082 cal/g), and May 21, 1975, (i.e., 0.86× 5,273), and between October 1, 1975, and May 11, 1976, was 5,833 (i.e., 10,368–4,535) and 3,387 kcal/m², respectively. Most of the nutrients released during mineralization of the root mass would be available for re-use, since, due to a low annual precipitation of only about 310 mm, removal of the bases would be slight. Mineralization, however, is only one avenue for explaining this overwinter loss. It is likely that not all of the energy of the organic matter will be channeled into decomposition. At least two other avenues for explaining overwinter loss of root mass should be considered. First, the rapid burst of above-ground spring growth of xerophytic grasses requires large energy reserves. The significant change in soluble and structural carbohydrates and solvent-extractable C about this time (Table 1) is probably a result of this growth burst. Second, increased production of root exudates in early spring may be another cause of the observed decrease in root mass. The production of root exudates with time and their transfer to the labile organic matter pool in grassland Ah horizons, however, is a subject in need of much more research.

The root mass decreased between October and May. This period has a number of months when chemical and biological rates are slow and biological decomposition is at a near standstill. It may well be that the chemistry per se of the root mass has, therefore, an effect on this decrease. Applying the expression (C:N)(% lignin)/(% carbohydrate$^{-0.5}$) to the nine root collections in our study, roots collected in October 1974 and in October 1975 were potentially the least resistant, and roots collected in July 1974, May 1975, and May 1976 were potentially the most resistant to decomposition. The methoxyl group contents were also low in October 1974 and in October 1975.

Khaziyev (1977) showed that the annual pattern for CO_2 liberation from the soil reached a maximum when the soil was frozen and potential enzymatic activity increased in winter and early spring but decreased in the summer according to all the characteristics he studied. Bremner and Zantua (1975) have shown that significant enzyme activity occurs in soils below 0°C. They attributed the occurrence of this activity to enzyme-substrate interaction in unfrozen water at the surfaces of soil particles. The dehydrogenase levels of soil obtained from the same sampling sites as those of the present study were about twice as high in winter as in the summer months (J.F. Dormaar, unpublished). Part of the root mass was probably transformed enough to become part of the soil organic matter during that time since the soil C content (Dormaar et al. 1977) increased over the same period.

It may thus be postulated that, under the xerophytic conditions that are mandatory for blue grama to flourish, late winter/early spring represents a crucial time for the decrease of its root mass. The equilibrium under which the organic matter of the soil of heavily grazed Mixed Prairie forms and exists is fragile (Dormaar et al. 1977). Since root mass and, possibly, root exudates are important sources for the soil organic matter, the mechanism of the seasonal fluctuations of these sources will, therefore, be useful for an understanding and subsequent management of this fragile equilibrium.

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