Root Dynamics of a Shortgrass Ecosystem

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Highlight: *Seasonal dynamics of roots of a shortgrass ecosystem were determined at 2-week intervals for the two growing seasons of 1969 and 1970 and at monthly intervals during the intervening fall and winter. Soil cores were taken to a depth of 80 cm during the first growing season to determine the amount and distribution of roots in the soil profile. Root samples in the second year were only taken to a depth of 10 cm, with periodic sampling to 80 cm. Some 55% of the root weight was found in the 0- to 10-cm segment, and 69% was found in the upper 20 cm of the soil profile. There were significant differences among sampling dates in root weights in the upper 10-cm increment. The mass of roots in the lower portion of the profile remained somewhat constant throughout the sampling period. No significant differences were found in the root mass among four grazing intensity treatments (ungrazed, light, moderate, and heavy).*

Vital contributions of plant roots include absorption of water, initiation of nutrient cycling, supporting structures for photosynthetic material essential for energy capture and transfer, and soil development and stability. An insight into the effect of herbivores and environmental factors on seasonal and annual dynamics of belowground plant organs is useful for increased understanding of the functioning of grassland ecosystems.

Several studies have included measurements of the effect of herbage removal upon root weights (Biswell and Weaver, 1933; Schuster, 1964; Lorenz and Rogler, 1967; and Hanson and Stoddart, 1940) and quantitative measurements of roots in various grassland types (Weaver, 1958; Weaver and Zink, 1946; Bray, 1963; and Dahlman and Kucera, 1965). Generally, herbage removal has been shown to be somewhat detrimental to root growth. However, in North Dakota no significant differences were found in amount and vertical distribution of roots in heavily and moderately grazed pastures after 45 years of treatment (Lorenz and Rogler, 1967).

The purpose of this research was to study seasonal and annual dynamics of the root system of a shortgrass prairie and to determine the influence of grazing by large herbivores on the underground portion of plants.

Study Area and Methods

The study plots were located on the Pawnee Site, U. S. IBP Grassland Biome[1], 40 miles northeast of Fort Collins, Colorado. Four areas used in the study had been grazed by cattle for 32 years at the following intensities: ungrazed, light, moderate, and heavy (Jameson, 1969).

[1] The Pawnee Site, U.S. IBP Grassland Biome, is located on the Central Plains Experimental Range (U.S. Dep. Agr., Agricultural Research Service) and adjacent to the Pawnee National Grassland (U.S. Dep. Agr., Forest Service).

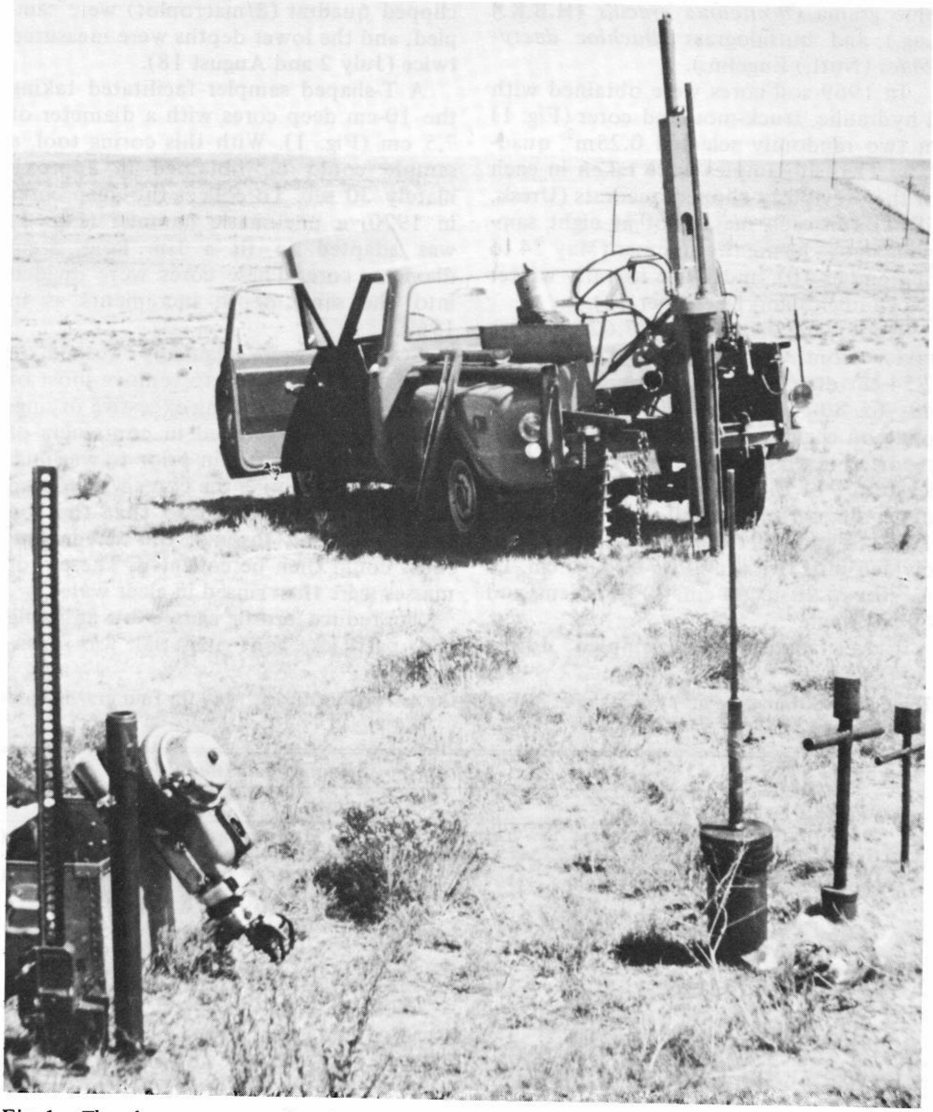

Fig. 1. *The three root sampling instruments used were the pneumatic hammer (left front), a T-shaped sampler (right front), and the hydraulic coring truck (background).*

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Table 1. Root mass (g/m²) in the upper 10 cm of the soil profile during 1969 and 1970 for four grazing intensity treatments at the Pawnee Site, U.S. IBP Grassland Biome.[1]

Grazing intensity	Sampling date (month/day) 1969										1970											Avg
	5/24	6/21	7/02	7/16	7/31	8/13	8/27	9/10	11/08	12/18	4/24	5/08	5/22	6/04	6/19	7/02	7/17	7/29	8/12	8/26	9/12	
Ungrazed	768	1047	978	784	732	768	717	806	829	623	949	1190	1034	944	1202	724	1278	1163	1147	883	945	925
	43[2]	66	56	66	28	35	68	33	24	29	15	15	16	15	17	19	19	22	14	3	14	
Light	709	798	997	642	483	570	818	1014	694	602	968	967	854	957	968	792	1171	1022	1079	885	976	850
	86	68	71	45	28	48	43	70	16	19	10	18	16	16	21	18	14	17	17	16	11	
Moderate	783	696	835	680	738	677	895	845	721	614	1044	1013	917	920	1180	1306	1304	1150	946	1026	1103	933
	43	92	30	101	74	80	105	69	26	33	15	21	20	15	21	49	24	23	15	29	21	
Heavy	849	868	748	666	492	806	968	812	858	578	938	1098	884	928	1191	940	1067	1138	1065	916	1133	896
	17	10	46	26	47	70	70	50	40	24	17	18	21	16	29	29	15	20	16	20	23	
Average	777	852	889	693	611	705	777	869	776	612	975	1067	922	937	1135	940	1205	1118	1059	928	1039	901

[1] Weights include plant crowns.
[2] Standard error of the mean.

Light, moderate, and heavy grazing averaged 21, 37, and 54% removal of the current year's growth, according to Klipple and Costello (1960). Replicate macroplots (.5-ha each) were established within the four grazing treatments on a loamy plains range site. Ascalon soils predominate and support, as dominants, blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.).

In 1969 soil cores were obtained with a hydraulic, truck-mounted corer (Fig. 1) in two randomly selected $0.25 m^2$ quadrats. Two subsamples were taken in each of the previously clipped quadrats (Uresk, 1971) for each macroplot at eight sampling dates during the summer (May 24 to September 10), and twice in early winter (November 8 and December 18).

Root core diameters of 7.62 cm were taken from 0- to 40-cm depths, and 2.54-cm diameter cores were taken from 40- to 80-cm depths. Preliminary sampling on the Pawnee Site and earlier work reported in the literature indicated that at least 95% of the roots would occur in the upper 80 cm of the soil profile (Weaver, 1958; Shantz, 1911). The 80-cm core was divided into five sections: 0 to 10 cm, 10 to 20 cm, 20 to 40 cm, 40 to 60 cm, and 60 to 80 cm.

Eleven dates were sampled during 1970 at approximately 2-week intervals during the growing season. Modification of the 1969 sampling technique was implemented in 1970 to facilitate more rapid and efficient collection of roots. The 0- to 10-cm increment was sampled more intensively during the 1970 growing season. Three 0- to 10-cm cores per clipped quadrat (8/macroplot) were sampled, and the lower depths were measured twice (July 2 and August 18).

A T-shaped sampler facilitated taking the 10-cm deep cores with a diameter of 7.5 cm (Fig. 1). With this coring tool, a sample could be obtained in approximately 30 sec. To collect the deep cores in 1970, a pneumatic hammer (Fig. 1) was adapted to fit a 1-m long, 5-cm diameter core. These cores were divided into the same depth increments as in 1969.

Soil cores were manually washed on the day of collection to remove most of the soil, thus preventing excessive drying. Soil cores were soaked in containers of water for 15 to 30 min prior to washing. All water containing the cores was poured over a 32-mesh screen so that the soil material passed through the screen and roots could then be collected. These root masses were then rinsed in clear water.

To reduce errors caused by adhering soil particles, root material was oven-dried for 48 hr at 105°C, weighed, ashed at 610°C for 4 to 8 hr, and reweighed. Data on belowground material were then expressed on an ash-free basis and the values converted to grams per square meter.

The deep samples taken in 1970 were used to develop a regression equation which was used to predict total root mass from 0- to 10-cm increments. These values were calculated so a comparison could be made between 1969 and 1970 samples.

Results and Discussion

Individual samples for root measurements were taken on 21 sampling dates between May 24, 1969, and September 14, 1970. All data for the 0- to 10-cm increments (Table 1) includes both the plant crowns and roots. These data show that the amount of roots in the upper 10 cm of the soil profile for the different grazing intensity treatments varied significantly ($P.<05$) between sampling dates with no apparent trend. This variability may be attributed to the fluctuation in amounts of root crowns which were not separated from the root component, and, therefore, may have masked a seasonal trend in root dynamics.

Table 2. Root mass (g/m²) in the upper 80 cm of the soil profile during 1969 for four grazing intensity treatments at the Pawnee Site, U.S. IBP Grassland Biome.[1]

Grazing intensity	Sampling date (month/day) Summer								Fall		Average
	5/24	6/21	7/02	7/21	7/31	8/13	8/27	9/10	11/08	12/18	
Ungrazed	1350	1606	1473	1342	1129	1204	1189	1406	1381	1006	1309
	32[2]	116	98	65	22	45	106	43	19	35	
Light	1279	1230	1623	1082	981	994	1355	1640	1162	1006	1235
	98	54	126	62	43	72	94	100	26	28	
Moderate	1424	1080	1405	1163	1184	1137	1398	1511	1169	1074	1254
	78	128	28	130	71	94	103	104	33	36	
Heavy	1417	1589	1258	1095	852	1447	1724	1311	1302	990	1301
	41	81	75	10	57	126	92	70	45	35	
Average	1368	1376	1440	1171	1037	1190	1417	1472	1254	1019	1275

[1] Weights include plant crowns.
[2] Standard error of the mean.

Table 3. Root mass (g/m²) in the upper 80 cm of the soil profile during 1970 for four grazing intensity treatments at the Pawnee Site, U.S. IBP Grassland Biome.[1, 2]

Grazing intensity	Sampling date (month/day)											Average
	4/24	5/08	5/22	6/04	6/19	7/02	7/17	7/29	8/12	8/26	9/14	
Ungrazed	1639	1827	1706	1635	1837	1464	1896	1806	1794	1588	1636	1711
	42[3]	77	49	42	79	67	71	71	68	43	42	
Light	1654	1653	1565	1646	1654	1517	1816	1696	1741	1589	1660	1654
	42	42	46	42	42	55	73	47	55	43	43	
Moderate	1714	1690	1614	1616	1821	1918	1917	1796	1637	1700	1760	1744
	50	17	42	42	75	103	102	69	42	48	60	
Heavy	1630	1756	1588	1622	1828	1632	1731	1786	1730	1613	1783	1700
	42	58	43	42	77	42	54	66	53	42	66	
Average	1659	1731	1618	1630	1785	1633	1839	1771	1726	1623	1710	1702

[1] Weights include plant crowns.
[2] These data were estimated using a predictive equation which was formulated using actual data collected on two sampling dates (July 2 and August 26). The equation used was Y + 1122 + .9768X, where X is the root mass in the upper 10 cm and Y is the root mass in the upper cubic meters of soil.
[3] Standard error of the mean.

On the average there were about 900 g/m² of root material in the upper 10 cm of the soil profile on the shortgrass prairie. In general there was more root material in the moderately grazed and the ungrazed grasslands than in the lightly grazed and heavily grazed treatments. On the average, the lightly grazed treatment had the least amount of root material in the upper 10 cm of the soil profile. These treatment differences were significantly different at the $P<.10$ level of probability.

In 1969 the amount of roots in the upper 80 cm of the soil profile in the heavily grazed treatment ranged from 852 g/m² at the end of July to 1724 g/m² in late August (Table 2). All treatments had a peak root mass during early summer followed by a decline. This was followed by a general increase in the mass of roots by fall. No similar trend was apparent in 1970 (Table 3). Generally, a decrease in the amount of root material occurred between the November and December sampling period in 1969. This decrease was approximately 400 g/m²/80 cm.

The maximum, as well as the minimum, amounts of roots and crowns were recorded in the heavily grazed treatment. During the summer of 1969 all treatments were found to reach the minimum amount of roots on July 31, except for the moderately grazed treatment (Table 2). Although this treatment had slightly more roots on July 31 than on June 21, the difference was not statistically significant. The data from the November sampling indicate that total roots and crowns in all treatments decreased during the fall. The December sampling period shows a uniform root mass which is lower than the November period for all treatments.

During the summer of 1970 (Table 3) the amount of root material for the upper 80 cm of the soil profile varied as follows for each grazing treatment: Heavy grazing, 1828 g/m² (June 19) to 1613 g/m² (August 26); moderate grazing, 1614 g/m² (May 22) to 1918 g/m² (July 2); light grazing, 1517 g/m² (July 2) to 1816 g/m² (July 17); and ungrazed, 1464 g/m² (July 2) to 1896 g/m² (July 17).

Analysis of variance of the data using a factorial design showed no differences in the root mass among the grazing treatments. Significant differences were found only among dates, depth increments, and the dates by depth increment interaction.

The lack of grazing treatment effect is in contrast to many results reported in the literature. Most grazing studies have shown that root mass decreased with increased grazing intensity (Schuster, 1964; Lorenz and Rogler, 1967; Biswell and Weaver, 1933; Cook, Stoddart, and Kinsinger, 1958; and Jameson and Huss, 1959). Pearson (1965) and Smoliak et al. (1972) reported an increase in root mass with increased grazing pressure. The root extraction procedures used in this study did not recover all root material, i.e. fine roots passed through the 32-mesh screen. This factor may mask some treatment differences, if some treatments had significant amounts of small roots.

Research has shown that grass roots stopped growing when the aerial portions were clipped. Crider (1955) found that for various species no root growth occurred for 6 to 18 days after clipping. He also found that roots of clipped plants weighed one-eighth as much as the roots of the unclipped plants. Clipped blue grama, for example, produced approximately 85% less root biomass than unclipped blue grama.

On the Pawnee Site, 55% of the root and crown weight occurred in the upper 10 cm and 69% in the upper 20 cm of the soil profile. These data are comparable to values for blue grama-buffalograss communities reported by Weaver (1958) who found 79% in the upper 15 cm and Weaver and Zink (1946) who found 80% in the upper 35 cm of soil. In addition to the above, 16% of the total roots collected occurred between 20 and 40 cm, 9% between 40 and 60 cm, and 6% between 60 and 80 cm of the soil profile.

These data indicate that shortgrass prairies have a shallow root system maintained by low and erratic precipitation (Stoddart and Smith, 1955). Weaver (1958) substantiated this finding by stating that blue grama and buffalograss have a shallow root system which probably derives maximum benefit from soil water furnished by light showers. Weaver and Albertson (1943) indicated root depth corresponded to the most frequent depth of penetration of soil water under the ambient rainfall regime. Shantz (1911) indicated that the shortgrass root system was limited to the upper 18 inches of soil. Markle (1917) suggested that a superficial root system was due to soil water content, and Weaver and Crist (1922) said the main factor was available water. Most roots occur in the upper levels of the soil profile (Weaver, 1958; Nilsson, 1970) and decrease rapidly with depth (Dahlman and Kucera, 1965). Nilsson (1970) stated that grass roots were concentrated in the upper soil layers because grasses are shallow rooted and, further, that grass roots have thicker proximal parts.

Distribution of the root mass in this study follows that hypothesized by other investigators (Nilsson, 1970; Hanson and Stoddart, 1940; Ovington, Heitcamp, and Lawrence, 1963). Varying degrees of grazing had no significant influence on the amount of roots and crowns present. Concentration of shortgrass roots in the upper layers of the soil might be attributed to frequent small and shallow penetrating rain showers.

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