Distribution of Nitrogen in Root Materials of Blue Grama

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Highlight: *Root materials of blue grama were compartmentalized into three categories—live, senescent, and detrital. Their mean N contents were 0.89, 1.90, and 2.56%, respectively. For each root category there were significant differences both with soil depth and time of sampling. Soil N differed significantly with depth but not across dates of sampling. The standing crop of root N was found to occur largely in senescent and detrital materials. Compartmentalization of the plant N belowground as well as that aboveground should promote more successful simulation of root growth dynamics and nutrient flows.*

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Comprehensive data are available on the total amount of root materials in various grasslands and on biomass responses to stresses and perturbations (Sims and Singh, 1971). Although aboveground biomass is readily separable into four or more compartments (standing green, standing yellow or recent dead, old dead, and one or several types of litter), separating gramineous roots into even two compartments, live and dead, is time-consuming and not routinely undertaken. Measurements of root nutrient contents are commonly based on composite samples of the total root biomass. Recently proposed simulations of carbon and nutrient flows in shortgrass prairie have emphasized the paucity of information concerning the belowground ecosystem (Marshall, 1975). That in many grasslands the major portion of the total standing crop is belowground further stresses the importance of an adequate data base for describing root and nutrient dynamics

belowground.

A detailed study of roots of blue grama (*Bouteloua gracilis*) has recently been reported by Ares (1976). He used morphological characteristics to classify root materials into five categories; his interest was primarily in root growth dynamics and not in nutrient content. Concurrently with Ares work and also using shortgrass prairie in northeastern Colorado, Clark (1975) conducted an isotopic nitrogen study in which a pulse application of ^{15}N was monitored as it moved into and from different parts of blue grama plants. Clark's study involved only three root categories; these, however, could be separated by gross techniques not involving individual examination of each root or root segment. The current study concerns the N content of categories of root materials collected during the course of the ^{15}N experiment. The data are based on 11 samplings spaced over three growing seasons.

Study Site and Methodology

The study area was grassland located 56 km northeast of Fort Collins, Colo. The site has been described in some detail by French (1971). The soil is Ascalon fine sandy loam, a Mollisol, with the parent material a fluvial outwash, primarily granitic. Rooting depth exceeds 100 cm, to which the estimated available water storage is 11 cm. The annual precipitation ranges from 25 to 38 cm. Blue grama commonly constitutes 50 to 95% of the vegetative cover. Fringe sage (*Artemisia frigida*) and pricklypear (*Opuntia polyacantha*) are usually secondarily dominant components.

Mini-enclosures of blue grama were established in May 1971. Open-ended steel cylinders (20 cm in diameter and 40 cm long) were driven to nearly ground level into undisturbed blue grama. Eleven destructive samplings were made during the 1972-1974 growing seasons. In sampling, cylinders in triplicate were excavated together with their soil (c. 15 kg) and herbage content, and transported to a laboratory bench. Aboveground herbage was clipped to the soil surface and each soil column separated into its 0 to 10, 10 to 20, and 20 to 36 cm segments. Three categories of root materials were collected from each of three profile depths. The live-root category consisted of nonbrittle, lightly colored (ivory to yellowish) roots obtained by handpicking. Senescent roots were the generally brittle, shorter segmented, and darker colored roots obtained partly by handpicking and partly by air-suction pickup from thinly spread soil. The detrital category comprised the fine particles recoverable by water flotation from soil following the hand and air-suction removals.

Root dry weight, organic C, total N, and ash content were measured. Carbon was determined by combustion in an

automated electric furnace, and nitrogen by standard micro-Kjeldahl procedure. Because two of the three categories of roots were dry-sorted and unwashed before analyses, ash content frequently exceeded 50%. The standard correction of N percentage to ash-free basis was considered to be misleading since such correction included the N content of any adhering soil. Therefore, root N percentages are reported on a modified ash-free basis. The organic C value of a root sample was used to fractionate that sample into a soil and a root component. The soil N content, as determined from a root-free aliquot from the corresponding profile depth, was used to determine the amount of N in the gross root sample attributable to the soil fraction; then the remainder was attributed to the root fraction.

The N percentages determined were subjected to analyses of variance, which for the roots included two-way factorial analysis for each category across depths and dates and three-way repeated measures analysis across depth, root category, and dates. When significance was encountered at the 0.05 level, Tukey's Q value for $\alpha = 0.05$ was calculated (Snedecor and Cochran, 1959).

Results and Discussion

Table 1 presents the mean N contents of the three categories of root materials at three profile depths on 11 sampling dates. Also shown are the N contents of the soil profiles from which the roots were collected. Mean soil N content for the 0 to 10, 10 to 20, and 20 to 36 cm depths were 0.093, 0.079, and 0.072%. These differences were significant; the Q value was 0.006. Mean N contents of the three root categories (live, senescent, detrital) differed widely; the N values were 0.89, 1.90, and 2.56%, respectively. Such a progression with senescence and decomposition occurs because

Table 2. Mean N content for three root categories at three profile depths.

Root category	Profile depth (cm)	N content (%)	Q value
Live	0-10	1.081	0.093
	10-20	0.812	
	20-36	0.769	
Senescent	0-10	2.139	0.117
	10-20	1.866	
	20-36	1.642	
Detrital	0-10	2.658	0.159
	10-20	2.550	
	20-36	2.459	

Table 1. Nitrogen content (%) of blue grama roots (modified ash-free basis) and of the soil from which the roots were collected.

	Mar. 29 1972	May 10 1972	June 12 1972	Aug. 8 1972	Oct. 3 1972	Mar. 7 1973	June 13 1973	Aug. 3 1973	Oct. 12 1973	June 18 1974	Oct. 9 1974
Live roots											
0-10 cm	1.375	1.263	1.043	1.108	0.867	1.074	1.073	0.900	1.212	1.089	0.888
10-20 cm	0.847	0.744	0.796	0.731	0.777	0.863	0.896	0.710	0.955	0.750	0.862
20-36 cm	0.906	0.624	0.764	0.848	0.721	0.960	0.776	0.674	0.883	0.597	0.711
Senescent roots											
0-10 cm	2.340	2.032	1.993	2.073	1.938	2.358	2.316	2.114	2.298	2.020	2.050
10-20 cm	1.737	1.839	1.896	1.920	1.363	1.943	1.080	1.705	2.200	1.902	1.936
20-36 cm	1.502	1.630	1.500	1.527	1.783	1.678	1.909	1.633	1.858	1.419	1.624
Detrital roots											
0-10 cm	2.210	2.750	2.729	2.355	2.387	2.880	3.140	2.713	2.788	2.545	2.742
10-20 cm	2.304	2.825	2.876	2.485	1.989	2.618	2.973	2.406	2.678	2.347	2.546
20-36 cm	2.314	2.371	2.763	2.298	1.907	2.661	2.446	2.500	2.717	2.269	2.804
Soil											
0-10 cm	.100	.098	.094	.098	.089	.095	.094	.096	.087	.079	.093
10-20 cm	.079	.079	.081	.084	.077	.084	.076	.075	.080	.081	.075
20-36 cm	.070	.069	.072	.071	.064	.077	.068	.072	.074	.086	.064

carbon is lost as carbon dioxide while N is retained in the substrate.

Within each root category, the root N decreases with profile depth (Table 2). This decrease is apparently a function of the soil N content inasmuch as the ratios for root N:soil N at each depth are surprisingly constant. For live roots, the ratios are 11.6, 10.3, and 10.7. For senescent root N:soil N, the ratios (23.0, 23.6, and 22.8) are also closely similar. The detrital root N:soil N ratios are slightly less uniform—28.6, 32.3, and 34.2.

There were no significant differences across sampling dates in soil N content within any of the three profile depths, but there were significant differences with time in the N content of the three root categories. For live roots, such change with time was expected. It is well known that plant N concentration changes with growth stage. In the current study, the N content not only of live roots but also of senescent and detrital roots changed significantly within the growing season. Abiotic factors affect not only the transfer of root materials from the live root category but also the activity of decomposer organisms and, in turn, the N content of senescent and detrital roots.

Based on N contents and biomass determined in this study, the total N in root materials to a depth of 36 cm for blue grama on the site specified is 33 g/m². Distribution of this nitrogen according to categories of roots and profile depths is shown in Table 3. The 33 g/m² of root N represented 79% of the total plant N recovered. The remaining 21% was accounted for in green herbage (3.5%), in aboveground litter and standing dead (6.0%), and in crowns (11.5%). There were 380 g/m² of soil N to a 36-cm depth, therefore soil N accounted for 92% of the plant-soil total.

The current study has shown that the root materials in grassland can be compartmentalized successfully and that significant differences exist in the N contents of the root categories separable. Compartmentalization of the below-

Table 3. Distribution of nitrogen in three categories of root materials of blue grama.

Root category	Profile depth			
	0-10 cm	10-20 cm	20-36 cm	0-36 cm
	g N/m ²			
Live	2.23	0.28	0.17	2.68
Senescent	14.09	1.87	1.18	17.14
Detrital	7.63	2.66	3.07	13.36
Total	23.95	4.81	4.42	33.18

ground additionally to that of the aboveground herbage should permit more successful simulation of root growth, decomposition changes and nutrient flows.

Literature Cited

- Ares, J. 1976. Dynamics of the root system of blue grama. *J. Range Manage.* 29:208-213.
- Clark, F. E. 1975. Partitioning of added isotopic nitrogen in a blue grama grassland. *In: The belowground ecosystem—A synthesis of plant-associated processes.* (J. K. Marshall, Ed.) (In press)
- French, N. R. (Ed.). 1971. Preliminary analysis of structure and function of grasslands. *Range Sci. Dep. Sci. Ser. No. 10*, Colorado State Univ., Fort Collins. 387 p.
- Marshall, J. K. (Ed.). 1975. *The belowground ecosystem—A synthesis of plant-associated processes.* Dowden, Hutchinson & Ross, Philadelphia. (In press)
- Sims, P. L., and J. S. Singh. 1971. Herbage dynamics and net primary production in certain ungrazed and grazed grasslands. p. 59-124. *In: Preliminary analysis of structure and function in grasslands.* (N. R. French, Ed.) *Range Sci. Dep. Ser. No. 20*, Colorado State Univ., Fort Collins.
- Snedecor, G. W., and W. G. Cochran. 1969. *Statistical methods.* Iowa State Univ. Press, Ames. 593 p.