State of Dry Matter and Nutrients in Soil-Plant Systems of Arizona Fescue and Mountain Muhly

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Abstract

The state of dry matter, C, N, S and P for soil-plant systems of Arizona fescue and mountain muhly in the Arizona pine-bunchgrass community was determined as a first step to quantification of mineral cycles. These bunchgrass systems differed in stature, structure and accumulation of dry matter and nutrients, both on an absolute and per unit basal area basis for several components of the soil-plant systems. Dry matter/unit area was greater in fescue because of accumulation of standing dead vegetation and litter; weight of live shoots was 18% less in fescue than muhly. All 4 nutrients were present in greater concentrations and amounts in fescue than in muhly biomass, but accumulation patterns and influence on soil differed among nutrients. The standing state data suggest more rapid loss of dry matter and nutrients from muhly than fescue during senescence and decomposition.

The distribution and transfer of nutrients in trees and forest ecosystems has been of interest to researchers for some time, but similar investigations of grassland systems have been neglected (Rodin and Bazilevich 1967). The International Biological Program stimulated further interest in nutrient status and dynamics of ecosystems and attention was given to grasslands under this program. In particular, Bokhari and Singh (1975) examined the standing state and cycling of nitrogen in prairie ecosystems, Paul (1976) studied the distribution of nitrogen in a Canadian grassland and several studies, mostly involving nitrogen, were undertaken under the US/IBP Grassland Biome to elucidate nutrient distribution and transfer in the grasslands of the Great Plains Region (Clark 1977, Reuss and Innis 1977, Woodmansee et al. 1978).

The author has studied the distribution and transfer of nutrients in the soil-plant systems of Arizona pine forests (Klemmedson 1975, 1976; Welch and Klemmedson 1975). This paper reports research undertaken to extend that work to grasslands associated with the pine forest. It specifically deals with two key bunchgrasses, Arizona fescue (*Festuca arizonica*) and mountain muhly (*Muhlenbergia montana*), of the combined Arizona pine-bunchgrass community. The specific purpose of this study was to determine the standing state of dry matter, carbon (C), nitrogen (N), sulfur (S), and phosphorus (P) in soil-plant systems of these bunchgrasses as a first step to quantification of mineral cycles for these species (Duvigneaud and Denaeyer-DeSmet 1970).

Methods

Description of Study Area

The study area was a 2-ha grassy opening in the ponderosa pine forest on the south side of Wing Mountain, about 25 km northwest

of Flagstaff, Ariz. This is an area typical of the Southwest pine forest (Cooper 1961) that extends as a narrow strip for about 320 km across central Arizona and into New Mexico. Topographically, the region is a gentle plateau interspersed by cones of the San Francisco volcanic field (Cooley 1962). The study site is a level upland at about 2,280 m elevation. At Fort Valley Experimental Forest, about 8 km from the study site, mean annual precipitation is 57.4 cm and mean minimum and maximum temperatures are -3.2°C and 15.2°C, respectively (Schubert 1974). The Brolliar loam soil is derived from augite basalt and is classified as a Typic Argiboroll.

Vegetation of the pine-bunchgrass community consists of a mosaic of even-aged ponderosa pine groups averaging about 1/12 ha in size interspersed with grassy openings usually about the same size, but frequently ranging up to several hectares. The two bunchgrasses involved in this study are among the most common grasses in the mountainous Southwest and Southern Rocky Mountains. They dominate grassy openings of the pine-bunchgrass community in the Southwest. Welch (1973) found these two bunchgrasses account for from 81 to 91% of the total herbage in grassy openings, depending on soil parent material. Arizona fescue and mountain muhly produced 72 and 14% of the live herbage¹ respectively, on Welch's site with soil derived from basalt. Seventeen other grasses and forbs comprised the remainder of the vegetation of the grassy openings. At the site for this study basal cover was 4.0 and 2.9% for fescue and muhly, respectively.

Procedures

A pool of 30 plants each of Arizona fescue and mountain muhly was selected from the ungrazed grassy opening in which the plants appeared vigorous. Range condition of the stand was judged to be good. Criteria for selection of plants were: (1) plants must be growing as individuals in an uncrowded position with at least 2 plant diameters of distance separating potential sample plants from other plants, (2) trees or needlefall of adjacent pine stands should exert little or no influence and (3) size of plants should represent the size class range in the stand (i.e. about 4 to 13 cm average diameter).

Fifteen plants were selected at random from the pool for each species for sampling of each species at its normal maturity date (Pearson 1967). The only sampling restriction applied was that all size classes were about equally represented. After measurement of plants (two basal diameters, height of the tallest leaf and the tallest inflorescence), herbage was harvested at ground level and separated into seedheads, culms and leaves. The volume of soil in an imaginary cylinder directly beneath the plant constituted the "plant cylinder"; the volume between the boundary of the plant cylinder (edge of plant) and a vertically projected circle with twice the radius of the plant crown constituted the "open cylinder" (Fig. 1). Litter was collected from plant and open cylinders and bagged separ-

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¹Live herbage production will vary from 600-1800 kg/ha, depending on precipitation. Phil R. Ogden, personal communication.

Fig. 1. The soil-plant system with sampling scheme of soil layers depicted.

ately. An east-west bisect 5 cm in width and of variable length, as determined by the diameter of the open cylinder, was established across the center of the plant crown and the surrounding open cylinder (Fig. 1). A pit, with vertical face exposing the south side of the bisect, was dug for sampling soil and roots. The 0- to 5-, 5- to 15-, 15- to 30-, and 30- to 45-cm soil layers of the bisect were sampled individually and separated into portions associated with the plant and open cylinders (Fig. 1). Samples were immediately passed through 0.64- and then 0.32-cm screens to separate roots from soil. Root and soil samples from the open cylinder on either side of the plant cylinder were combined. Volumes of all soil samples were measured.

Herbage, root, and litter samples were oven-dried at 55° C, weighed and ground in a Wiley mill to pass a 40-mesh sieve. Soils were passed through a 2-mm sieve, oven dried and weighed, then ground in a Spex Mixer/ Mill to pass a 100-mesh sieve for chemical analysis. Vegetal and soil samples were analyzed for organic carbon (Allison et al. 1965) and sulfur (Tiedemann and Anderson 1971) by dry combustion in a LECO high frequency induction furnace. Nitrogen was determined by the macro-Kjeldahl method for soils and by semimicro Kjeldahl for vegetal samples (Bremner 1965). Phosphorus was determined using the Vanado-molybdophosphoric yellow color method following Na_2CO_3 fusion of soils and dry ashing of vegetal samples (Jackson 1958, Chapman and Pratt 1961).

Student's *t*-test was used to test hypotheses of differences between species. Unless otherwise indicated the level of significance used was $p < 0.05$.

Results

This study was not designed to evaluate the trend in dry matter and nutrients over the course of senescence and decomposition. However, with the assumption that nutrient composition of biomass components does not vary greatly from year to year, gross

inferences about these processes are possible by examining amounts and concentrations of nutrients and dry matter in components of the soil-plant systems representing various stages in the senescence-decomposition process.

Amount and Distribution of Dry Matter

The dry matter differences between species shown in Table 1 were expected. Nonetheless these comparisons are pertinent because of what differences in dry matter might suggest in terms of plant structure and function, or more specifically, what these differences might imply regarding decomposition and nutrient cycling regimes between the 2 species.

The two species were similar in height, but Arizona fescue plants were about 50% larger than muhly in basal area. Fescue plants ranged in basal area from 51 to 172 cm^2 ($\bar{x} = 96 \text{ cm}^2$) while muhly plants ranged from 26 to 126 cm^2 ($\bar{x} = 62 \text{ cm}^2$). Because of this basal area difference between species, the 2 soil-plant systems were analyzed primarily on the basis of weight per unit area and percentage distribution among components of the soil-plant systems for meaningful comparisons.

Average weight of total dry matter in the soil-plant system was 226 g for fescue and 116 g for muhly plants (Table 1). This large difference suggested significant ecological differences in structure or in fate of plant materials following senescence. Even when adjusted for basal area, dry matter of fescue plants exceeded that of muhly by 25% (2.26 vs 1.81 g/cm^2). This difference was significant at the $p < 0.10$ level and indicated greater density of dry matter in fescue. This was visually noticeable from examination of plant crowns.

Although the weight of dry matter (g/cm^2) in the live standing crop of fescue and muhly was the same (Table 1), its contribution to total dry matter differed between species (30 vs 38%). Dry matter in roots² was significantly greater in fescue while dry matter in seedheads was greater in muhly. Weight of leaves and culms per unit area was similar. Weight of dead standing crop was significantly different between species only for culms (Table 1). Weight of the litter in the plant cylinder was similar between species, while weight of litter in the open cylinder was higher for fescue than for muhly. The trend of increasing differences in weight of dry matter between fescue and muhly from standing live to standing live to standing dead to litter suggests more rapid disappearance of muhly than fescue upon senescence. The values for percentage distribution of dry matter between fescue and muhly for standing live shoots (22 vs 34%), standing dead (24 vs 21%) and litter (46 vs 41%) also portray this disappearance pattern.

Concentration of Nutrients

The status of C, N, S, and P concentration in the soil-plant systems of fescue and muhly is portrayed in Figures 2 through 5. Because of space limitations, only leaves and culms of the standing crop, and litter and soil (excluding roots) of the plant cylinder are shown. The data shown in these figures portray changes in nutrient concentration between biomass components and suggest the fate of nutrients in each system during senescence and decomposition.

Carbon

The stability in percentage C of fescue and muhly herbage observed by Welch (1980) over a 10-month period of senescence was confirmed by this study (Fig. 2). One-year-old senescent leaves were only slightly lower (4-5%) in C than that in live leaves; C in dead culms was slightly higher (2-4%). The litter component, representing both leaves and culms, was decidedly lower in C concentration than standing dead leaves or culms. The values for percentage difference in C concentration shown in the upper corner of Figure 2 portray larger differences of C between leaves and culms of muhly than between those of fescue during the transition from standing dead to litter. Moreover, a large difference in C percentage is noted between the litter and the 0- to 5-cm soil layer. Fescue appears not only to lose C less rapidly from

²Weights of root are acknowledged to be low, especially for muhly, despite sieving soil for roots during field collection. This is primarily because of the restriction of area and depth of the sample.

Table 1. Amount and distribution of dry matter in components of the soil-plant systems of Arizona fescue and mountain muhly.

Component	Arizona fescue			Mountain muhly			Significance level of difference between species (g/cm ²)
	g/plant	g/cm ²	%	g/plant	g/cm ²	%	
Standing Crop							
Shoot							
Seedheads	4.4 ± 1.5	0.04 ± 0.01	2.0	6.4 ± 1.3	0.11 ± 0.02	5.5	0.01
Leaves	37.3 ± 6.1	0.39 ± 0.05	16.5	26.7 ± 5.1	0.41 ± 0.05	22.9	ns
Culms	7.5 ± 2.7	0.07 ± 0.02	3.3	6.5 ± 1.3	0.10 ± 0.01	5.6	ns
Subtotal	49.2 ± 8.8	0.50 ± 0.07	21.8	39.6 ± 7.2	0.61 ± 0.08	34.0	ns
Roots	19.5 ± 4.2	0.20 ± 0.03	8.7	5.1 ± 1.1	0.08 ± 0.01	4.4	0.01
Total Live	68.7 ± 12.0	0.70 ± 0.09	30.5	44.7 ± 8.0	0.69 ± 0.08	38.4	ns
Dead							
Leaves	40.8 ± 9.1	0.39 ± 0.06	18.1	21.9 ± 5.5	0.32 ± 0.05	18.8	ns
Culms	13.0 ± 3.4	0.12 ± 0.03	5.7	2.6 ± 0.7	0.04 ± 0.01	2.2	0.01
Subtotal	53.8 ± 12.1	0.51 ± 0.08	23.8	24.5 ± 6.1	0.36 ± 0.06	21.0	ns
Total Standing Crop	122.5 ± 23.4	1.21 ± 0.16	54.3	69.2 ± 13.1	1.05 ± 0.12	59.4	ns
Litter							
Plant cylinder	40.0 ± 8.6	0.39 ± 0.05	17.7	25.0 ± 7.1	0.36 ± 0.05	21.5	ns
Open cylinder	63.2 ± 9.9	0.66 ± 0.09	28.0	22.3 ± 3.3	0.40 ± 0.06	19.1	0.05
Subtotal	103.2 ± 14.1	1.05 ± 0.09	45.7	47.3 ± 8.8	0.76 ± 0.09	40.6	0.05
Total Dry Matter	225.7 ± 34.5	2.26 ± 0.18	100.0	116.5 ± 21.3	1.81 ± 0.19	100.0	0.10
Mean Basal Area (cm ²)	96.0			62.2			

biomass components than muhly, but it seems to maintain a generally higher concentration of C than muhly after initial decay. Live leaves and culms, and dead leaves of muhly were higher in C than those parts of fescue. Carbon concentrations in the litter portion in both cylinders and soil of the 0- to 5-cm layer of fescue systems

were all significantly ($p < 0.01$) higher than those components in muhly. Although C percentage of litter in plant and open cylinders was similar for fescue, it was 1/3 lower in the open cylinder (15%) of muhly than in the plant cylinder (22%).

Nitrogen

Soil-plant systems of Arizona fescue were clearly more concentrated in N than those of mountain muhly and the differences were apparent in both plants and soil (Fig. 3). Seedheads and leaves

Fig. 2. Carbon percentage for components of fescue (F) and muhly (M) soil-plant systems. Standing biomass is labeled for species and either leaves (L) or culms (C).

Fig. 3. Nitrogen percentage and C/N ratios for components of fescue (F) and muhly (M) soil-plant systems. Standing biomass is labeled for species and either leaves (L) or culms (C).

(both live and dead) and litter differed in N between species; culms and roots did not. Every compartment of the soil except the 5- to 15-cm layer in the plant cylinder was significantly higher in N under fescue than under muhly. C/N ratios (Fig. 3) reflect the higher N concentration of fescue leaves and the high relative loss of N from both species during senescence. The enrichment of decomposing litter with N following transition from standing dead leaves to litter was accompanied by a decline in the C/N ratio. This has been observed elsewhere (Bocock 1963, Tchagina et al. 1968, Klemmedson 1975). Although live fescue and muhly culms have about the same N and C concentrations, and hence C/N ratios (Fig. 3), N in muhly undergoes more marked change in the transition from live to standing dead and then to litter than that in fescue. These changes were reflected in the C/N ratio. C/N ratios of muhly biomass components were consistently higher than those of fescue, but those of the soil were equal to those in fescue or lower.

Sulfur

The curves for concentration of S in fescue and muhly soil-plant systems (Fig. 4) are similar to those for N. They show significantly higher ($p < 0.01$) S percentages in fescue for standing live and dead leaves and for litter. In the soil, fescue and muhly systems differed in percentage S only in the 0- to 5-cm layer of the plant cylinder; that difference was significant at $p < 0.10$.

The difference in S concentration between standing live and standing dead leaves (Fig. 4) was slightly greater in fescue than muhly. However, in the transition from standing dead to litter, S concentration remained static in fescue while declining 23% in muhly. The overall difference in S percentage between standing live leaves and litter was somewhat greater for muhly than for fescue (-44 vs -38%). Although the S concentration of fescue and muhly leaves (live and dead) did not differ (Fig. 4), the relative magnitude of S concentration was reversed in standing dead culms from that of standing live culms because of the higher loss of S in muhly than in fescue (-59 vs -39%) during senescence. Assuming the distribution of leaves and culms in the litter was comparable to that in the standing dead category (Table 1), the high S percentage

Fig. 4. Sulfur percentage and C/S ratios for components of fescue (F) and muhly (M) soil-plant systems. Standing biomass is labeled for species and either leaves (L) or culms (C).

Fig. 5. Phosphorus percentage and C/P ratios for components of fescue (F) and muhly (M) soil-plant systems. Standing biomass is labeled for species and either leaves (L) or culms (C).

of fescue litter is surprising. The C/S ratios for biomass components in the muhly systems seem high, while those for the soil seem low. The magnitude of differences in C/S ratios between species, if significant for the soil layers, portrays a marked effect of each species on the soil in its soil-plant system.

Phosphorus

The status of P in fescue and muhly soil-plant systems shows similarities and differences with the other nutrients discussed. As for C, N, and S, fescue systems were generally higher in P than muhly systems (Fig. 5). Seedheads, live and senescent leaves, roots in the 0- to 15-cm layer, and litter and soil in the 0- to 5-cm layer, both in the plant cylinder, were all higher in percentage P in fescue than in muhly systems. However, in contrast to the other nutrients, the difference in P concentration between live and dead standing crop and litter components (presumably reflecting change of P status during senescence and decomposition) were similar for the two species (Fig. 5, upper right). The low P status of muhly leaves is reflected in high C/P ratios. However, as in the case of S, the C/P ratios narrowed markedly during decomposition and were lower in muhly than in fescue for the soil layers. The high status of P in soil layers of both systems compared to that of the biomass is noteworthy.

N/S and N/P Ratios

Except for recent dead shoots, the N/S ratios were constant among biomass components and did not differ among species (Table 2). However, soil under the two species differed in magnitude of the N/S ratio. The soil N/S ratio narrowed with increasing depth, but was narrower for muhly than for fescue. Kelly and Lambert (1972) found that although percentage N and S in radiata pine may change as a function of plant part, location or season, the total N/organic S ratio remained constant at 33.3 (on a gram atom basis) and was related to the constancy of N and S in plant protein (total N/total S ratios ranged up to 25). Total N/total S values for

Table 2. N/S and N/P ratios for components of fescue and muhly soil plant-systems.

Component	N/S		N/P	
	Fescue	Muhly	Fescue	Muhly
Shoots	10.0	10.0	4.8	5.0
Roots	10.0	10.0	5.0	5.3
Recent Dead	7.7	7.7	6.7	6.7
Litter	10.0	10.0	6.2	5.6
Soil				
0-5 cm	12.5	9.1	2.4	1.5
5-15 cm	11.1	8.3	1.1	1.0
15-30 cm	9.1	7.1	1.0	0.8
30-45 cm	8.3	6.7	0.8	0.6

fescue and muhly shoots were 23 and 21, respectively. Dijkshoorn and Van Wijk (1967) obtained values ranging from 40 for legumes to 31 for grasses.

N/P ratios were constant among shoots and roots and among species, but widened in dead shoots and litter (Table 2). In the soil, N/P ratios narrowed appreciably and, as in the case of N/S ratios, a species difference showed up with narrower N/P ratios under muhly than fescue. Thus, N, S and P were differentially retained by the soil fractions of fescue and muhly soil-plant systems.

Amounts of Nutrients

Carbon

Fescue soil-plant systems contained about 20% more C than

muhly systems, most of which (70%) was in the soil (Table 3). But, soil under fescue and muhly differed in amount of C only in the 0- to 5-cm layer; this layer under fescue contained 37% more C than that under muhly.

The pattern of differences in C between fescue and muhly for the total standing crop of the systems agrees closely with the pattern for dry matter (Table 1). This was expected since carbon concentration by plant parts was similar between species. Amount of C in the total standing crop did not differ between species. However, it did differ in seedheads, roots in 0- to 15-cm layer and standing dead culms, the same categories that differed in dry matter.

In the litter, a difference between species in amount of C occurred only in the open cylinder. But, the difference was large (3-fold) and associated with both dry matter (Table 1) and concentration (Fig. 2) differences. Because of the large differences in C in the four components of the biotic system described above there was also a difference shown in C for the total of the biotic components.

Nitrogen

Per unit of basal area, fescue plants contained 19% more N in their soil-plant systems than muhly plants (Table 3). Most of this additional N (78%) showed up in the soil component, but differences between species in amounts of soil N were significant only for the 0- to 5-cm soil layer. Soil in this layer under fescue contained nearly 30% more N than the same soil layer under muhly.

Although the total live standing crop of the two species did not differ in amount of N (Table 3), differences did show up for certain plant parts (i.e. seedheads, leaves, roots), in which case both plant

Table 3. Weight (mg/cm²) basal area of carbon, nitrogen, sulfur, and phosphorus in plant-soil systems of Arizona fescue and mountain muhly.

Component	Carbon			Nitrogen			Sulfur			Phosphorus		
	Fescue	Muhly	Significance level	Fescue	Muhly	Significance level	Fescue	Muhly	Significance level	Fescue	Muhly	Significance level
Standing Crop												
Live												
Aboveground												
Seedheads	17	44	0.05	0.5	1.4	0.05	< 0.1	0.1	0.01	0.1	0.2	0.10
Leaves	154	166	ns	5.5	3.6	0.50	0.5	0.3	0.05	1.1	0.8	0.05
Culms	28	42	ns	0.4	0.6	ns	0.1	0.1	ns	0.1	0.2	ns
Subtotal	199	252	ns	6.4	5.6	ns	0.6	0.5	ns	1.3	1.2	ns
Roots	81	31	0.01	1.4	0.5	0.01	0.2	0.1	0.01	0.3	0.1	0.01
Total Live	280	283	ns	7.8	6.1	ns	0.8	0.6	ns	1.6	1.3	ns
Recent Dead												
Leaves	143	124	ns	2.9	1.7	0.05	0.3	0.2	0.05	0.4	0.3	0.05
Culms	52	18	0.01	0.3	0.1	0.01	0.1	< 0.1	0.01	< 0.1	< 0.1	0.01
Subtotal	195	142	ns	3.2	1.8	0.05	0.4	0.2	0.01	0.4	0.3	0.01
Total Standing Crop	475	425	ns	11.0	7.9	0.10	1.2	0.8	0.05	2.0	1.6	0.10
Litter												
Plant Cylinder	100	75	ns	3.4	2.2	0.05	0.3	0.2	0.01	0.5	0.4	ns
Plant Cylinder	192	58	0.01	5.5	2.1	0.01	0.4	0.2	0.01	0.7	0.4	0.05
Subtotal	292	133	0.01	8.9	4.3	0.01	0.7	0.4	0.01	1.2	0.8	0.01
Total of Biotic Components	768	558	0.05	19.9	12.2	0.05	1.9	1.2	0.01	3.2	2.4	0.05
Soil												
0-5 cm layer, plant cylinder	242	151	0.01	11.5	8.1	0.01	1.0	0.8	ns	5.1	5.6	ns
0-5 cm layer, open cylinder	754	581	0.05	38.1	30.4	0.05	3.2	3.3	ns	16.3	19.0	ns
Subtotal	996	732	0.01	49.6	38.5	0.05	4.2	4.1	ns	21.4	24.6	ns
5-15 cm layer	898	862	ns	52.3	50.4	ns	4.8	6.1	0.05	45.7	48.9	ns
15-30 cm layer	857	737	ns	60.2	51.1	ns	6.5	7.3	ns	62.0	63.2	ns
30-45 cm layer	543	486	ns	41.2	36.0	ns	5.1	5.5	ns	50.9	58.6	ns
Total Soil	3294	2817	0.10	203.3	176.0	0.10	20.6	23.0	ns	180.0	195.3	ns
Total for Soil-Plant Systems	4062	3375	0.05	223.2	188.2	0.05	22.5	24.2	ns	183.2	197.7	ns

Table 4. Percentage of total nutrients in aboveground standing crop, litter, and soil plus roots for fescue and muhly soil-plant systems.

	C		N		S		P	
	Fescue	Muhly	Fescue	Muhly	Fescue	Muhly	Fescue	Muhly
Aboveground								
Standing Crop	9.7	11.7	4.3	3.9	4.4	3.2	1.0	0.7
Litter	7.2	3.9	4.0	2.3	3.4	1.4	0.6	0.4
Soil and Roots	83.1	84.4	91.7	93.8	92.2	95.1	98.4	98.9

structure (Table 1) and nitrogen concentration (Fig. 3) played a part in the response. As suggested earlier, fescue systems contained higher amounts of N per unit of basal area in standing dead and litter components. Amount of N in the total biotic part of the system was also significantly higher in fescue than in muhly; this follows because of the heavy contribution of standing dead and litter components to the biotic fraction of the soil-plant system.

Phosphorus

For the entire soil-plant system, amount of P did not differ among species, nor did it differ among species for the soil component alone as was the case for N and C. P did differ between species for the total of biotic components (Table 3). Biotic components of fescue systems contained 40% more P than those in muhly systems. But this difference did not extend to all components. P differed in seedheads, leaves and roots of the 15- to 45-cm layer at the $p < 0.10$ level and in roots of the 0- to 15-cm at the 0.01% level (not shown in Table 2). In the standing dead, both leaves and culms of fescue contained more P than those of muhly. Only litter in the mulch cylinder differed in amount of P between species. Where differences between species did occur, they were explained more by differences in dry matter (Table 1) than by differences in nutrient concentration (Fig. 5).

Sulfur

Sulfur and P displayed similar patterns among species with respect to distribution of nutrients. Species did not differ in amount of S in the soil-plant system or in the soil component (Table 3). However, S for the total of the biotic components differed between species ($p < 0.01$). In components of the biotic system, differences were more marked for S than for P, especially in seedheads and leaves of standing crop and in the litter where fescue contained more S than muhly in both the plant and open cylinders. Depending on the component, both the amount of dry matter and the concentration of S contributed to differences in amount of S between species.

Discussion and Summary

Differences in the appearance and structure of Arizona fescue and mountain muhly were largely verified by the inventory of dry matter. Higher biomass values for most biotic components of fescue were taken for granted, given the greater basal area per plant for fescue. Moreover, the greater weight of dry matter per unit area for fescue was not unexpected. This confirmed the obvious higher density of dry matter in fescue that is readily noticeable even in casual field observations. Arizona fescue is characteristic of the genus *Festuca* in that culms and leaves are tightly packed in the crown of the plant. In contrast, the crowns of muhly plants are not compacted. As manifested by dry matter analysis, the greater weight/unit area and density of the plant crown in fescue was at least in part attributable to accumulation of standing dead vegetation and litter (Table 1). Weight of the live shoot of fescue was 18% less per unit area than that of muhly.

Appearance is deceiving; the erect, stiffer leaved, heavier-culmed fescue plants were consistently more concentrated in N, S and P than muhly plants. In 14 of 15 instances where a significant difference occurred in concentration of N, S or P for a biotic component, the nutrient concentration was greater in the fescue component. Welch (1973) found N was almost always more concentrated in live and dead standing crop of fescue than muhly, regardless of soil parent material.

Although the 4 nutrients were present in fescue systems in greater concentration and amount than in muhly systems, the accumulation patterns differed among nutrients. Increased accumulation of S and P in fescue was largely restricted to biotic components and influenced the soil only in the 0- to 5-cm layer. However, for N, increased accumulation extended throughout the fescue soil-plant system. Differences between species in N/S and N/P ratios for soil are a manifestation of these differential accumulation patterns. Differences in organic C between the two systems resulted not from accumulation at higher concentrations in the live tissue, but because of differences in retention of C during senescence and decomposition.

If distribution of the 4 nutrients among the 3 most distinct compartments (aboveground standing crop, litter, and soil plus roots) is considered (Table 4), then the most marked difference between fescue and muhly systems was in the litter compartment. Here differences ranged from 50% for P to 242% for S. Thus, dry matter (Table 1) and nutrients tend to accumulate in fescue litter. Differences are less pronounced in the standing crop and not apparent in the soil-root compartment.

Results of this study suggest the following working hypothesis: that loss of dry matter and nutrients proceeds more slowly in soil-plant systems of Arizona fescue than those of mountain muhly. Because the C/N ratio is less favorable for decomposition in muhly than in fescue, it is hypothesized that translocation is largely responsible for N, S and P losses during senescence. Several studies (Charley 1977, Clark 1977, Cole et al. 1977) have demonstrated the importance of translocation of elements in senescing plants. Techniques similar to those used by Clark (1977) would be required to demonstrate the latter hypothesis. Physical arrangement of dry matter would seem to be an obvious factor influencing rate of disappearance of dry matter by decomposition in these systems, but other indices of organic matter quality not evaluated here, such as initial content of lignin, Ca and K (Van Cleve 1974) are possibly involved.

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