Rooting characteristics of four intermountain meadow community types

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Abstract

Healthy meadow communities generally have excellent soil binding properties. However, belowground characteristics of these communities have seldom been evaluated. In 4 meadow community types (CTs) we measured root mass and root length density (RLD) at 10-cm intervals to 40 cm soil depth. The CTs occurred along a wet to dry soil moisture gradient. The ranking of CTs from wettest to driest was: *Carex nebrascensis* (CANE) > *Juncus balticus* (JUBA) > *Carex douglasii* (CADO) > *Poa nevadensis* (PONE). Total RLD and mass to 40 cm paralleled the order of soil wetness, i.e., there were more roots at the wetter sites. Values of total RLD and mass for the 4 CTs were: 95.6 cm cm^{-3} and 3,382 g m^{-2} respectively for CANE; 33.6 cm cm^{-3} and 2,545 g m^{-2} for JUBA; 25.7 cm cm^{-3} and 1,526 g m^{-2} for CADO; and 8.8 cm cm^{-3} and 555 g m^{-2} for PONE. Root mass and RLD declined with depth, a result consistent with other graminoid systems. The RLD values for CANE, JUBA, and CADO are exceptionally high compared to literature values from other graminoid plant communities. The high RLD of the wet CTs suggests that they have superior site-stabilizing characteristics.

Key Words: root length density, root mass, root distribution, meadow ecology, soil water regime

Although management of riparian communities has recently received considerable attention, there is limited information on many important attributes of these communities. Rooting characteristics influence many aspects of community function. Moore and Rhoades (1966) concluded that there is a link between the large mass of surface roots and low soil bulk density in wet meadows. Smith (1976) found an inverse relationship between the amount of roots and bank erosion rate, and concluded that plant roots can be critical in stabilizing channel banks of rivers. Little information is currently available on rooting characteristics of either individual species or communities with riparian systems. When rooting data have been collected, generally root mass rather than root length density (RLD) has been the measured variable. However, RLD more accurately reflects the amount of active root absorbing surface (Troughton 1957, Andrews and Newman 1970, Jordan and Miller 1982, Kramer 1983), and RLD may better relate to soil binding ability and/or root activity in relation to environmental variables (Bohm 1979). The objectives of this study were to: (1) characterize the soil water regime of 4 meadow community types (CTs); (2) compare root length density, mass, and distribution of the 4 CTs; and (3) relate soil moisture gradients to rooting habits among the CTs.

Materials and Methods

Study Site and Data Collection

The study was conducted on the Sheldon Antelope Refuge in northern Washoe County, Nevada. Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) dominates the uplands, with various associated forbs and bunchgrasses. Nomenclature follows Hitchcock and Cronquist (1973). The meadows are located at an elevation of 1,915 m. The refuge is part of the Basin and Range geological province (Hunt 1967). A uniform layer of Miocene/Pliocene olivine basalt dominates the landscape, as broad flat tables and rimrock canyons (Bonham and Papke 1969).

After an initial reconnaissance, 4 herbaceous meadow community types (CT) were identified within several large meadows in a 20-ha area of the refuge. Selection was based upon floristic characteristics (Manning 1988). Each CT was named by the dominant graminoid: *Carex nebrascensis* (CANE) CT, *Juncus balticus* (JUBA) CT, *Carex douglasii* (CADO) CT, and *Poa nevadensis* (PONE) CT. Four replications of each CT were selected, for a total of 16 stands. The stands were at least 100 m apart within the larger meadows. Each stand was moderately grazed during the summer.

Water table fluctuations and soil matric potential were monitored weekly from 25 March to 11 September 1986 using observation wells and gypsum blocks (Manning 1988). Three wells were placed within each stand and installed to either 100 cm soil depth or to a confining layer. Three gypsum block pairs (10 and 40 cm depths) were interspaced between the wells. Aboveground biomass was clipped to ground level during full-flower or soft dough stage to attain peak standing crop. Root samples were collected in late March, 1986. All species were dormant except *C. nebrascensis*, which is an overwintering sedge (Ratliff 1983). A hand corer (7.2 cm diameter) (Equipment for Soil Research B.V. Eijkelkamp, Lathum, The Netherlands) was used to extract the samples. Six cores per stand were sampled at random. Samples were collected at 4 depth increments: 0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm.

Laboratory Analysis

Roots were separated from soil using a hydropneumatic elutriation system and 0.5-mm mesh screens (Gillison's Inc., Benzonia, Mich.). Each sample was floated in water; live roots were partially separated from debris and dead roots and sorted into 3 categories: rhizomes, large roots (diameter 0.9 mm or greater), and fine roots (diameter less than 0.9 mm). We chose 0.9 mm because it appeared to be a natural break. Presence of an intact stele was the criterion used to determine live roots (Nye and Tinker 1977). The length of rhizomes and large roots was manually measured to the nearest mm. The length of fine roots was measured with a root length scanner (Commonwealth Aircraft Corp., Melbourne, Australia). To remove the effect of debris and dead roots, a subsample of fine roots was manually counted for live and debris plus dead root intersections using a 10 power binocular microscope. Root length density (RLD) was calculated from the total live root length of the sample and the volume of soil that the roots occupied. The scanned samples were oven dried at 75° C for 24 hours and weighed. A subsample was ashed at 500° C for 24 hours, and root mass was corrected to an ash-free basis.

Data Analysis

The data were analyzed as a completely randomized design using

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Table 1. Floristic and edaphic characteristics for the *C. nebrascensis* (CANE), *J. balticus* (JUBA), *C. douglasii* (CADO) and *P. nevadensis* (PONE) CTs.

	Community Type			
Variable	CANE	JUBA	CADO	PONE
% composition of the dominant (CV%)	58 (8)	59 (12)	62 (22)	61 (31)
Species richness	13	21	17	17
Annual production (g m^{-2})	602.40	766.40	206.30	322.80
Soil (great group)	Haplaquolls	Haplaquolls	Haploxerolls/Argixerolls	Haploxerolls
Sampling date at which soil moisture dropped below -0.3 MPa (1986)				
10 cm depth	Sept. 11	Aug. 9	June 11	June 4
40 cm depth	Sept. 11	Sept. 11	July 9	June 19

the Statistical Analysis System (SAS). The General Linear Model procedure was used because the number of replications was not equal across treatments. Two stands were floristic outliers based upon classification and ordination (Manning 1988) and were eliminated. When treatment effects were significant ($p<.05$), means were separated using the least significant difference (LSD) method. Mass and RLD values are reported in 10-cm increments.

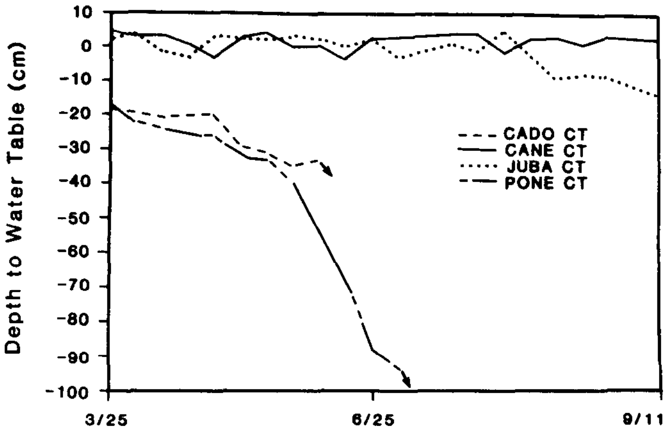

Fig. 1. *Representative water table fluctuations for CANE, JUBA, CADO and PONE CTs taken from 3/25/86 to 9/11/86. Arrows indicate that the water table fell below the depth of the well bottoms.*

Results and Discussion

Based on both soil (Table 1) and hydrologic characteristics (Fig. 1), the 4 CTs could be separated into 2 wet meadow types (CANE and JUBA) and 2 dry meadow types (CADO and PONE). Ordination of the 4 CTs based on floristics revealed a wet to dry coenocline with CANE at the wettest end followed by JUBA, CADO, and PONE at the driest end (Manning 1988). Large differences among CTs for root mass and RLD (Fig. 2) appeared to be related to the edaphic and hydrologic characteristics. Values of total root mass to 40 cm for the 4 CTs were: 3,382 g m^{-2} for CANE, 2,545 g m^{-2} for JUBA, 1,526 g m^{-2} for CADO and 555 g m^{-2} for PONE. The wetness of the CANE CT indicates that the large root mass was not essential to acquire sufficient moisture for growth. Thus, it appears that factors other than water availability *per se* were influencing root growth. Nutrient limitations probably affected root growth and distribution (Andrews and Newman 1970). Both Auclair (1982) and Bernard and Fiala (1986) have suggested that nutrient limitations may help explain the extensive root growth in *Carex* meadows.

The CT rankings were similar for mass and RLD; however, there were relatively small differences in root mass at 0–10 cm between CANE and JUBA, yet RLD in the CANE CT was more than double that for the JUBA CT (Fig. 2). Root length density of CANE declined only 44% between 0–10 and 10–20 cm depths, whereas RLD for the other 3 CTs at 10–20 cm was about one-fifth the value at 0–10 cm (Fig. 2). Svejcar and Christiansen (1987) have suggested that fibrous roots may have more length per unit mass with increasing depth, and thus mass may decline more rapidly with depth than length. For root mass all CTs exhibited the decline

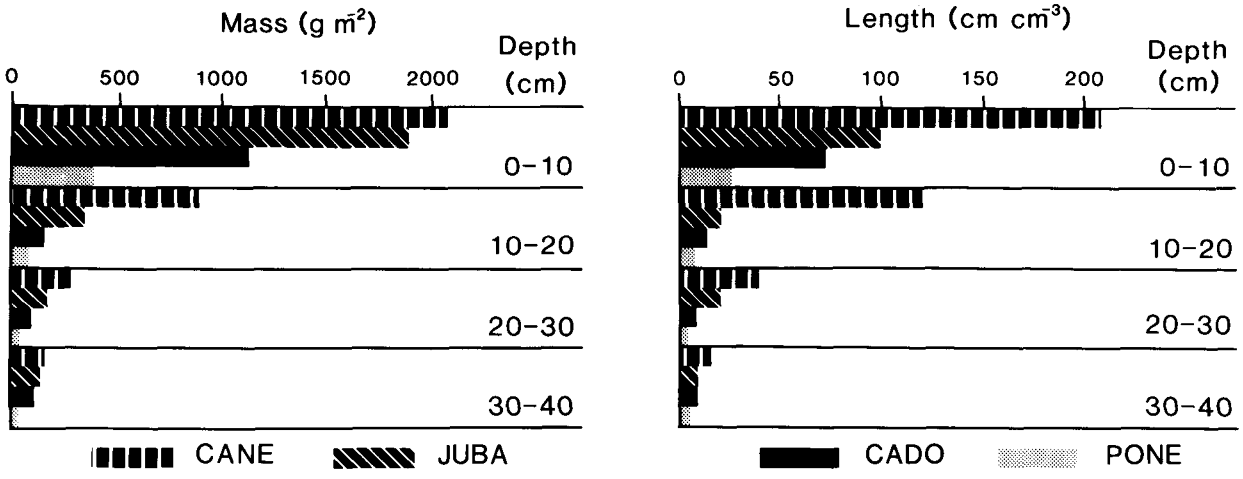

Fig. 2. *Total root mass and root length density for CANE, JUBA, CADO and PONE CTs for the 0-10, 10-20, 20-30, and 30-40 cm depths.*

Table 2. Mass per unit area of soil (g m^{-2}) of rhizomes, large[1] and fine roots for *C. nebrascensis* (CANE), *J. balticus* (JUBA), *C. douglasii* (CADO) and *P. nevadensis* (PONE) CTs.

	Rhizomes				Large				Fine			
Depth (cm)	CANE	JUBA	CADO	PONE	CANE	JUBA	CADO	PONE	CANE	JUBA	CADO	PONE
0–10	679.2a[1]	680.5a	349.1b	97.7c	241.8a	265.3a	159.6a	76.8c	1153.7a	934.1a	628.6a	213.8b
10–20	62.4a	6.9b	1.8b	.2b	272.6a	190.3b	82.5c	49.8c	543.3a	151.5b	84.3b	34.1b
20–30	3.6a	8.9a	1.9a	1.2a	108.4a	97.2a	55.2b	13.1c	166.0a	71.0b	42.7b	20.2b
30–40	3.8a	2.9a	.4a	4.3a	59.4a	96.1a	67.7a	21.6b	87.9a	40.8bc	51.3b	22.6c

[1]Large roots are greater than 0.9 mm in diameter; fine roots are less than 0.9 mm in diameter.
[2]Means within size class rows followed by different letters are significantly different ($P<.05$).

with depth typical of many graminoid systems (Smoliak et al. 1972, Bartos and Sims 1974). Bernard and Fiala (1986) reported that over 90% by weight of *Carex trichocarpa* roots were in the upper 10 cm of soil.

The total root mass values reported in this study are comparable to values reported in the literature (Table 2). Kuramoto and Bliss (1970) measured root mass to 25 cm of 3,527 g m^{-2} for a "tall sedge snowbank" community and 750 g m^{-2} for a "mesic grass" community. In a sub-humid tallgrass prairie, Dahlman and Kucera (1965) reported root mass of 954 g m^{-2} in the 0–10 cm soil layer. However, there are relatively few studies of root length with which to compare our results. Annual crop species generally exhibit surface horizon RLD values in the range of 2.0 to 8.0 cm cm^{-3} (Taylor and Klepper 1974, Gregory et al. 1984, McGowan et al. 1984), although lower values have been reported (Allmaras et al. 1975). Svejcar and Christiansen (1987) measured maximum RLD values of 9.0 cm cm^{-3} on Caucasian bluestem *(Bothriochloa caucasica)* pastures at the 0–30 cm depth. In this study, average RLD in the 0–40 cm depth averaged 95.6, 33.6, 25.7, and 8.8 cm cm^{-3} for the CANE, JUBA, CADO, and PONE CTs, respectively. Thus it appears that RLD of the PONE CT is comparable to that reported from other grassland communities; but RLD from the other 3 CTs, especially CANE, is much higher than generally found in graminoid systems.

Separation of belowground components allows an assessment of how each component influences mass and length. The fine roots (<.9mm) had an overwhelming influence on RLD (Table 3). In general, rhizomes and large roots (>.9mm) together accounted for less than 5% of the total root length in a given sampling depth. However, in a number of instances, the combined mass of rhizomes and large roots was nearly twice as high as that of fine roots.

If root length is critical for soil binding (Pavlychenko 1942, Crider 1945, Troughton 1957), then total belowground mass may not be sufficient for assessing the erosion control potential of a given community. Root length density is probably more closely related to erosion control; it may at least be necessary to separate mass of fine roots from mass of other belowground components. An additional consideration is that roots and rhizomes may have different growth periods (Gallagher et al. 1984), and a seasonal change in belowground mass could reflect either root or rhizome growth.

Summary and Conclusions

Root length density was relatively high in the 4 meadow CTs, but especially high in the 2 wet meadow CTs (CANE and JUBA). There was a direct relationship between the wetness of a site and the RLD and mass of the existing CT, i.e., the wetter sites had more length and mass than the drier sites. Thus, the extensive growth in the 2 wet CTs must have been a response to factors other moisture acquisition; nutrient uptake has been suggested in the literature. Further research will be necessary to determine how rooting patterns influence the stability and soil-binding characteristics of a given riparian community.

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Table 3. Length per unit volume of soil (cm cm^{-3}) of rhizomes, large[1] and fine roots for *C. nebrascensis* (CANE), *J. balticus* (JUBA), *C. douglasii* (CADO) and *P. nevadensis* (PONE) CTs.

	Rhizomes				Large				Fine			
Depth (cm)	CANE	JUBA	CADO	PONE	CANE	JUBA	CADO	PONE	CANE	JUBA	CADO	PONE
0–10	.24b[2]	.27b	.32a	.12b	1.90a	1.83a	1.31a	.99b	206.75a	97.09b	71.86b	22.65c
10–20	.03a	.00b	.01b	.00b	1.22a	.85b	.70b	.43c	117.83a	17.93b	12.69b	4.33b
20–30	.00a	.00a	.01a	.00a	.58a	.51a	.49a	.22b	37.81a	9.23b	6.59b	3.13b
30–40	.00b	.00b	.00b	.01a	.39ab	.56a	.52ab	.35b	15.54a	6.28b	8.18b	3.04c

[1]Large roots are greater than 0.9 mm in diameter; fine roots are less than 0.9 mm in diameter.
[2]Means within size class rows followed by different letters are significantly different ($P<.05$).

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