NOTE

FINE ROOT BIOMASS AND PRODUCTION IN A SEMIARID MEXICAN SHRUBLAND

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ABSTRACT—I describe the vertical distribution of root biomass and root productivity in a xeric shrubland of central Mexico. The effect of the soil nitrogen on root production was evaluated with a fertilization experiment. The highest percentage of roots was found at a depth of 40 to 60 cm. Monthly variation in root biomass for diameter class was significant. Fine and very fine roots were the most important fraction in terms of biomass and production. The highest production of fine root occurred in native soil versus the other treatments.

RESUMEN—Se describe la distribución vertical de la biomasa de raíces y la productividad de raíces en un matorral semiárido del centro de México. Con un experimento de fertilización se evaluó el efecto del nitrógeno del suelo sobre la producción de raíces. El mayor porcentaje de las raíces se encontró entre 40 y 60 cm de profundidad. La variación mensual en la biomasa de raíces por clases de diámetros fue significativa. Las raíces finas y muy finas fueron la fracción más importante en términos de biomasa y producción. La producción de raíces finas más alta ocurrió en el suelo nativo en contraste con los otros tratamientos.

The study of roots in arid and semiarid ecosystems has received little attention. Estimates of standing crop root biomass are scarce, and semiarid shrubland ecosystems are one of the least studied with respect to root dynamics (Lauenroth and Gill, 2003). Fine roots represent a significant component of belowground biomass and carry out essential functions of soil resource acquisition (Eissenstat and Yanai, 1997). Fine root production in desert ecosystems is limited principally by water availability (Ludwig, 1987; Pavón and Briones, 2000). Terrestrial ecosystems are receiving unprecedented amounts of anthropogenic nitrogen; however, the effects of soil nutrients, especially nitrogen, on fine root biomass and production have been poorly documented (Norby and Jackson, 2000). Evidence indicates that with increasing N availability, root biomass decreases, but it is unclear whether fine root production also decreases (Nadelhoffer, 2000). Root dynamics in relation to soil nutrients can be examined with a fertilization experiment within a site. This approach reduces some of the confounding intersite environmental factors and allows for species composition to be held constant, although the results might not be comparable to natural fertility gradients, because plants growing at each site might be adapted to fertility at that site (Ostertag, 2001).

The main goal of this work was describe the vertical distribution of root biomass and root productivity in a semiarid shrubland in central Mexico. With a fertilization experiment, I evaluated fine root production in relation to nitrogen changes in the soil.

The study was carried out at Puerto la Zorra in the Barranca de Metztitlán biosphere reserve, a mountainous area of the state of Hidalgo, Mexico (20°14′ to 20°45′N, 98°23′ to 98°57′W). The study area has a dry climate, with rainy season occurring between May and October. Mean annual precipitation is 564.5 mm and mean annual temperature is 20.8°C (García, 1981). The vegetation of the study site is a semiarid microphyllous shrubland dominated by *Mimosa leucaenoides* and other shrubs, including *Senna wislizeni*, *Krameria cytisoides*, *Pseudosmodingium*, *Acacia palmeri*, *Sebastiana pavoniana*, and *Rhus virens*. A plot of 50 m × 50 m was established at 1,578 m elevation on a 33° southwest-facing slope. The soil in the site is a shallow loam (60 cm deep) with abundant rocky outcrops.

In March 2001 (dry season), 2 trenches 1.2 m × 0.6 m and 60 cm deep were excavated inside the plot. To quantify vertical distribution of root biomass, 2 soil samples (10 cm × 10 cm × 10 cm deep) were extracted on one smooth wall in each trench (Böhm, 1979). Roots from each soil sample were sorted by hand and washed under running tap water through 0.96-mm² sieves. Roots were then dried to constant mass at 90°C and weighed to the nearest 0.01 g. All biomass data were converted to g/m². The roots were divided into 3 diameter classes: <1 mm (very fine), 1 to 3 mm (fine), and >3 mm (coarse).

To describe monthly variation in root biomass and estimated root productivity, 30 cylindrical soil cores (7 cm diameter, to a depth of 20 cm) were extracted each month from March through October 2001. Coring locations were randomly placed within the plot. To avoid disturbance, care was taken to ensure that they were at least 60 cm from the base of any nearby shrub and sampling sites never coincided. The roots from each soil core were extracted and sorted as described above. Root production was estimated as the sum of differences between annual maximum and minimum dry-matter biomass for each root diameter class (McClaugherty et al., 1982). I selected the max-min method on the assumption that fine root production occurs in pulses of one to several months duration. In the study site, and other semiarid areas in central Mexico, plant production is related to the rainy season and occurs as a single pulse (Pavón and Briones, 2000).

A fertilization experiment consisted of 3 treatments applied within the plot: (i) native soil (0.65% N_{total}), (ii) native soil enriched with urea (0.96% N_{total}), and (iii) soil poor in nitrogen (0.27% N_{total}). The urea was incorporated to the soil at rate of 20 kg/ha, and the soil of a different site was used as soil poor in nitrogen. Fifteen PVC tubes (20 cm long and 7.5 cm in diameter, with circular holes of 19.6 mm² at 0.5-cm intervals) were assigned to each soil type. On 14 June 2001, the PVC tubes were filled with sifted soil from each treatment and buried horizontally at a depth of 7 to 14.5 cm. Tubes were randomly placed within the plot. Two months later (August 17), the tubes were carefully uncovered. All roots that grew around the tubes were cut to retain only portions contained within the tubes. The experiment was carried out during the rainy season, when water was not a limiting factor.

A Kruskal-Wallis test and nonparametric multiple comparisons were used to determine differences in root biomass between depth and root diameter in the soil profile (Zar, 1999). Monthly root biomass was analyzed using nonparametric repeated-measures analysis with root diameter classes (<1 mm, 1 to 3 mm, and >3 mm) as a factor (Potvin et al., 1990). A nonparametric multiple comparisons test was used to estimate differences in root diameter classes. The effect of the nitrogen on fine root production was evaluated using analysis of variance with soil treatment (native soil, enriched soil, and poor soil) as a factor. Root biomass and fine root production were transformed to $\log_{10}$ (datum + 1) to fulfill the assumptions of normality and equal variances (Zar, 1999).

Mean root biomass in the complete soil profile was 2.1 kg/m² (SE = 1.4). A significant difference in root biomass was obtained between depths (H = 10.9, $P < 0.05$), but not between diameter classes (H = 4.4, $P > 0.05$) (Fig. 1). The highest root biomass was found within a depth of 40 to 50 cm. Nonparametric multiple comparisons showed a significant difference only between depth strata of 40 to 50 cm and 30 to 40 cm (q = 4.6, $P < 0.05$). Mean monthly root biomass (0 to 25 cm deep) was 115.23 g/m² (SE = 12.3). Monthly variation in root biomass for diameter class was significant (H = 19.6, $P <$ 0.01). However, the difference between very fine roots and coarse roots was not significant (q = 2.14, $P > 0.05$) (Fig. 2). Fine and very fine root production between 0 to 20 cm deep was estimated at 2.74 Mg/ha/year. Considering that 40.8% of very fine and fine root biomass was found at this depth, I extrapolated the production at the surface to 60 cm deep to be 6.7 Mg/ha/year. In the soil nitrogen experiment, only very fine roots were obtained. Root production was significantly (F = 125.7, $P < 0.001$) highest (21.73 g/m², SE = 3.64) in native soil compared with urea-enriched soil (0.36 g/m²,

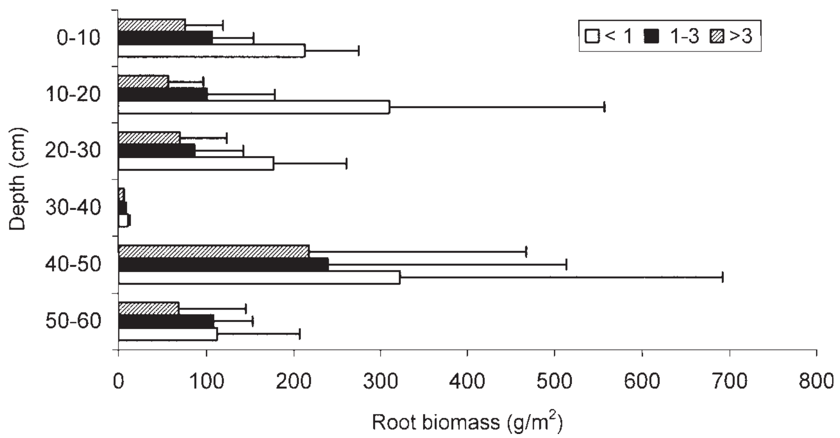

FIG. 1—Vertical distribution of root biomass; values represent means + *SE*. The roots were classified in 3 diameter classes: very fine roots (<1 mm diameter), fine roots (1 to 3 mm), and coarse roots (>3 mm).

SE = 0.2) or under the nitrogen-poor soil treatment (3.86 g/m^2, *SE* = 0.36).

At this study site, fine and very fine roots comprised the largest fraction of biomass (78.3%), as has been described for other ecosystems of temperate forest (Eissenstat and Yanai, 1997). The standing crop root biomass of the site (2.1 kg/m^2) was higher than has been found in other arid and semiarid ecosystems, where values ranged from 0.077 to 0.73 kg/m^2 (Evenari et al., 1975; Ehleringer and Mooney, 1982; MacMahon and Wagner, 1985; Pavón and Briones, 2000). In contrast to other desert ecosystems, the soil in this study site is fertile, with high values of organic matter (12.9%), total nitrogen (0.65%), and available phosphorus (9 mg/kg). These soil characteristics might increase root biomass and root production (Espeleta and Donovan, 2002; Lavelle and Spain, 2003)

Root production estimated in this study was higher than reported for other arid and semiarid shrublands (0.3 and 4.43 Mg/ha/year; Caldwell and Camp, 1974; Ehleringer and Mooney, 1982; Walter and Box, 1983; Pavón and Briones, 2000). Norby and Jackson (2000) enumerated several problems associated with the estimation of root production, one of which is an underestimation with the max-min method because it assumes fine root production occurs in pulses and that mortality does not occur during this period. The values reported in the present study might also be underestimated because root turnover was not considered.

Greater fine root production was recorded in native fertile soil than in poor soil. This result supports the hypothesis that increased fine root production occurred with increased nitrogen availability (Norby and Jackson, 2000). More-

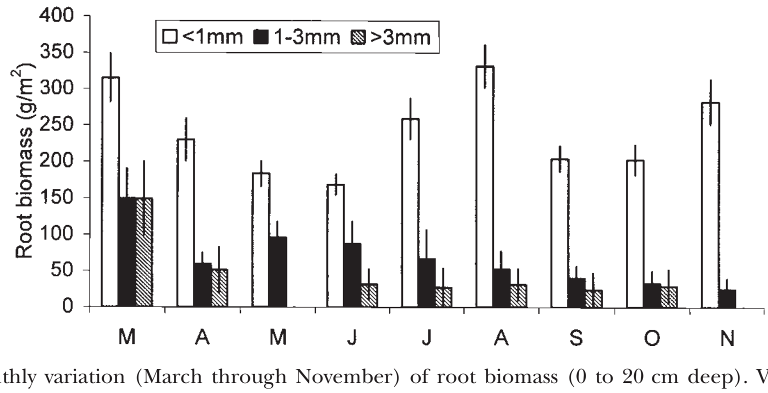

FIG. 2—Monthly variation (March through November) of root biomass (0 to 20 cm deep). Values represent means ± *SE*. The roots were classified in 3 diameter classes: very fine roots (<1 mm diameter), fine roots (1 to 3 mm), and coarse roots (>3 mm).

over, the smallest root production was recorded in enriched soil. This results support the hypothesis that fine root production decreases when nitrogen availability increases, if fine root turnover remains constant (Nadelhoffer, 2000). Although I did not carry out a study of root turnover, the brief duration of the experiment could have maintained a low or constant fine root turnover. This result should be considered cautiously because the enriched soil was alkaline (pH = 8) and the urea might have been converted to ammonia, which is toxic for plants; additionally, reduced root biomass in the urea-enriched treatment might have been a consequence of osmotic effects of added urea.

Data in this study were collected from only one study site (50 m × 50 m) during a 9-month sampling period. This apparent spatial homogeneity in the plot made it possible to more closely examine differences among sampling depths and dates. However, these data represent only one study site and conclusions are limited to this study site. Nonetheless, this study contributes to a better understanding of the dynamics of roots in desert ecosystems, and it supports the hypothesis that in semiarid ecosystems, nitrogen is a limiting factor for primary production.

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