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Soil nutrient distributions of mesquite-dominated desert grasslands: changes in time and space

Thomas B. Wilson*, Thomas L. Thompson[1]

Department of Soil, Water, and Environmental Science, University of Arizona, Shantz Building #38, Rm. 429, Tucson, AZ 85721 USA

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Abstract

Mesquite trees in desert grasslands create localized distributions of soil N, C, and P, through N fixation, nutrient uptake, and subsequent litterfall. Fires may prevent or reverse this accumulation, but the results of this process are poorly understood. Our objectives were to (1) characterize temporal and spatial variation in velvet mesquite litter mass and C, N, and P concentration; (2) characterize temporal and spatial variation of soil inorganic N in the upper 10 cm, and (3) characterize spatial variation in total soil C, total N, and available P concentrations (0–10 cm) relative to velvet mesquite locations on two sites of contrasting fire frequency. In 1997 and 1998, we sampled velvet mesquite litter monthly and soil seasonally in two adjacent sites with similar physical characteristics but different fire histories at Woodcutter's Canyon, Fort Huachuca, in southeastern Arizona. No fires had occurred in more than 50 years on one site (Site A), and the other site (Site B) had five fires within the 20 years prior to our study. Significantly more litter accumulated under trees at Site A, and most litterfall occurred during the winter months. For both sites and years, litter accumulation was highest during December. In 1997, the maximum average monthly litterfall/tree (total dry mass collected/total trap surface area) was 18.16 ± 13.65 g/m^2 on Site A, and 5.43 ± 2.98 g/m^2 on Site B. In 1998, the peak average litterfall/tree was 24.10 ± 6.52 g/m^2 on Site A, and 9.32 ± 6.85 g/m^2 on Site B. Litterfall C, N, and P concentrations did not differ significantly between locations. Litterfall C concentrations averaged 46%, and did not vary significantly over time. During both years, summer litter contained significantly higher concentrations of N and P than winter litter. Each year, litter C/N ratios ranged from 12:1 (summer) to 23:1 (winter). Soil inorganic N varied significantly over time and was significantly higher (56%) at Site A. Soil inorganic N, total N, total C, and available P concentrations were significantly higher under mesquite canopies compared to intercanopy zones at Site A. Available P concentrations were significantly higher in the intercanopy zones of Site B (6 mg/kg) compared to Site A (4 mg/kg), indicating that it was less localized. Overall, the soil nutrient distribution was more uniform on Site B. Litter mass and N, C, and P concentrations varied significantly over time, but were not correlated with soil inorganic N concentrations. Our study supports the concept that differences in mesquite stand development due to fire directly influences soil nutrient distributions in this plant community.
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Keywords: Fire frequency; Season; Litterfall; Nitrogen; Phosphorus; Carbon

* Corresponding author. Tel.: +1 520 621 9308.
E-mail address: twilson@ag.arizona.edu (T.B. Wilson).
[1] Tel.: +1 520 621 3670.

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1. Introduction

The colonization of honey and velvet mesquite trees (*Prosopis glandulosa* Torr. and *P. velutina* Woot., respectively) in grasslands of the southwestern United States has resulted in a concentration of plant-available soil nutrients under their canopies (Barth and Klemmedson, 1982; Martens and McLain, 2003). Schlesinger et al. (1990) found the coefficient of variation for soil total N to be four times higher in honey mesquite-dominated areas than in black grama (*Bouteloua eriopoda* (Torr.) Torr.) grassland at the Jornada Experimental Range in New Mexico. In southern California, Virginia and Jarrell (1983) found that concentrations of soil total N and organic C (TOC), and available NH_4^+, NO_3^-, P, and K were significantly higher under honey mesquite than in adjacent open areas. Biggs (1997) found similar results for NH_4^+, NO_3^-, available P, and total C under velvet mesquite canopies in southeastern Arizona. Kemp et al. (2003) determined that honey mesquite litter decomposed independently of seasonal precipitation. However, seasonal patterns in concentrations of soil nutrients, and any association with seasonal variation in litterfall nutrient concentrations, remains to be identified, and may provide useful information for characterizing the short- and long-term effects of mesquite tree establishment in this region.

Litterfall is a major mechanism for transferring N from N-fixing plants, such as mesquite trees, to the soil system (Klemmedson et al., 1990), and this transfer is inversely proportional to resorption of leaf N into woody tissue. Killingbeck (1996) found that among 89 plant species, N-fixing plants resorbed significantly less leaf-N than non-fixing plants. Rundel et al. (1982) found a green-leaf N content of about 2.8% for honey mesquite, virtually identical to that for velvet mesquite (Klemmedson, 1974); in neither case were these values compared to the N concentration in senesced leaves. Killingbeck and Whitford (1996) compared green leaf with senesced leaf tissue of honey mesquite, finding 3.5% and 2.6%, respectively; this suggests a resorption rate of about 26%. In contrast, among arid land shrubs worldwide, they determined that most litterfall contains <1.5% N, after 40–60% resorption. Honey mesquite has growth periods in March and August; leaf abscission occurs abruptly prior to the onset of the next years' growth in March, and is strongly correlated with soil moisture potential at 400-cm depth (Sharifi et al., 1983). This implies that the maximum deposition of leaf litter occurs during late winter, which could result in a significant increase in available soil N during the following spring.

Grassland fires may help reverse the accumulation of nutrients under mesquite canopies. Mesquite may often survive fires (Martin, 1983; Wright et al., 1976), but basal resprouting of the surviving trees creates a different growth form of reduced stature (Ansley et al., 1996) and canopy diameter. Fire not only alters the nutrient distribution of landscapes in the short term through volatilization (Raison, 1979), leaching (Smith, 1970), or erosion (DeBell and Ralston, 1970); it also plays an indirect role by reducing the ability of mesquite to localize concentrations of macronutrients at frequently burned locations. Emmerich (1999) found significant losses of soil N and P through soil erosion following repeated fires. Smith (1970) determined that leaching following a burn accounted for almost half of the total loss of available soil P during the first 15 months, while Sharrow and Wright (1976) found that N concentrations in tobosagrass (*Hilaria mutica* (Buckl.) Benth) litter were reduced for up to 8 years following a fire.

We predict that: (1) velvet mesquite litterfall varies significantly among seasons in quantity and concentrations of total N, C, and P, (2) this variation is associated with variation in inorganic soil N, (3) soil inorganic N, total N, TOC, and available P concentrations are higher under velvet mesquite canopies than open areas and (4) fire history directly affects velvet mesquite distribution and average canopy size; therefore, the distribution of soil inorganic N, total N, TOC, and available P is more strongly associated with velvet mesquite in less frequently burned locations. In this study, our objectives were to (1) characterize temporal and spatial variation in velvet mesquite litter mass and C, N, and P concentration; (2) characterize temporal and spatial variation in soil extractable N, and (3) characterize spatial variation in total soil C, total N, and extractable P concentrations relative to velvet mesquite locations on two sites of contrasting fire frequency.

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