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Changes of Mass Loss and Nitrogen Content during Root Decomposition in the Chihuahuan Desert

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치화화사막에서 뿌리의 분해과정에 따른 질소함량의 변화

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ABSTRACT

We examined spatial and temporal patterns of root decomposition for three and half years, from October 1986 to April 1990, in semi-arid Chihuahuan Desert. Decomposition of roots occurred in a two-phased pattern: an early period of rapid mass loss followed by a period of slower loss. The rate of root decomposition had a high negative correlation with the initial lignin concentration in roots ($r=-0.84$, $p<0.05$). Annual mass loss rate of *Baileya multiradiata*, a herbaceous annual, was the highest with the value of 0.60, while that of *Panicum obtusum*, a perennial grass which was restricted to playa, was the lowest with 0.13. The mass loss rate of roots in the playa was the lowest among the vegetation zones along the transect. After 42 months elapsed, fluffgrass roots in playa lost 40% of the initial mass, while in other sites it lost on average 55% of the initial mass. In all roots except for desert marigold, there was an initial release of nitrogen early in decomposition followed by net nitrogen immobilization. Nitrogen concentration of the desert marigold roots showed linear increase from the beginning. Lignin concentration of perennial grass roots were higher than those of herbaceous annual and woody perennial root.

Key words: *Baileya multiradiata, Bouteloua eriopoda*, Decomposition rate, *Erioneuron pulchellum*, Long-term decomposition, *Panicum obtusum, Xanthocephallum sarothrae*

INTRODUCTION

Nutrient regeneration within an ecosystem can be maintained by decomposition proocesses of organic materials. Much attention has been paid to the study of the rates of decomposition of different types of plant materials (Anderson 1973, McClaugherty *et al.* 1984, Berg *et al.* 1982), and uncovered that many factors such as climate, edaphic factors, soil biota and resource quality can affect decomposition rates (Swift *et al.* 1979). Meentemeyer (1978) and Melillo *et al.* (1982) reported that the rates of decomposition in mesic environments varied with actual evapotranspiration and inversely related with lignin content. However, decomposition processes in desert ecosystems differ quantitatively and qualitatively from those in more mesic environments, because the activities of desert soil animals, microarthropods and termites, are relatively independent of actual evapotranspiration (Elkins *et al.* 1982, Whitford *et al.* 1981).

Spatial and temporal patterns of decomposition processes are central to the dynamics of desert ecosystems. But a little is known about the decomposition processes in arid or semi-arid desert environments, which largely has been limited to the Chihuahuan Desert (Whitford *et al.* 1981). Most of the studies concerning about organic matter decomposition in the northern Chihuahuan Desert are restricted to the surface litter (Fowler and Whitford 1980, Whitford *et al.* 1981). However, belowground decomposition has a more direct effect on nutrient availability than those surface litter decomposition because roots are more easily attacked by soil organisms.

A number of studies showed that the root decomposition processes are important to the overall organic matter and nutrient dynamics in ecosystems (McClaugherty *et al.* 1982, 1984, Parker *et al.* 1984). In case of windy desert, belowground decomposition is more important for the nutrient regeneration in the soil because most of the surface litter might be transported from the original site to the depressions by wind. There are some data for decomposition of roots on herbaceous annuals, a perennial grass and-woody shrubs in desert ecosystems (Parker *et al.* 1984, Whitford *et al.* 1988). Whitford *et al.* (1988) found that the rates of mass loss of leaf litter and roots in arid environment are relatively independent of rainfall, C:N ratio and lignin content, but almost entirely due to termite consumption. However, those studies were relatively short term, deficient of chemistry of the materials and limited to one soil-vegetation type.

This study was designed to examine the long-term spatial and temporal patterns of mass loss and changes of nitrogen content during the root decomposition in the Jornada LTER site. Spatial differences were recognized by changes in vegetation along each transect.

MATERIALS AND METHODS

Site description

This study was carried out from October 1986 to April 1990 on the Jornada LTER site, about 40km north of Las Cruces, New Mexico. This LTER site is located on an east-facing alluvial piedmont (Wierenga *et al.* 1987). The long-term average precipitation is 225 mm/yr, 55% falling during July through September as convectional thundershowers.

Table 1. Vegetation zones along the transect in the study area

Vegetation zone	Dominant species
Playa (grassland)	*Panicum obtusum*
Lower Basin Slope Ⅰ (grassland)	*Aristida longiseta*
Lower Basin Slope Ⅱ (grassland)	*Erioneuron pulchellum, Aristida longiseta*
Upper Basin Slope (shrubland)	*Larrea tridentata*
Lower Piedmont (grassland)	*Erioneuron pulchellum, Bouteloua eriopoda, Eragrostis lehmanniana*
Upper Piedmont (grassland)	*Bouteloua eriopoda*

Temperatures usually exceed 40℃ in summer and drop below 0℃ in winter. Two parallel 2.7km transect (70m apart) were established in 1981. Each transect ranged from a piedmont area (elevation ca. 1,400m) to a small playa basin (elevation ca. 1,300m). Six vegetation zones (Table 1), based on the cover of perennial species, have been identified along the transect (Wierenga *et al.* 1987).

Rootbag preparation and treatment

Root samples were collected by excavation in summer 1986 from the outside areas of the transects. They were moved to the laboratory and dried to constant mass at 50℃ after washing with tap water to remove soil particles. The roots of snakeweed and desert marigold were tethered with fine wire bearing aluminum tag giving the weight of the roots. Grass roots were confined in fiberglass bags. The rootbags measuring 12×12 cm were made of fiberglass net with a mesh size of 1mm. Each rootbag enclosed about 1g of root. Aluminum tags were attached to every rootbag giving the weight of the roots enclosed. The rootbags of *Panicum obtusum*, blackgrama grass (*Bouteloua eriopoda*) and tethered roots of desert marigold (*Baileya multiradiata*) were confined to the playa, blackgrama zone and basin slopes, respectively. However, root decomposition of snakeweed (*Xanthocephallum sarothrae*) and fluffgrass (*Erioneuron pulchellum*) were investigated in all 6 vegetation zones. In all sites, tethered roots and rootbags were buried at 5~10 cm soil depth from which the roots had been collected in October 1986. Eight samples of each species were retrieved after 1, 3, 6, 12, 18, 24, 30, 36 and 42 months in each site. Retrieved samples were promptly moved to the laboratory. They were gently washed in tap water to remove adhering soil particles and weighed after drying to constant mass at 50℃. An exponential decay model was used to estimate the mass loss rate:

$$X/X_0 = e^{-kt}$$

where X= mass remaining at time t (months), X_0= original weight, e is the base of the natural logarithm, and k is the decomposition constant (Olson 1963). Samples were ground in a laboratory mill equipped with 1mm screen for chemical analysis. Sub-samples of roots were digested for total nitrogen analysis. By using an automated salicylated procedure,

NH_4-N in the digest was measured (Nelson 1983). Three organic fractions (solubles, acid solubles and acid insolubles) were analyzed. Solubles which include non-polar and water soluble substances were extracted using dichloromethane followed by hot (100℃) water (McClaugherty *et al.* 1984). Acid solubles, largely holocellulose, was separated from acid insolubles, largely lignin and suberin, using a two-staged digestion in sulfuric acid (Effland 1977).

RESULTS

Mass loss

Decomposing roots declined steadily in mass during the experimental period (Figs. 1 and 2). In case of snakeweed, there was no significant spatial variation of decomposition among the vegetational zones (Fig. 1B). However, fluffgrass roots in Playa showed higher percentage of remaining mass than other sites (Fig. 1A). After 1 month elapsed, roots of desert marigold lost about 25% of the initial mass, while the others lost about 10% of the initial mass. After 36 months, the roots of desert marigold had lost 80% of the initial mass, but *P. obtusum* lost only about 30%. Snakeweed, blackgrama and fluffgrass showed similar decomposing pattern and lost about 55% of the initial root mass during the same period. After 36 months elapsed, mass loss rate of desert marigold was the highest with the value of 0.60, while that of *P. obtusum* was the lowest with 0.13 (Table 2).

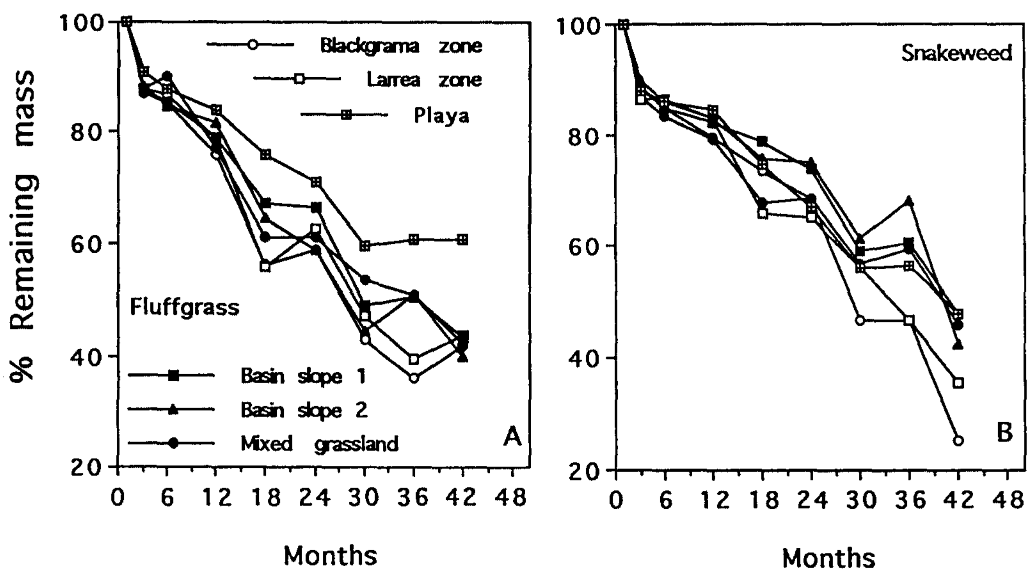

Fig. 1. Percentages of remaining root mass of fluffgrass (A) and snakeweed (B) along the vegetation zones in the LTER site after various periods of decomposition.

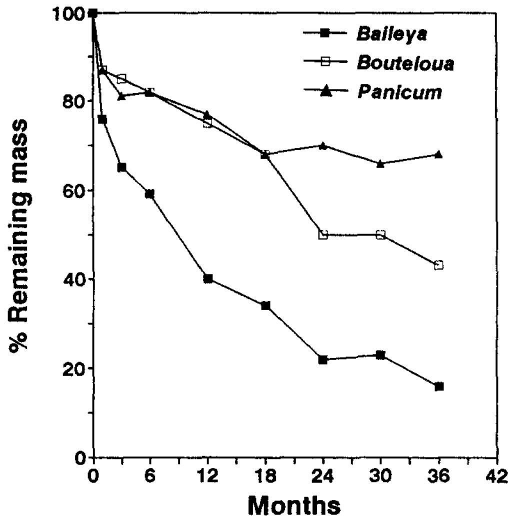

Fig. 2. Percentages of remaining root mass of *Baileya, Bouteloua* and *Panicum* in the LTER site after various periods of decomposition.

Nitrogen

Initial nitrogen concentration of snakeweed and desert marigold were higher than those in perennial grasses (Table 2). In all roots except for desert marigold, there was an initial release of nitrogen early in decomposition followed by net nitrogen immobilization (Fig. 3). Nitrogen concentration of the snakeweed root decreased by 20% of the initial concentration after 3 months elapsed. Thereafter, nitrogen concentration gradually increased by 122% of the initial concentration after 24 months elapsed. Nitrogen in blackgrama root decreased by 16% of the initial concentration after 6 months elapsed, and then increased to 137% of the initial concentration after 36 months (3 years) elapsed. In contrast, nitrogen in the desert marigold root showed linear increase from the beginning. After 12 months elapsed, it

Table 2. Initial concentration of nitrogen (mg/g), organic fractions (%) in the root sample, and decomposition rate (*k*) after 36 months elapsed

Species	N	Non-polar	Water solubles	Acid solubles	Lignin	k
B. multiradiata	7.2	5.2	12.0	66.1	16.7	0.60
X. sarothrae	7.3	5.3	13.3	57.8	23.6	0.30
E. pulchellum	6.5	4.8	9.7	58.5	27.0	0.28
B. eriopoda	5.9	4.9	9.3	54.3	29.5	0.24
P. obtusum	6.9	4.7	11.0	55.6	28.7	0.13

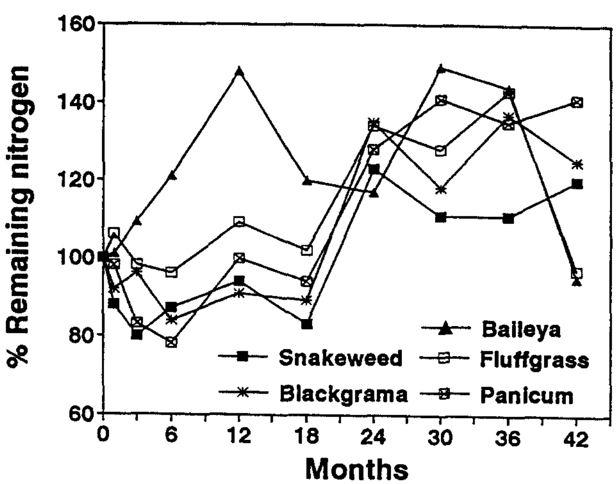

Fig. 3. Percentages of remaining nitrogen in decomposing roots in the LTER site after various periods of decomposition.

had increased to 148% of the initial concentration. But it decreased rapidly after 36 months elapsed.

DISCUSSION

Since there were no available data on long-term studies of root decomposition in semi-arid desert environment, it was impossible to compare this data with others. Decomposition of roots occurred in a two phased pattern; an initial period of rapid loss (1 month) followed by a period of slower loss. Initial mass loss was more apparent in the roots of desert marigold than the other species. This was because the concentration of soluble fraction in the root of desert marigold was higher than that in perennial grass roots, and lignin concentration in desert marigold root was lower than the others (Table 2). McClaugherty *et al.* (1984) have reported that the mass loss of fine roots in litterbags during the early period of incubation may be due to the leaching and microbial respiration of readily soluble compounds. This could be supported by the results that the concentration of soluble fractions (nonpolar substances + water solubles) decreased rapidly during the early period of incubation (Mun and Whitford, unpublished data). The snakeweed root, however, had a high soluble fraction concentration than that of desert marigold (Table 2). The possible reasons for the lower mass loss of snakeweed root at early period compared with the desert marigold root may be due to the high lignin concentration and woodiness of snakeweed roots.

Whitford *et al.* (1988) have reported that the mass loss of desert marigold roots was 62% in plots with termites, which was very similar with our result (average 60% loss after 1 year). They also found that mass loss from roots of an annual herb and a perennial grass were almost entirely due to termite consumption. They reported that termites removed up to 50% of the mass in a 2~3 months period. According to our observation, subterreanean termites are most abundant in the basin slope areas and *Larrea* zone, and absent in the playa. We could observe some roots of desert marigold and snakeweed in the basin slope II and the *Larrea* zones disappeared partially due to the termites from October 1987. Some roots of snakeweed and desert marigold began to disappear completely from April 1988. If the mass losses were largely due to termite consumption, the rate of decomposition is relatively independent of climatic factors and root qualities (Whitford *et al.* 1988).

Roots of *P. obtusum* which are located in the playa showed the lowest decomposition rate among the perennial grasses (Fig. 2). The playa is located at the lowest portion of the Jornada LTER watershed. Wierenga *et al.* (1987) reported that the clay and organic matter content of the playa soils are much higher than those of other areas along the transect. Existence of plentiful organic matter sources and hardened soil due to the high clay content of the soil might have influenced decomposition rates in the playa. Another possible reason for the low decomposition rates in the playa is the absence of termites in this zone.

The decomposition rate of nitrogen-rich litter was higher than that of the nitrogen-poor litter (Berg *et al.* 1982). Berg and Staaf (1980) suggested that nitrogen release or accumulation during litter decomposition depend upon the nitrogen level of litter. Changes of nitrogen concentration during the early period of decomposition in desert marigold were quite different from those of the other roots. We could observe that the root color of desert marigold became black due to the fungi infection from the early period of decomposition. But, we could observe white fungal hyphae in grass rootbags and snakeweed roots frequently after 12 months elapsed. This suggested that most mass loss and changes of nitrogen concentration in desert marigold during the early period of decomposition depended upon microbial activities, while the other roots depended upon leaching processes. The results of this study suggested that changes of nitrogen concentration during the early period of decomposition of roots depend upon lignin content of the substrate.

The roots of perennial grasses had more lignin than herbaceous annual, desert marigold, and woody perennial, snakeweed. Annual decomposition rates of the roots after 36 months elapsed indicated that the concentration of lignin in resources is one of the controlling factors for root mass loss in this semi-arid desert environment. Lignin concentration had a high negative correlation ($r=-0.84$, $n=5$, $p<0.05$) with root decomposition rates.

적 요

치화화 사막에서 몇 가지 식물 뿌리의 분해율과 분해 과정에 따른 질소함량의 변화를 조사하였다 (1986년 10월 ~ 1990년 4월). 뿌리의 분해는 리그닌 함량과 역상관 관계를 보였다 ($r=-0.84$, $n=5$, $p<0.05$). 1년생 광엽초본인 *Baileya multiradiata*의 분해율이 가장 높았고 다년생 협엽 초본인 *Panicum obtusum*의 분해율이 가장 낮았다. 지역에 따른 분해율은 playa에서 가장 낮았다. *Baileya multiradiata*를 제외하고 모두 분해 초기에 질소의 무기화가 있은 다음 질소의 부동화가 나타났다. *Baileya multiradiata*의 뿌리는 분해 초기부터 질소 함량이 계속 증가하는 것으로 나타났다. 다년생 협엽초본 뿌리의 리그닌 함량은 광엽초본 뿌리의 리그닌 함량보다 높았다.

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