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The failure of nitrogen and lignin control of decomposition in a North American desert

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Abstract. We measured mass losses of both buried and surface litter of six litter types: leaves of the perennial evergreen shrub, *Larrea tridentata*, leaves of the winter deciduous perennials *Fluorensia cernua, Prosopis glandulosa* and *Chilopsis linearis* (a desert riparian species), an evergreen monocot, *Yucca elata*, and a mixture of annual plants. These species differed in lignin content and carbon-nitrogen ratios. There was no correlation between rates of mass loss and percent lignin, carbon-nitrogen ratio, or lignin-nitrogen ratio. The leaves of *F. cernua* and the mixed annuals exhibited the highest rates of mass loss. Surface litter of *Y. elata*, the mixed annuals and *C. linearis* exhibited higher mass loss than buried litter of the same species. The patterns of mass loss of buried and surface litter differed with buried litter mass loss occurring as a negative exponential and surface litter exhibiting low rates in winter and spring and high rates in summer. There was no correlation between mass loss in surface bags that were field exposed for 1 month and actual evapotranspiration (AET) but there was a correlation between AET and mass losses in buried litter. A model relating mass loss to AET and initial lignin content underestimated mass losses in all species examined.

Although there have been a number of studies of decomposition in North American deserts, (Santos and Whitford 1981; Elkins et al. 1982; Whitford et al. 1981a; Santos et al. 1983) they have concentrated on a single litter type, creosotebush leaf litter, (*Larrea tridentata*). These studies have shown that the general model for decomposition proposed by Meentemeyer (1978) fails to predict decomposition rates in desert ecosystems. That model for mass loss is $Y_1 = -1.31369 + 0.05350x_1 + 0.18472x_2$; where Y_1 = annual weight loss (%), x_1 = annual AET (millimeters), x_2 = AET millimeters/lignin (%). Whitford et al. 1981a and Santos et al. 1983 attribute the failure of the Meentemeyer model to activities of soil organisms that affect mass loss from leaf material but that are relatively independent of moisture constraints.

Since most studies of mass loss in deserts have been based on a single litter type, it is plausible to hypothesize that other litter species would behave differently and that there may be some correlations between the chemical and physical nature of the substrate and mass losses from these materials in deserts (Mellilo et al. 1982; Zielinski 1980). We therefore chose to examine mass losses of six different litter types: 5 shrub species and mixed litter of herbaceous annual plants. We hypothesized that mass loss in these would differ as a function of percent lignin, lignin-nitrogen (L/N) ratio or carbon-nitrogen (C/N) ratio.

In North American deserts, leaf litter is blown into holes and depressions made by animals and is subsequently buried (Steinberger and Whitford 1983). Buried litter decomposes in a moderate environment compared with litter on the soil surface. While there are some data on decomposition of buried creosotebush leaf litter (Steinberger and Whitford 1983; Santos and Whitford 1981; Santos et al. 1983) there are no data comparing litter species buried and on the surface over the same time periods. Since the environments differ considerably, it is important to know if decomposition of buried litter varies as a function of percent lignin, lignin-nitrogen ratio and carbon-nitrogen ratio as predicted for surface litter. Therefore, we studied decomposition of both surface and buried litter.

Study site

The studies were conducted on the upper slopes of a desert watershed on the New Mexico State University Ranch 40 km NNE of Las Cruces, New Mexico. This is an area with sandy to sandy loam soils and a vegetative cover of 27.4%, 86% of which is of creosotebush *Larrea tridentata.* The vegetation along water courses includes mesquite *Prosopis glandulosa*, tarbush, *Flourensia cernua*, desert willow, *Chilopsis linearis*, Apache plume, *Fullugia paradoxa,* soaptree yucca, *Yucca elata* and banana yucca, *Yucca bacatta.*

Meteorological data were obtained from a weather station on the site. Data used in this study included rainfall recorded with a weighing bucket rain gauge, and air temperature with a standard hygrothermograph.

Methods

Senescent leaves or plant parts were collected from 5 perennial plant species: tar bush *Flourensia cernua*, creosotebush *Larrea tridentata*, mesquite *Prosopis glandulosa*, desert willow *Chilopsis linearis,* soaptree yucca *Yucca elata* and three species of annual plants: buckwheat *Eriogonum abertianum*,

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Table 1. Change in percent lignin, lignin-nitrogen ratio and carbon-nitrogen ratio in 6 species of litter after 6 months field exposure (January–June)

	Percent lignin 6 months			Lignin/nitrogen 6 months			Carbon/nitrogen 6 months		
	Initial	Surface	Buried	Initial	Surface	Buried	Initial	Surface	Buried
Annuals	10.25	–	15.08	4.95	33.33	15.38	24.2	134.9	55.0
Flourensia cernua	9.56	23.63	23.63	3.97	13.51	13.33	20.7	50.9	39.8
Larrea tridentata	10.63	12.75	12.75	5.68	15.15	25.64	26.7	87.0	70.1
Prosopis glandulosa	7.85	10.55	9.27	2.53	5.35	17.24	16.1	38.4	78.4
Chilopsis linearis	14.63	11.61	23.58	5.59	58.82	32.25	19.1	163.8	125.3
Yucca elata	9.89	13.05	16.83	10.31	38.46	19.23	51.8	174.6	82.7

pepperweed *Lepidium lasiocarpum* and desert marigold *Baileyea multiradiata*. The plant material was oven dried to a constant weight at 60° C. We made a total of 720, 15 cm × 15 cm fiber glass mesh bags, mesh size 1.5 mm. This provided 120 bags for each species filled with 10 g of the appropriate litter. The annual plant litter was thoroughly mixed and the bags filled with this mixture. One half of the bags were buried at 10 cm depth in the soil under the canopy of the appropriate species and the other half were placed on the soil surface under the canopy of the appropriate plant species. We placed groups of bags in the field on January 15, May 7 and June 25. The group placed in the field on January 15 were retrieved on March 12 (2 months), June 25 (6 months) and January 20 (12 months). The bags placed in the field on June 25 were retrieved on July 25 (1 month) and January 20 (6 months). The bags placed in the field on May 7 were retrieved on July 5 (2 months). This sequence of placement and retrieval allowed us to examine seasonal effects separately from time of exposure in the field. Some bags were lost during the study which required use of statistics for unequal sample sizes.

All mass loss data were arc sine transformed and subjected to analysis of variance using a GT2 test for unequal sample sizes (Sokal and Rohlf 1969) with $P<0.05$ as the acceptable level for significant difference.

The contents of bags returned from the field were oven dried at 60° C and burned in a muffle furnace. The percent organic matter loss was calculated using the formula for correction of soil infiltration in Santos and Whitford (1981).

Chemical characteristics of the plant material were measured or estimated on the freshly collected dead leaves to obtain chemical content at time 0 and the contents of litter bags that were retrieved from the field after 6 months exposure. There was insufficient residual material at the end of one year to make comparable measurements. Leaf material from three bags were ground in a Wiley Mill to provide three replicates for each reported analysis. Nitrogen content was measured by a micro-kjedahl technique (Bremner and Mulvaney, 1982). Lignin was measured by the Van Soest method (Van Soest 1963). Carbon was estimated from data summarized by Schlesinger (1977).

Results

The range of initial lignin values of the plant materials studied was small (7.8–14.6%) but there was a wide range of carbon-nitrogen ratios (16.1–51.8) (Table 1). There was no correlation between chemical parameters and rates of mass loss (K) of surface litter using a least squares best fit for the time series data: r for percent lignin was 0.81, lignin-nitrogen ratio 0.46 and carbon-nitrogen ratio 0.20. The correlation coefficients for the buried litter were 0.12 for percent lignin content, 0.6 for lignin-nitrogen ratio and 0.71 for carbon-nitrogen ratio. An examination of rate constants showed that the annual plant litter and *Yucca elata* leaves lost mass at the same rate K = −0.78 surface and

Table 2. Annual decomposition rates (K) of surface leaf litter of several species of plants in a Chihuahuan desert ecosystem

Species	Buried	Surface
Mixed annuals	−0.777	−0.996
Chilopsis linearis	−0.631	−1.461
Flourensia cernua	−0.947	−0.524
Larrea tridentata	−0.677	−0.432
Prosopis glandulosa	−0.654	−0.374
Yucca elata	−0.777	−0.996

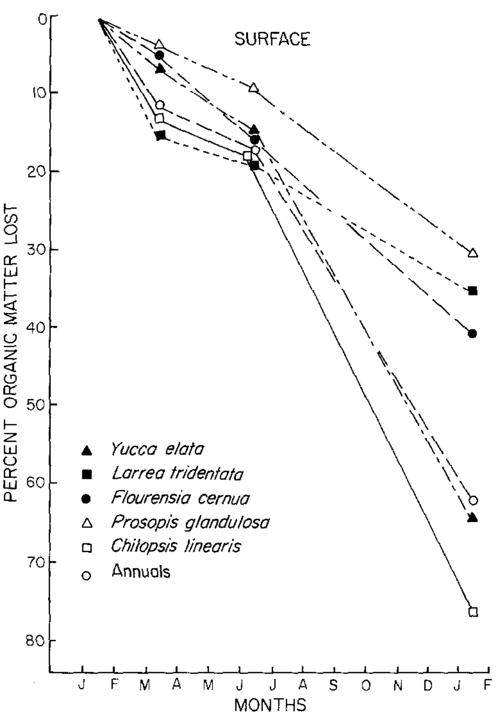

Fig. 1. Comparison of organic matter loss in six types of leaf litter confined in fiber glass mesh bags. The litter bags were placed on the soil surface under canopies of plants of the same species in the northern Chihuahuan desert