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The contribution of abiotic processes to buried litter decomposition in the northern Chihuahuan Desert

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Summary. Creosobebush (*Larrea tridentata*) fine litter was treated with either the general biocide $HgCl_2$ and $CuSO_4$ or water (controls) and buried 5 cm beneath the soil surface in the northern Chihuahuan Desert. The treated litter showed significantly less mass loss than controls during the three month summer-autumn field study; controls lost about 20% of the original mass while treated litter lost less than 2%. In addition, the total nitrogen content of the control litter increased from an initial concentration of about 14.08 g kg^{-1} to 17.62 g kg^{-1} dry weight by the end of the study, while treated litter nitrogen content decreased to 13.30 g kg^{-1}. Results suggest abiotic processes other than leaching have little effect on the decomposition of buried litter in this environment.

Key words: Decomposition – Buried Litter – Abiotic – Deserts

While a variety of biotic and abiotic factors influence plant litter decomposition (Swift et al. 1979), few studies have attempted to quantify the direct contribution of abiotic factors to litter losses (Moorhead and Reynolds 1988). Furthermore, studies investigating abiotic mechanisms have examined degradation of surface or exposed materials and not buried litter (e.g., Vossbrinck et al. 1979; Castellan et al. 1987; Frimmel and Bauer 1987). In the northern Chihuahuan Desert about 10–20% of the surface litter is buried annually by aeolian and fluvial processes, as well as by small mammal activities (Steinberger and Whitford 1983; Whitford et al. 1983). This buried litter normally loses between 40% and 60% of its mass annually (Schaefer et al. 1985; Santos et al. 1984). Although treatment with selective biocides (e.g., insecticides, fungicides or nematicides) significantly reduces buried litter decomposition rates (Santos et al. 1981; Parker et al. 1984; Elkins and Whitford 1982) mass losses are still substantial. For example, Santos and Whitford (1981) reported mass losses of 10% to 30% for buried litter treated with a combination of insecticide and fungicide (3 and 6 months, respectively), suggesting abiotic processes may play a significant role in buried litter decomposition. However, we are aware of no studies which have examined buried litter losses in the absence of essentially *all* biological activity. The objective of the present study was to use such a general biocide treatment to exclude the activity of all soil biota ($HgCl_2$ and $CuSO_4$; Vossbrinck et al. 1979) and to quantify the contribution of abiotic mechanisms to buried litter decomposition in the northern Chihuahuan Desert.

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Methods

This study was conducted on the Jornada Long Term Ecological Research (LTER) site in the northern Chihuahuan Desert, 40 km NNE of Las Cruces, New Mexico, USA. Mean annual rainfall is 211 ± 77 mm with most precipitation occuring during late summer in convectional storms. Air temperatures occasionally fall below freezing during the winter and reach 40° C in the summer. The site is an alluvial piedmont sloping from Mt. Summerford on the west to the Jornada basin on the east and north. The soil is an Aridic Entic Haplustoll coarse loam with a bulk density of 1.62 g cm^3, pH of 7.6, and a caliche ($CaCO_3$) layer $\geqq 40$ cm below the surface. The study site is dominated by the perennial evergreen shrub, *Larrea tridentata* (creosotebush). The study area is described in detail in Parker et al. (1984).

The use of traditional litter-bags for placing litter in soils makes nutrient analyses difficult because gravitational soil and water movement through the litter-bags results in a mixing of soil particles and the remaining organic matter (Parker et al. 1984). To minimize this effect, "litter-dishes" (LD) were created from small polyethylene petri dishes (60 mm diameter). Disks (45 mm diameter) were removed from the centers of the petri dish lids and nylon window-screening (1.5 mm mesh size) was spot-welded over these openings by fusing the screen to the lid with a soldering iron. Air-dry litter was placed in each LD and the lid sealed around the full circumference with cellophane tape before being placed in the soil. The screen side of the LDs was oriented downward, in contact with the soil. The litter-dishes permit buried litter to be exposed to prevailing soil moisture conditions while excluding gravitational soil and water movement through the litter.

Senescent litter was collected from litter traps placed beneath creosotebushes. Air-dry creosotebush litter (leaves and fine twigs) was soaked overnight in either a saturated solution of $HgCl_2$—$CuSO_4$, a general biocide treatment (Vossbrinck et al. 1979), or distilled water (control treatment). Litter was air-dried and 40 2-g samples from each treatment were placed in LDs. Additional samples were oven-dried to constant weight to determine the moisture

content of air-dry litter. Forty creosotebushes were randomly selected on the study site and 8 LDs (4 controls and 4 treatments, alternating) were buried at a depth of 5 cm (depth to petri dish base), lid-side down, around each plant. The LDs were placed in the field on July 1, 1986 and two LDs (1 control and 1 treatment) were randomly collected from each bush on July 27, August 16, September 14, and October 18, 1986. LDs were placed in polyethylene bags and returned to the lab for analyses.

Litter was removed from the LDs, oven-dried to constant weight, and ground in a Wiley mill to pass a 40 mesh sieve. Four treatment and 4 control samples were randomly selected from each sampling date for total Kjeldahl nitrogen analysis (Bremner and Mulvaney 1982). Ground litter was digested and ammonium concentration of the Kjeldahl digest was determined on a Technicon Autoanalyzer. Litter dry weights (g) and nitrogen concentrations (g kg^{-1}) were examined for significant differences over time and between treatments by analysis of variance (ANOVA, SAS 1985).

Results and discussion

The ANOVA indicated significant main effects (date and treatment) and interaction (date x treatment) for both mass loss ($F_{8,312}=35.55$, $P<0.001$) and nitrogen content ($F_{8,26}=18.46$, $P<0.001$). Mass loss of the control litter was significant over time ($F_{4,158}=16.18$, $P<0.001$) while mass of the biocide-treated litter remained constant ($F_{4,157}=0.81$, $P<0.52$) (Fig. 1A). The mass of control litter was less than biocide-treated litter for all dates after initial placement ($P<0.001$) (Fig. 1A). Nitrogen concentration in the controls significantly increased during the study ($F_{4,14}=7.55$, $P<0.002$) while no change was found in the treated litter ($F_{4,15}=2.23$, $P<0.11$) (Fig. 1B). The nitrogen concentration of control litter was greater than biocide-treated litter for all dates (except initial values) ($P<0.005$).

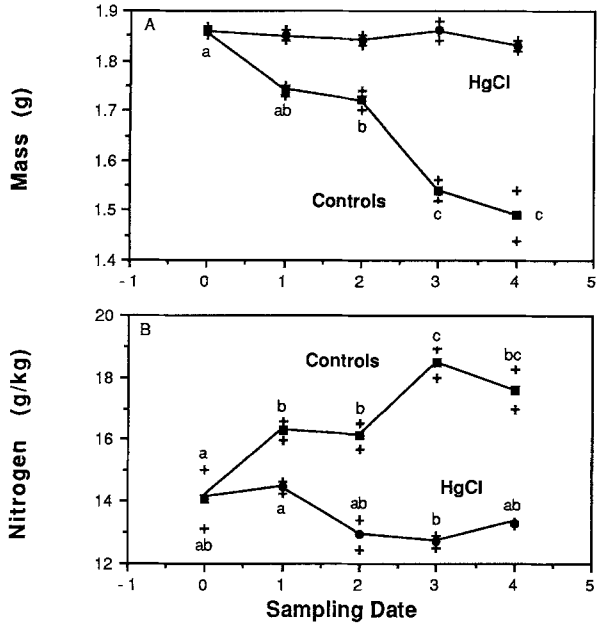

Fig. 1. **A** Litter dry weight throughout study period (mean ± standard error) different letters beneath control means indicate significant differences (Duncan test, $P<0.05$) between dates (no differences between dates for $HgCl_2$—$CuSO_4$ treatment). **B** Litter nitrogen content during study (mean ± standard error), different letters indicate significant differences ($P<0.05$) between dates within treatments

Untreated litter lost 21% of its original mass during the 4-mo experiment compared to losses of 39–51% during similar time periods reported in other studies at this site (Santos et al. 1984; Parker et al. 1984; Urbaniak and Whitford 1983). These differences in mass loss may have resulted from differences in the initial preparation and treatment of the litter. The creosotebush litter used in the earlier studies was either not treated or was immersed in aqueous solutions for only a couple of hours, while litter in this study was soaked for approximately 14 h (overnight). This treatment may have removed as much as 25% of the initial mass (Comanor and Staffeldt 1978). We observed a litter nitrogen concentration of 1.4% following soaking (Fig. 1B), about 0.5% less than the reported nitrogen concentration (ca. 1.9%) of untreated senescent creosotebush litter (Schaefer et al. 1985). This suggests that about 26% of the estimated original 1.9% nitrogen concentration was lost through soaking. Combining the observed mass losses (21%) with possible leaching losses associated with this treatment (25%) yields a potential mass loss of 41%, comparable with the studies cited above. Conversely, the litter dishes used in the experiment may have reduced the effective contact between soil and litter leading to lower decomposition. However, no means of evaluating this mechanism is apparent.

Suppression of biological activities greatly inhibited decomposition. In contrast to surface litter studies (Vossbrinck et al. 1979; Loring et al., unpublished work), we found no detectable mass loss in biocide-treated litter throughout this 4-mo study. Although reported losses of buried litter treated with combinations of insecticide, fungicide and nematicide suggest a significant role of abiotic decomposition mechanisms in this desert system (Santos et al. 1981; Santos and Whitford 1981), exclusion of all biological activity ($HgCl_2$—$CuSO_4$) resulted in no apparent mass loss. Therefore, with the possible exception of leaching, abiotic mechanisms do not appear to directly contribute to buried litter mass losses.

Litter in the control treatment showed a significant increase in nitrogen concentration through time (Fig. 1B), strongly suggesting colonization by soil microbiota. Although several other studies have examined buried litter decomposition patterns in this desert (e.g., Elkins and Whitford 1982; Urbaniak and Whitford 1981; Santos et al. 1981, 1984; Santos and Whitford 1981; Schaefer et al. 1985) the use of traditional litter-bags makes nutrient analyses very difficult since soil and litter are intimately mixed. Parker et al. (1984) followed nitrogen dynamics of buried litter by comparing litter nitrogen pools to those of nearby soil cores taken when litter-bags were collected. They found the total nitrogen content of *Lepidium lasiocarpum* roots increased 32% over initial values after 96 days (May–August). This increase is similar to the 31.25% increase in total nitrogen concentration of buried creosotebush litter we found after 75 days (September 14), although this decreased to 25.14% by 110 days (October 18). Parker et al. (1984) identified the principle source of the additional nitrogen to be associated with fungal development.

In contrast to the controls, the biocide treatment showed little or no decline in nitrogen concentration (Fig. 1B).