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FACTORS AFFECTING LOSS IN MASS OF CREOSOTEBUSH LEAF-LITTER ON THE SOIL SURFACE IN THE NORTHERN CHIHUAHUAN DESERT

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ABSTRACT—We examined the relative importance of biotic factors (microarthropods, termites, and fungi), and abiotic weathering on loss in mass of creosotebush leaf-litter on the soil surface in the northern Chihuahuan Desert. We treated litter with either an insecticide (chlordane), a fungicide (benomyl), a general biocide ($HgCl_2$-$CuSO_4$ solution or, as a control, distilled water. Our results suggest that microarthropods and fungi do not play significant roles in creosotebush litter decomposition in arid habitats. The rate of loss in mass from fungicide treated litter was not significantly different from control litter. Litter in fungicide treatment plots differed from that of the abiotic treatment plots in having higher rates of loss, suggesting that other components of the litter communities compensate for the lack of certain organismal groups. The rate of loss in litter treated with the general biocide during late summer was not significantly different from the rates for other litter, demonstrating that abiotic factors have an important effect. We suggest that these factors include intense sunlight and high UV-radiation and heat of the soil surface in summer. Actual evapotranspiration and decomposition rates of surface litter are uncorrelated in desert ecosystems. This may be due to abiotic fragmentation of the litter and the necessity of a threshold (amount or intensity) of rainfall which is necessary to fragment litter and wash it into the soil.

Decomposition rates of plant litter in the northern Chihuahuan Desert are surprisingly high, often higher than those found in mesic deciduous forests and tropical rain forests (Whitford et al., 1981; Elkins et al., 1982; Schaefer et al., 1985). These high rates have been attributed to the activities of termites and microarthropods (Whitford et al., 1981, 1983; Silva et al., 1985). On the other hand, Pauli (1964) suggested that high solar-energy flux in the wavelengths between 200 and 800 μm in hot desert regions break hydrogen bonds and cause oxidation and reduction, especially of phenols and other aromatic molecules. Molecular changes in structural molecules of litter under the influence of short wavelength radiation could contribute to the high rates of mass loss of litter on the soil surface of desert regions.

To study the effects of intense sunlight and temperature, and of various groups of soil biota on decomposition of creosotebush litter on the soil surface, we conducted a series of experiments measuring decomposition of litter treated with three biocides. Our specific hypotheses were that 1) litter treated with a general biocide would lose little mass over time because of little or no biological activity, and 2) both fungicide- and insecticide-treated litter would have biotic activity and mass loss rates intermediate between control and abiotic litter.

MATERIALS AND METHODS—The study area was located on the Jornada Long Term Ecological Research (LTER) Site, 40 km NNE of Las Cruces, New Mexico. The long-term average annual precipitation is 211 mm (Houghton, 1972), with over half occurring in late summer. Maximum air temperatures reach 40°C, while winter temperatures regularly fall below 0°C. The study sites are on non-arroyo areas of a watershed drainage slope (bajada). Silva et al. (1985) provided detailed site descriptions.

Three hundred-sixty fiberglass-mesh litter bags (15 × 15 cm) were filled with 10 g of oven dried (60°C, 3 days) creosotebush leaf-litter. This litter was collected near the study area either as sensecent leaves shaken from the shrubs or as living leaves stripped from branches and dried in the field. Fowler and Whitford (1980) found no differences in decomposition rates between senescent and fresh litter. Ninety litter bags were immersed overnight in either distilled water (control), 50 ppm active ingredient fungicide solution (fungicide), 5,000 ppm solution of chlordane (insecticide), or saturated mercuric chloride-cupric sulphate solution (general biocide, Vossbrinck et al., 1979; Scharpenseel et al., 1984).

Twenty creosote bushes of uniform height were chosen from an undisturbed area and each bush was randomly assigned a treatment set of 18 litter bags (one treatment/shrub, 5 shrubs/treatment) on 19 June 1984. Biocides (and distilled water controls) were reapplied at 1-, 3- and 5-month intervals on bags in the field when sample litter bags were collected. Two sets of 40 litterbags (four per shrub) were collected before retreatment and one week after retreatment; one set of forty (10 replicates × 4 treatments) was extracted by Tullgren funnels to estimate microarthropod populations (Santos and Whitford, 1981). Both sets were then dried and ashed to estimate mass loss. One set of 40 litter bags (two from each shrub) was collected for another experiment (Fisher et al., unpublished). This experimental design did not control for differences in site heterogeneity and could not discern site-treatment interactions, but did eliminate contamination between bags as all closely placed bags under a single shrub received the same treatment.

Mass-loss data were statistically analyzed after a natural log transformation. The PROC GLM subprogram of SAS (Statistical Analysis System, Inc., 1982) was used to perform Analysis of Covariance (ANCOVA). We fit a family of linearized single exponential-loss equations to mass-loss data and then tested for significant differences between slopes and intercepts of the resulting lines (one line was fitted for each of the four treatments). Significant differences between individual slopes and intercepts were tested using planned contrasts (Freund and Littel, 1981). The resulting exponential-loss equations were of the form

$$\ln(X_t) = \ln(X_0) - kt$$

where t is the time of the observation, k is the exponential loss coefficient, X_0 is the estimated mass in the litter bag at time 0 (%), and X_t is the measured mass at time t (%).

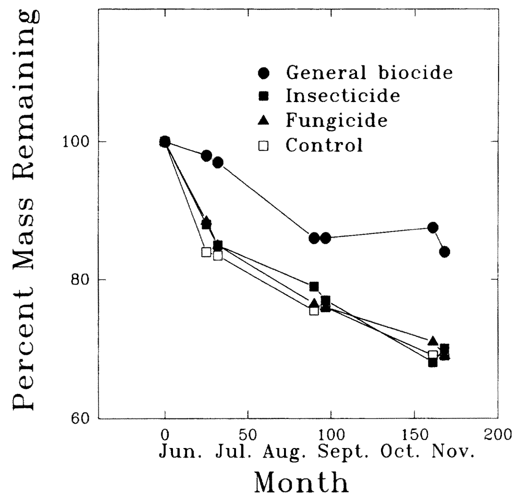

FIG. 1—Biocide effects on creosotebush-litter decomposition. Treatment with general biocide differed significantly ($P < 0.05$) from other treatments according to Student-Newman-Keuls test of means. Data were transformed by $P' = \arcsin(p^{-1/2})$.

RESULTS—Treatments resulted in significant differences in percent litter-mass remaining (Fig. 1, Table 1). Significantly higher mass remained in litter samples treated with the general biocide relative to those subjected to the other treatments and the control (Student-Newman-Keuls test). All of the treatments had X_0 parameters that were

TABLE 1—Effects of treatments on decomposition parameters (X_0 indicates y intercepts, k is the slope, d refers to day) calculated for various periods during the experiment. Letters indicate results of planned contrasts between treatment means. Means with same letters are not significantly different ($P < 0.05$).

	Months 1–5		Month 0–1	Months 1–3		Months 3–5	
Treatment	X_0 (%)	$-k$ (d^{-1})	$-k$ (d^{-1})	X_0 (%)	$-k$ (d^{-1})	X_0 (%)	$-k$ (d^{-1})
Control	85.8 a	0.00132 a	0.00615 a	86.4 a	0.00143 a	84.4 a	0.00121 a
Insecticide	89.2 b	0.00149 a	0.00515 a	90.7 a	0.00179 a	85.7 a	0.00121 a
Fungicide	90.3 b	0.00155 a	0.00524 a	88.8 a	0.00123 a	**93.9 a	0.00182 a
General biocide	**98.1 c	0.00094 b	0.00082 b	**103.8 b	0.00200 a	85.2 a	*−0.00004 b

* k not significantly different from 0.00000 ($P < 0.05$).

** X_0 not significantly different from 100.00 ($P < 0.05$).

TABLE 2—Numbers of Acarina and Collembola extracted from creosotebush litter (totals for all littering/collection) after 1, 3, and 5 months. Numbers of Collembola are in parentheses.

	Treatment			
	Control	Fungicide	Insecticide	General biocide
1 month	4 (1)	3 (1)	2 (1)	2 (0)
3 months	268 (114)	96 (59)	4 (2)	9 (1)
5 months	912 (19)	301 (0)	0 (0)	16 (0)

significantly lower than 100% for some period during the experiment (Table 1). For the control, insecticide, ahd fungicide treatments, this indicates that a single exponential-loss model is inadequate to describe decomposition dynamics. This is probably because of the presence of a labile organic-matter pool that was largely decomposed during the first month of the experiment. It is the decomposition of this pool that appears to be affected by the insecticide and fungicide treatments.

During months 1–3, the decomposition rate (k) of litter treated with the general biocide was not significantly different from those of litter treated with fungicide or insecticide (Table 1). During months 0–1 and 3–5, the decomposition rate associated with the general biocide was significantly lower than for the other two treatments and was not significantly different from zero (Table 1).

During the first month (June to July), few microarthropods were associated with the litter (Table 2). After three and six months, control litter had the highest numbers of microarthropods, followed by fungicide-treated litter. Insecticide and abiotic treated litter had virtually no microarthropods.

DISCUSSION—Photo-oxidation seems particularly likely to play an important role in the decomposition of litter in the northern Chihuahuan Desert. The humidity is usually low and altitudes typically exceed 1,000 m, resulting in high ultraviolet radiation. Temperatures exceed 60°C at the soil surface on a daily basis during the summer (MacKay et al., 1986). With the loss of structural integrity, rain could fragment the weakened litter and mix the material into the soil where the fragments would then be processed by the soil microflora and fauna.

Soil fauna have also been implicated as regulators of litter decomposition in terrestrial ecosystems, either by grazing on litter, fungi, and bacteria (Popovici, 1972; Freckman, 1978) or as predators of fungivorous and bacteriophagus organisms (McBrayer et al., 1977; Vossbrinck et al., 1979; Santos and Whitford, 1981; Elkins and Whitford, 1982). In the northern Chihuahuan Desert, microarthropods and termites are major faunal groups affecting buried litter decomposition (Johnson and Whitford, 1975; Santos and Whitford, 1981; Elkins and Whitford, 1982; Silva et al., 1985). The subterranean termite *Gnathamitermes tubiformans* consumes at least 50% of the net annual primary productivity in the northern Chihuahuan Desert (Johnson and Whitford, 1975; Whitford et al., 1982; Silva et al., 1985).

Our data demonstrated the importance of both abiotic, and to a lesser extent, biotic factors, in the decomposition of creosotebush litter in the northern Chihuahuan Desert. Mass-loss data suggest that abiotic decomposition can account for nearly 50% of the mass loss of creosotebush litter from the soil surface. Vossbrinck et al. (1979) found that abiotic decomposition accounted for about 25% of the total mass loss over a nine-month period in a more moderate short-grass prairie environment. Our data indicate that mass loss was concentrated during the period from mid-July to September, which is the rainy season for the northern Chihuahua Desert. Almost no precipitation occurred between June (6.5 mm total in 4 events) and July (22.3 mm in 6 events). If chemical bonds were weakened by intense sunlight and heat, then the summer rains may have fragmented the litter and washed it out of the litterbags, accounting for the rapid mass losses for all treatments. The lower air temperatures and solar radiation intensities that occur from September–December would account for the lower mass losses during this time period.

Previous studies have shown that mass loss of creosotebush litter from the soil surface is rapid in the summer and slow in winter, yet is unaffected by moisture availability, availability of nitrogen, and microarthropod populations (Schaefer et al., 1985; Silva et al., 1985; Whitford et al., 1986; MacKay et al., 1986, 1987). Our results suggest that organic matter must be fragmenting into the soils. Such fragmentation processes are mediated by litter fauna in many systems, but these organisms have little effect here. Our data confirm previous studies indicating that the role of microfauna is quite limited in the decomposition of surface litter in the northern Chihuahuan Desert (Silva et al., 1985; MacKay et al., 1986; Whitford et al., 1986). The intense light and heat at the soil surface seem sufficient to produce the observed mass losses. The hypothesis that much of the surface litter loss in the northern Chihuahuan Desert is due to fragmentation as a result of abiotic processes, seems to be the best explanation of the data.

Rainfall may enhance the fragmentation of litter and be necessary for movement of the material into the soil. There may be a threshold amount, or intensity, of rainfall which fragments the litter to the point that there is little further abiotic decomposition. If so, this would explain why actual evapotranspiration (AET) and decomposition rates of surface litter are uncorrelated in desert ecosystems (Whitford et al., 1981; Schaefer et al., 1985).

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