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Rainfall and decomposition in the chihuahuan desert

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Summary. We tested the hypotheses that rates of decomposition in a desert should be higher following single large rain events of 25 mm than evenly spaced 6 mm events and that supplemental rainfall should result in higher populations of soil biota. There were no significant differences in mass losses of creosotebush, *Larrea tridentata*, leaf litter on plots receiving water supplementation and no added water. On some sampling dates, there were higher mass losses in the 6 mm·week^{-1} treatment. Weekly rainfall produced higher coefficients of variation in mass losses than the other rainfall regimes. A single event pulse compared with weekly pulses of rainfall during the normal "dry" period resulted in no differences in mass losses. Microarthropods and nematodes exhibited numerical responses to supplemental rainfall but the litter microflora did not. These studies provide direct experimental evidence that the conventional wisdom linking decomposition to rainfall in deserts is wrong. The studies also suggest that the effects of litter fauna on surface litter decomposition are minimal; therefore, future studies should focus on activites of the microflora.

Conventional wisdom holds that deserts are water limited systems and that their biological processes are triggered and maintained by rainfall (Noy Meir 1973; Louw and Seely 1982). Statements to the effects that decomposition in deserts must be limited to short periods when soil and litter are moist (Noy-Meir 1973) are generally accepted hypotheses despite some evidence that decomposition does not vary with rainfall as predicted by general climate models (Whitford et al. 1981; Elkins et al. 1982). In studies of decomposition in several North American deserts, we found a better correlation between decomposition and long-term average rainfall and the season when rainfall is most likely to occur, than with the actual rainfall occurring during the study period (Santos et al. 1984). These findings led us to reexamine the trigger-pulse-reserve paradigm proposed by Noy Meir (1973) in terms of its' applicability to decomposition processes in desert ecosystems.

Investigators working in North American deserts have argued that high quantity rainfall events, e.g. events of greater than 25 mm are needed to trigger biological activity such as ephermeral plant germination, and that low quantity events such as 6 mm are relatively ineffective as triggers of biological pulses (Beatley 1974; Tevis 1958; Went 1949). We hypothesized (1) that decomposition processes should respond like ephemeral plant populations, i.e. that decomposition should be higher following a single 25 mm rain event than after four evenly spaced 6 mm events, and (2) that both rainfall patterns should result in higher decomposition rates than occur after natural rainfall.

Methods

We established nine plots on an area where creosotebush, *Larrea tridentata* occurs as a monotypic dominant shrub. The study site in the northern Chihuahuan desert 40 km NNE of Las Cruces, NM receives a long-term average rainfall of 250 mm·yr^{-1}. The "rainfall supplemented" plots were irrigated with sprinklers that delivered water above the shrub canopy to mimic natural rainfall as closely as possible. The irrigated plots thus received the natural rainfall plus the scheduled supplement. Three plots received 25 mm every four weeks, 3 plots received 6 mm per week and 3 plots received no additional water.

We measured mass loss of organic matter and estimated population sizes of biota in open bottom aluminium screen cylinders that initially contained 20 gms of creosotebush (*L. tridentata*) leaves. We also measured mass loss in fiberglass mesh bags. The creosotebush (*Larrea tridentata*) leaves were collected from shrubs in April and May and air dried in outdoor drying racks. Subsamples of leaves were oven dried to a constant weight to obtain a correction for the air dried leaves. *Larrea tridentata* leaves have a C:N ratio of 26.7 and an initial lignin content of 10.63% (Schaefer et al. 1985). The experiment was started in June 1981 and a second set of cylinders was placed in the field in December 1981 and collected at 3 month intervals for

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1 year. The aluminium window screen cylinders with moveable screen tops were 10 cm diameter, 14 cm height. They were then placed in the mineral soil that had been swept clear of leaf litter and organic matter under shrub canopies. When collected, the cylinders were carefully lifted and the remaining organic matter plus a small quantity of mineral soil that was enclosed by the cylinder was transferred into a plastic bag for transport to the laboratory. Organic matter remaining was measured by drying the collected material, obtaining the mass then transfering that material into crucibles and ashing in a muffle furnace at 500° C for 8 h. The organic matter remaining was calculated from the original dry mass and ash mass by the equation in Elkins and Whitford (1982).

On each collection date, we collected 15 cylinders from each treatment, 5 from each plot. Of these 15, 5 were used for microarthropod extraction and mass loss measurement, 5 were used for nematode extraction and the remaining 5 were used for microflora and protozoan population estimates. Fifteen cylinders were collected just prior to the monthly 25 mm water application and another set of 15 were collected three days after the water application. Cylinders were collected in the field within 3 hours of sunrise in order to obtain comparable estimates of litter biota populations (Whitford et al. 1981). Since there were no measureable differences in mass loss before and after water application, the mass loss data were analyzed together ($n=10$). Forty litter bags were placed on each set of treatment plots under shrub canopies. Ten litter bags from each treatment were collected at 3 month invervals and organic mass loss measured in the same way as mass loss from the cylinders.

In order to evaluate the effects of rainfall pulses on litter decomposition during a period without natural rainfall, we placed three sets of litter bags in the field in April 1984. One set received no water, one set was soaked with 17 mm simulated rainfall for 1 h at the initiation of the experiment and the third set received 6 mm of water delivered in 20 minutes per simulated storm each week. Litter bags were collected and processed as described for the cylinders.

Organic matter remaining was analyzed by analysis of variance (ANOVA) and significant differences in organic matter remaining across dates were assessed by calculating the honestly significant difference (Sokal and Rohlf 1969). Decay constants (K) were calculated using the negative exponential decay function.

Soil microarthropods were extracted from the litter in modified Tullgren funnels. Nematodes were extracted from the litter by the Coolen technique (1979). The litter from three cylinders was subsampled for bacteria, fungi and protozoans. Protozoa were estimated by the most probable number method (Elliot and Coleman 1977; Cutler 1921; Singh 1946). Bacteria numbers were estimated by the flourscein isothiocyanate (FITC) staining method (Babuick and Paul 1972). Fungal biomass was estimated by the method of Olsen (1950).

Results

There were no significant differences in mass losses among treatments on most sampling dates (Fig. 1). There were no differences in mass loss from litter bags and screen cylinders ($P>0.14$) (Fig. 1). There were significant differences in mass loss among the cylinders on the control plots and among the cylinders on the 6 mm·wk^{-1} and 25 mm·month^{-1} supplemental rainfall plots on some sampling dates (Fig. 1).

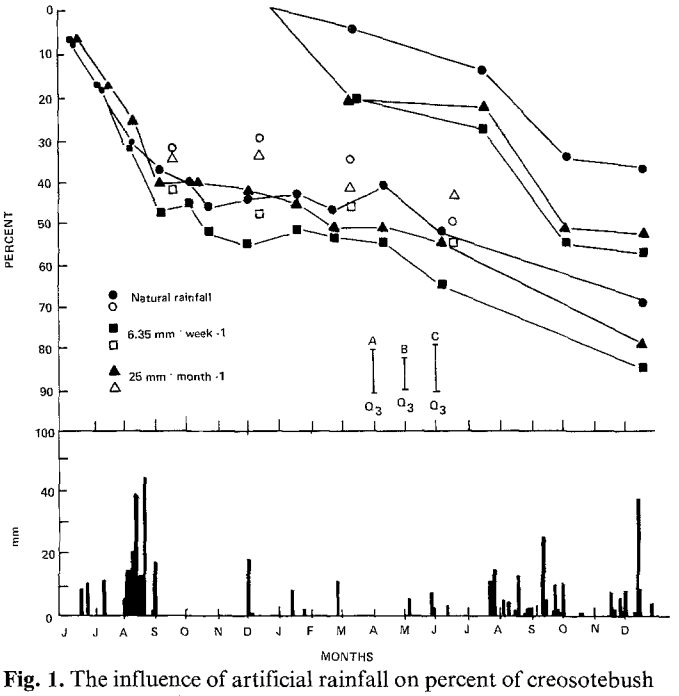

Fig. 1. The influence of artificial rainfall on percent of creosotebush (*Larrea tridentata*) leaf litter lost from litter bags (open symbols) and aluminium screen enclosures in a northern Chihuahuan desert ecosystem (upper panel). The lower panel summarizes water inputs in natural rainfall events. The lines labeled Q_3 equal Tukey's Q values for honestly significant differences between treatment means $P<0.05$. A is the value for the June–December data. B is the Q value for the litter bags and C is the Q value for the December to December data

However, the differences not attributable to handling errors (the October to January 6 mm·week^{-1} values) are in the mass losses after 1 year. The decomposition rate constant (K) of the litter receiving the 6 mm·week^{-1} supplemental water was significantly higher than the control and 25 mm·month^{-1} (Table 1). There were no significant differences among treatments in decomposition rate constants for the litter bags nor for litter placed in the field in December 1981 (Table 1).

During the first four months of the experiment, the coefficients of variation in all treatments were less than 20%. On subsequent sampling dates the coefficients of variation were larger and were consistently higher in the 6 mm·wk^{-1} treatment than in the other treatments. Coefficients of variation in the 6 mm·wk^{-1} treatment ranged from 50% to 78% on the sampling dates from October 1981 to December 1982. Coefficients of variation in the other two treatments on those dates ranged from 30% to 45%.

There were significant differences in the quantity of mass loss from the litter placed in the field in December 1981 among treatments after 3 months field exposure ($P<0.01$) (Fig. 1). However, the rates were not significantly different (Table 1) and obviously the only significant difference in rate was between December and March (Fig. 1). When we compared a single event pulse with small weekly pulses with no supplementation and started the experiment in the spring (long-term average driest period) there were no significant differences in mass losses nor in rate (Fig. 2).