Interactive effects of UV radiation and soil coverage on leaf litter decomposition in velvet mesquite (*Prosopis velutina*)

Michele L. Abbene[1], Paul W. Barnes[1], Heather L. Throop[2]; and Steven R. Archer[3]

[1] Loyola University New Orleans, New Orleans, LA; [2] New Mexico State University, Las Cruces, NM; [3]University of Arizona, Tucson, AZ

Abstract

Recent studies have shown that leaf litter decomposition in dryland ecosystems can be influenced by both soil deposition and solar UV radiation, but how these factors interact to drive decomposition has received little attention. We conducted a growth chamber study to test whether coverage with sterile soil could reduce the direct effect of UV on litter photodegradation in senescent leaflets of velvet mesquite (*Prosopis velutina*), a common woody plant of desert grasslands and shrublands in the southwestern USA. Leaf samples were exposed to two UV treatments (no UV and simulated clear-sky, ambient summer UV [added as UV-B and UV-A; 280-390 nm] for SE Arizona, USA) and three soil coverage treatments (no soil, low soil coverage [ca. 10-20% of leaf surface covered], and heavy soil coverage [ca. 80-90% coverage] in a factorial treatment design [n=5-6 replicates/treatment]). After nearly 32 weeks of UV exposure, leaf dry mass loss was significantly (p<0.01) greater in the +UV than the –UV treatments, when averaged over soil treatments, and there was a significant UV x soil treatment interaction (p<0.01). Specifically, mass loss was greater in the +UV than the –UV treatment for the no soil and low soil coverage treatments, but UV had no significant (p=0.12) effect on mass loss in the heavy soil treatment. Leaf C loss data revealed similar UV and soil coverage patterns to that of the mass loss data, while N loss data showed no consistencies. These findings suggest that soil coverage can potentially ameliorate the direct effects of UV on litter decomposition in desert ecosystems where soil erosion and deposition commonly occur together with high solar UV irradiances.

Introduction

- Decomposition of organic material is a crucial component of global biogeochemical cycles that influences soil fertility, the fate and residence times of carbon and nutrients in organic matter pools, and ultimately plant community composition and production (Hobbie 1992, Wardle et al. 1998).
- Although carbon and nutrients in the litter pool account for only a small portion of system-wide totals, the relatively rapid turnover of this pool makes leaf litter decomposition a key component of biogeochemical cycles (Aerts 1997).
- Considerable progress has been made in developing a mechanistic understanding of the controls over decomposition at local, regional, and global scales (Meentemeyer 1978, Couteaux et al. 1995, Aerts 1997, Hibbard et al. 2005). However, predicting decomposition dynamics in globally extensive arid and semi-arid systems has proven to be problematic (Whitford et al. 1981, Moorhead & Reynolds 1991, Kemp et al. 2003, Parton et al. 2007) due to the pulsed nature of the precipitation drivers and the relatively small size of litter, soil organic matter and mineral nutrient pools (Moorhead & Reynolds 1991) relative to other ecosystems.
- Recent studies have shown that leaf litter decomposition in dryland ecosystems can be influenced by both soil deposition (Throop & Archer 2007) and solar UV radiation (Austin & Vivanco 2006), but how these factors interact to drive decomposition is unknown.

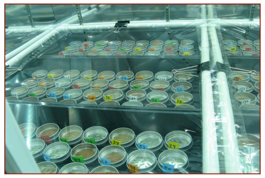
Objective

Experimentally determine how soil deposition and UV radiation interact to influence decomposition of mesquite (*Prosopis velutina*) litter in a controlled lab experiment.

Methods

Mesquite leaf litter was collected just prior to senescence from the Santa Rita Experimental Range (SRER), a desert grassland/ shrubland in SE Arizona, USA.

Leaf litter was placed in shallow, open-topped, stainless steel containers beneath either UV-transparent film (cellulose acetate; cutoff near 290 nm), or UV-absorbing film (UV-B+UV-A; Llumar film; cutoff near 390 nm) in an EGC growth chamber (30 C) equipped with HID (400-W sodium vapor) and UV lamps (40-W Q-Panel UVB-313).



Surface soil collected from the field site was sterilized (autoclaved) and then applied in one of 3 coverage levels over the litter; no soil, moderate soil, or heavy soil.

No Soil Coverage, Moderate Coverage, and Heavy Coverage

UV lamp duration and distance to samples was set to provide daily effective UV exposures that simulate conditions for clear skies in summer months at SRER (Daily $UV\text{-}B_{BE}$ = ca. 8.5 kJ m^{-2} d^{-1}).

The experiment ran for 32 weeks and consisted of 216 microcosms [2 UV levels (+UV, -UV) X 3 soil coverage levels X 6 harvest dates X 6 reps/treatment]

Decomposition was assessed by measuring mass changes, and C and N content.

Results

- Across the 6 harvest dates, decay constants (k; determined using a negative exponential decay model) were higher in +UV than in –UV in the no soil (R^2 > 0.76; p = 0.03) and the moderate soil (R^2 > 0.82; p = 0.02) but comparable in the heavy soil (R^2 > 0.65; p = 0.21) coverage treatments (Fig 1).
- After 32 weeks of UV exposure, leaf dry mass loss was greater in + UV than in –UV when averaged over soil treatments (ANOVA; p < 0.01).
- There was a significant UV X soil treatment interaction (ANOVA; p <0.01).
- Specifically, there were differences in mass loss between +UV and –UV treatments in no soil and moderate soil cover treatments, but UV treatments had no effect on mass loss in heavy soil cover treatment (Fig. 2).
- UV and soil coverage effects on leaf C loss were similar to that of mass loss (Fig. 3), while N loss data showed no consistent patterns or trends (data not shown).

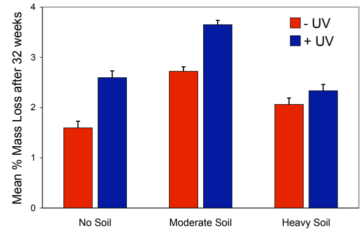


Fig. 2. Effects of UV radiation and soil coverage on mass loss (mean ± 1 SE; n=5-6) of mesquite leaflets after 32 weeks of UV exposure in a growth chamber. Approximate percent of leaflet area covered by sterilized, air-dry soil in the no, moderate and heavy soil treatments were 0, 10-20 and 80-90%, respectively. UV-B exposures simulated ambient clear-sky summer daily doses for the SRER.

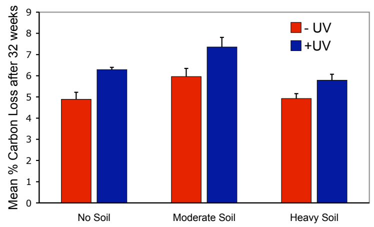


Fig. 3. Effects of UV radiation and soil coverage on total C loss (mean ± 1 SE; n=5-6) of mesquite leaflets after 32 weeks of UV exposure in a growth chamber.

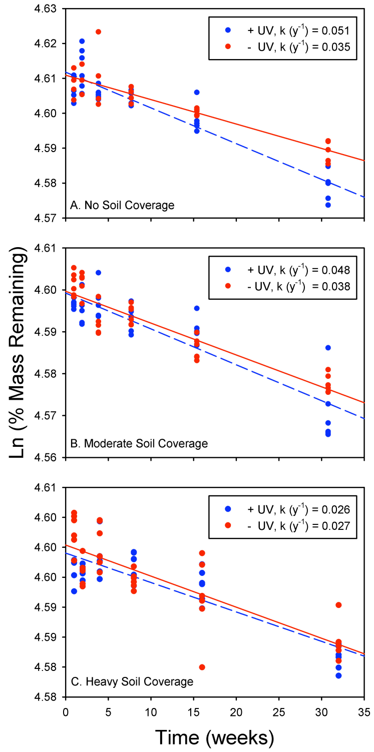


Fig. 1. Natural log (Ln) of % mass remaining of mesquite litter through time for soil coverage treatments (A) no soil, (B) moderate soil, and (C) heavy soil exposed to no UV (-UV; red symbols and lines) and simulated summer UV (+UV; blue symbols and lines). Decay constants (k) are derived from an exponential decay model.

Summary & Conclusions

- Under controlled environment conditions, mesquite leaf litter exposed to UV radiation decomposed more rapidly than leaf litter receiving no UV;
- However, UV effects on decomposition were only apparent when leaf litter was covered with little or no soil;
- These findings indicate that soil coverage can potentially ameliorate abiotic UV photodegradation of leaf litter;
- Rates of mass loss in this growth chamber study using dry, sterile soil (i.e., minimal microbial activity) were, however, an order of magnitude lower than those in the field (Throop & Archer 2007);
- The nature of UV and soil coverage interactions under field conditions where leaf litter from different species is subjected to natural microbial colonization is the topic of future planned studies.
- The long-term goal of these studies is to provide an improved mechanistic understanding of the ecological effects of the changes in land cover (notably increases in woody plant abundance) on biogeochemical cycles in dryland ecosystems.

References

Aerts, R. 1997. Climate, leaf litter chemistry, and leaf litter decomposition in terrestrial ecosystems: a triangular relationship. Oikos 79:439-449
Couteaux, M. M., P. Bottner, and B. Berg. 1995. Litter decomposition, climate and litter quality. Trends In Ecology & Evolution 10:63-66.
Hibbard, K. A., B. E. Law, M. Reichstein, and J. Sulzman. 2005. An analysis of soil respiration across northern hemisphere temperate ecosystems. Biogeochemistry 73:29-70.
Hobbie, S. E. 1992. Effects of plant species on nutrient cycling. Trends in Ecology and Evolution 7:336-339.
Kemp, P. R., J. F. Reynolds, R. A. Virginia, and W. G. Whitford. 2003. Decomposition of leaf and root litter of Chihuahuan desert shrubs: effects of three years of summer drought. Journal of Arid Environments 53:21-39.
Meentemeyer, V. 1978. Macroclimate and lignin control of litter decomposition rates. Ecology 59:465-472.
Moorhead, D. L. and J. F. Reynolds. 1991. A general model of litter decomposition in the northern Chihuahuan Desert. Ecological Modeling 56:197-219.
Parton, W., W. L. Silver, I. C. Burke, L. Grassens, M. E. Harmon, W. S. Currie, J. Y. King, E. C. Adair, L. A. Brandt, S. C. Hart, and B. Fasth. 2007. Global-scale similarities in nitrogen release patterns during long-term decomposition. Science 315:361-364.
Throop, H. L. and S. Archer. 2007. Interrelationships among shrub encroachment, land management and leaf litter decomposition in a semi-desert grassland. Ecological Applications 17:1809-1823.
Wardle, D. A., M.-C. Nilsson, C. Gallet, and O. Zackrisson. 1998. An ecosystem-level perspective of allelopathy. Biological Review 73:305-319.
Whitford, W. 2002. Ecology of Desert Systems. Academic Press, San Diego, CA.
Whitford, W. G., V. Meentemeyer, T. R. Seastedt, K. Cromack, D. A. Crossley, P. Santos, R. L. Todd, and J. B. Waide. 1981. Exceptions to the AET model - deserts and clear-cut forest. Ecology 62:275-277.

Acknowledgements

Funding support was provided by the Loyola University J.H. Mullahy Endowment in Environmental Biology, and a Faculty Research Grant. G. Estrada and G. Hutchinson provided additional assistance.