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UV-B radiation and shrub canopy effects on surface litter decomposition in a shrub-invaded dry grassland

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ABSTRACT

Background & Aims: We assessed the joint role of shrub cover and UV-B on decomposition in a Sonoran Desert grassland. UV is considered an important driver of biogeochemistry in arid grasslands and shrub proliferation in these landscapes can alter both abiotic and biotic drivers of biogeochemistry.
Methods: We manipulated ambient solar UV-B exposure of *Prosopis velutina* leaf litter under and away from shrub canopies and assessed decomposition responses over 320 days.
Results: Leaf litter mass declined 40% during the first 50 days, but only an additional 10% during the remaining 270 days. Decomposition was slower under shrubs, where ground temperatures and total solar radiation were lower than locations away from shrubs. However, the presence/absence of UV-B radiation had no detectable influence on mass loss either under or away from shrubs. UV-B exposure decreased N immobilization suggesting UV-B photodegradation is facilitating microbial access to litter N.
Conclusions: Higher decomposition of litter away from shrubs may reflect a combination of greater rates of thermal degradation and photodegradation. While UV-B did not directly influence decomposition rates, exposure may alter litter nutrient dynamics. Our study suggests landscape-scale decomposition could decline with increases in woody plant canopy cover owing to shrub-driven changes in microclimate.

1. Introduction

Decomposition of plant litter is an important facet of carbon and nutrient cycles and a key factor in soil fertility and nutrient availability in shallow rooting zones (Berg and Laskowski, 2005). Litter decomposition can also influence ecosystem production by altering soil organic matter content and thus soil water holding capacity and nutrient retention. Decomposition is particularly important in dryland ecosystems where pools of litter and soil nutrients are smaller than those in mesic systems (Moorhead and Reynolds, 1991). Decomposition models developed in mesic systems typically under-predict decomposition in drylands relative to measured values (Vanderbilt et al., 2008), suggesting the existence of unique abiotic drivers or unique interactions between abiotic drivers and biotic decomposition processes in these ecosystems (Austin, 2011; King et al., 2012; Throop and Archer, 2009). Given that drylands account for approximately 45% of the global land area (Prăvălie, 2016) and comprise a considerable portion of inter-annual variability in the terrestrial C sink (Ahlström et al., 2015), an accurate representation of arid land decomposition in ecosystem models is imperative.

1.1. Abiotic drivers of decomposition

Abiotic drivers of unique importance in drylands may include photodegradation by ultraviolet radiation (UV-B, 280–315 nm; UV-A, 315–400 nm) and short wavelengths of photosynthetically active radiation (PAR, 400–700 nm) (Austin and Vivanco, 2006; Brandt et al. 2007, 2010). However, while UV radiation can enhance decomposition (Austin et al., 2016; King et al., 2012), some studies show no, or minimal, effects (e.g., Kirschbaum et al., 2011; Yanni et al., 2015) and

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detrimental effects are also observed (e.g. Paul and Gwynn-Jones, 2003; Zepp et al., 1998). These conflicting results may reflect the differential impacts of UV radiation on abiotic and biotic decomposition processes. UV radiation can increase abiotic decomposition rates through photodegradation of recalcitrant material (Austin and Vivanco, 2006), but negatively impact biotic processes where highly actinic shorter UV-B wavelengths occur (Barnes et al., 2015; Brandt et al. 2007, 2010). Biotic decomposition may, however, be enhanced if UV radiation alters the structure of the microbial community or changes microbial growth or activity via indirect effects on litter substrates or direct effects on microbial enzymes (Baker and Allison, 2015; Wang et al., 2015).

UV effects are also mediated by precipitation amount and frequency (Smith et al., 2010), differences in plant species litter chemistry and/or structure (King et al., 2012), and the extent to which litter is covered by soil (Barnes et al., 2015). The net effect of UV radiation on decomposition may therefore depend upon the relative importance of several interacting biotic and abiotic processes (Baker and Allison, 2015; Lin et al., 2015) that can vary with location and ecosystem (Wang et al., 2015) and from one stage of decomposition to another (Austin and Ballaré, 2010; Day et al., 2015).

1.2. Canopy structure influences on decomposition

Plant canopies influence litter quality, soil physicochemical properties, soil microbial communities, and microclimate (Aanderud et al., 2008; Barron-Gafford et al., 2012; Grant, 1997; Osanai et al., 2012). These variables have the potential to directly influence decomposition and can interact with incoming PAR and UV radiation to indirectly mediate decomposition. Drylands are often characterized by mixtures of grasses and shrubs, and the structural differences associated with these contrasting life forms affect a variety of ecosystem functions (Barger et al., 2011; Eldridge et al., 2011), including decomposition (Throop and Archer, 2007). Shrubs have increased in abundance in recent decades in many drylands (Archer et al., 2017). One consequence of this shrub encroachment is alteration of biogeochemical cycling, which is ostensibly influenced by the litter inputs from woody plants and its subsequent decomposition in shrub canopy microclimates (Throop and Archer, 2008).

Shrubs may either promote or retard surface litter decomposition rates relative to rates in shrub-free patches (Fig. 1). Solar radiation at ground level is typically lower under shrub canopies than away from shrubs, with radiation attenuation greater for UV than PAR (Grant, 1997). But, as reviewed earlier, these environmental changes could either stimulate or suppress decomposition. Canopy interception of precipitation and lower soil temperatures under shrubs would presumably reduce decomposition rates relative to locations away from shrubs. However, canopy shading and surface litter reduce soil evaporation, potentially promoting decomposition by helping retain moisture in shrub patches. Shrubs can also influence decomposition indirectly by altering ground cover and hence patterns of soil-litter mixing (Throop and Archer, 2007). Microbial biomass, organic carbon, and total nitrogen tend to be higher in soils associated with shrubs (e.g., Hollister et al., 2010) and each of these factors would also promote decomposition rates relative to locations away from shrubs. Elevated respiration and mineralization in shrub-associated soils relative to soils away from shrubs support this notion (Barron-Gafford et al., 2012).

1.3. Combined effects of drivers

The net effect of shrub alteration of microclimate and the importance of UV exposure on decomposition rates were assessed by manipulating ambient UV exposure of shrub leaf litter under and away from shrub canopies at a Sonoran Desert site where shrub displacement of grasses has been well-documented. We focused on UV-B as these wavelengths have the greatest potential to simultaneously exert both positive and negative effects on decomposition (Bornman et al., 2015). In addition, we assessed differences in decomposition drivers by quantifying shrub-induced changes in radiant energy (PAR and UV), soil moisture, and temperature regimes. We conducted weekly sampling at the beginning of the experiment to quantify the role of these drivers during the initial phases of the decomposition process, when rates of mass loss are typically most rapid. This allowed us to more thoroughly assess the relative importance of abiotic and biotic drivers, the balance of which may change as litter decomposes.

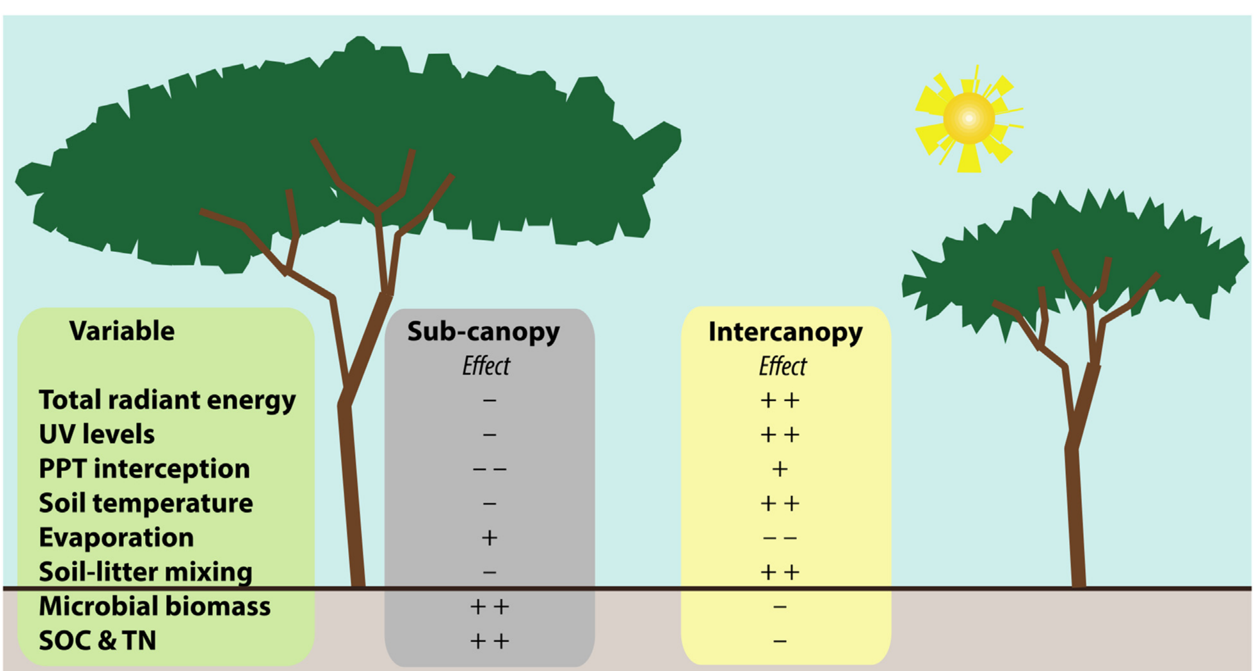

Fig. 1. Heuristic model of decomposition drivers in a shrub-invaded grassland, where "*magnitude*" indicates the hypothesized strength of a given parameter and "*effect*" the hypothesized influence of shrub canopy presence/absence on decomposition rates (+ = positive; 0 = neutral; - = negative).