Soil Biology & Biochemistry 115 (2017) 383–392

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

Photodegradation effects are related to precipitation amount, precipitation frequency and litter traits in a desert ecosystem

Gang Huang, Yan Li*

State Key Lab of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, 818 South Beijing Road, Urumqi 830011, Xinjiang, China

ARTICLE INFO

Article history:
Received 10 March 2017
Received in revised form
28 August 2017
Accepted 29 August 2017
Available online 17 September 2017

Keywords:
Litter decomposition
UV photodegradation
Precipitation pattern
Temperate desert

ABSTRACT

Photodegradation due to litter exposure to solar UV radiation (UV) is presumed to contribute to the surprisingly fast decomposition in some arid and semi-arid regions; however, precipitation may affect the relative importance of photodegradation versus microbial decomposition in litter decomposition. To assess the dependence of photodegradation effects on precipitation, we subjected litters from three plant life forms (spring annual, summer annual and shrub) to two UV treatments (UV block and sunlight) combining four precipitation treatments (two frequencies plus two amounts) over 2.5 years. UV radiation increased k, and it interacted with litter type, with the strongest stimulating effects on low lignin content litter. Precipitation amount and frequency both affected k, and UV photodegradation was dependent on precipitation, with the strongest photodegradation effects in low frequency and low amount of precipitation. UV radiation decreased microbial PLFAs, and altered microbial community in two litters by depressing fungi development. High precipitation frequency significantly increased microbial PLFAs in *E. oxyrrhynchum* litter. Litter decomposition rate was negatively correlated with initial lignin concentration, and UV photodegradation effects increased with increasing lignin loss, suggesting that the increased decomposition rate under UV radiation may primarily result from photochemical mineralization of lignin, rather than from facilitation of microbial decomposition. Our results demonstrate that UV radiation plays an important role in desert litter decomposition. The dependence of photodegradation on litter type and precipitation underscores the importance of incorporating UV radiation-induced C release into modeling of C cycling in desert ecosystems.

1. Introduction

Litter decomposition is dependent on local climate and litter quality (Moorhead and Reynolds, 1989; Abelho, 2016; Ma et al., 2016). Litter decomposition models are in line with enzymolysis kinetics, showing the dominance of microbial decomposition in litter degradation (Moorhead et al., 1999; Moorhead and Sinsabaugh, 2006). However, in arid regions, litter mass loss declines linearly with time, and cannot be well predicted by exponential decomposition models (Austin and Vivanco, 2006; Parton et al., 2007). Photodegradation is recognized as one of the most important mechanisms for this unexpected rapid litter decomposition in arid regions (Brandt et al., 2007; Day et al., 2007, 2015; Gallo et al., 2009; Austin and Ballare, 2010). UV radiation can break down resistant substrates, and thus facilitate microbial degradation (Brandt et al., 2009; Lee et al., 2012a, b). Laboratory studies have shown increased gas release during litter decomposition under UV radiation (Smith et al., 2010; Lee et al., 2012a), while how litter mass loss and microbial communities respond to UV radiation remain controversial (Duguay and Klironomos, 2000). A model study at the global scale demonstrated limited photodegradation effects because of the low organic matter content in drylands (Foereid et al., 2011). However, this study may have underestimated the significance of the break/shortcut of C cycling resulting from photodegradation in these regions; especially in temperate deserts, where the temporal synchrony of intense solar radiation and high litter production can lead to the feasibility of photodegradation (Austin and Vivanco, 2006).

Photodegradation alone cannot fully explain litter decomposition dynamics, and two reasons are attributable to the controversial photodegradation effects (Brandt et al., 2007; Smith et al., 2010). On the one hand, photodegradation can break down resistant

---

* Corresponding author.
E-mail addresses: hg@ms.xjb.ac.cn (G. Huang), liyan@ms.xjb.ac.cn (Y. Li).

http://dx.doi.org/10.1016/j.soilbio.2017.08.034

substrates and facilitate microbial decomposition; on the other hand, UV radiation can inhibit microbial growth and activities, inhibiting microbial decomposition (Epp et al., 2007; Austin et al., 2009). Besides UV radiation, precipitation is another primary factor microbial communities, and microbial decomposition can be initiated even with low available water in arid areas (Austin et al., 2004). Moreover, because of the sporadic precipitation in arid regions, microbes may experience dormancy or death in dry periods, leading to decreased microbial decomposition (Salamanca et al., 2003); thus, changes in precipitation have significant consequences for microbial decomposition, and it is reasonable to expect that photodegradation would interact with precipitation patterns to affect litter decomposition in arid and semiarid regions.

Plant traits also contribute to the large variation in litter decomposition (Pugnaire and Valladares, 2007). For instance, litter decomposition rates are positively related to plant relative growth rate (Kazakou et al., 2006) and to specific leaf area (Cornelissen and Thompson, 1997). In arid regions, litter lignin and cellulose contents are low, and plant leaves are characterized by special structural traits, including higher water conservation tissues and fewer palisade cells; all these traits can cause plant litter to be more fragile and decomposable (Cepeda and Whitford, 1987; Cornwell et al., 2008; Vanderbilt et al., 2008). Lignin is demonstrated to be the primary contributor to mass loss in photodegradation due to its high UV absorption ratio (Gallo et al., 2009; Austin and Ballare, 2010), therefore, mass loss is dependent on lignin loss (Brandt et al., 2007; Uselman et al., 2011). Litter stoichiometric ratio affects microbial decomposition, which can lead to alterations in decomposition rate and nutrient release during decomposition (Perez-Harguindeguy et al., 2000; Brandt et al., 2007). Despite the profound differences in litter traits, few studies have examined photodegradation effects in association with litter traits in arid and semiarid regions (Throop and Archer, 2009). Further studies examining photodegradation effects on litter decomposition with contrasting litter traits can help to understand the photodegradation role in litter decomposition (Brandt et al., 2007; Austin and Ballare, 2010).

The Gurbantunggut Desert is a temperate desert in northwestern China, where intense litter production is in synchrony with peak solar radiation (Huang et al., 2015a), leading to the feasibility of litter photodegradation. Future climate change scenarios have predicted increasing precipitation with more extreme events in northwestern China (Wang and Zhou, 2005). In this study, a manipulative field experiment was conducted to understand how UV radiation, precipitation frequency and amount, and their interactions would affect litter decomposition of five native plants exhibiting different initial litter qualities. We hypothesized that (1) UV radiation would increase litter decomposition of all species, and the magnitude of UV photodegradation effects would depend on litter quality, with the highest UV photodegradation effects on high quality litter; (2) UV photodegradation effects on litter decomposition would depend on precipitation, specifically, precipitation frequency would exert stronger effects on litter photodegradation than precipitation amount; (3) the positive UV photodegradation effects on litter decomposition would be associated with changed microbial communities, and it would be enhanced under high precipitation frequency.

2. Material and methods

2.1. Site description

This study was conducted in the vicinity of the Fukang Station of Desert Ecology, Chinese Academy of Sciences, on the southern edge of the Gurbantunggut Desert (44°17′N, 87°56′E and 475 m a.s.l.). This region has an arid temperate continental climate, with a hot dry summer and cold winter. The annual mean temperature is 6.6 °C, and the annual mean precipitation is 160 mm, of which 70%–80% is distributed in the plant growth season from April to September. The soil is desert solonetz, with aeolian sandy soil at the top (0–100 cm). The soil surface in lowland and the slope of sand dunes is covered with cyanobacterial-lichen crusts (Su et al., 2013), which is very common in desert ecosystems in northern China (Liu et al., 2006; Su et al., 2007; Li, 2012). The shrubs and semi-shrubs are primarily *Haloxylon ammodendron*, *H. persicum*, and *Seriphidium santolinum*, with coverage of ca. 30%. The herbaceous layer is composed of spring annuals and summer annuals, with peak coverage reaching 40%. The dominant herbaceous plants are *Schismus arabicus*, *Erodium oxyrrhynchum*, *Salsola passerine*, *Alyssum linifolium*, *Lactuca undulata*, *Salsola subcrassa*, and *Ceratocarpus arenarius*.

2.2. Experiment design

Three treatments, UV radiation, precipitation amount and precipitation frequency, were used in this study. Two levels of UV treatment were used, UV block from full sunlight and full sunlight. The UV block treatment was manipulated by deploying litters under frames (1.5 m × 2.0 m) with special acrylic sheets (Plexiglass 2458, China), which can resist solar radiation below 380 nm and allow more than 85% transmission of 400–700 nm solar radiation (Fig. S1). The film frames were propped up with steel, fixed by four rebar lengths, and pounded into the soil to a height of 30 cm above the surface. In the sunlight treatment, the same frame without film was fixed in the same way. The frame horizontally covered litter bags. The soil surface temperature was continuously monitored using a thermocouple (Fourtec MicroLab Lite, Israel) near the corner of the frame; the soil temperature under UV block was 0.33 °C higher than that under sunlight (Fig. S2).

Precipitation amount and precipitation frequency were determined based on the nearly 20-year meteorological record; two levels of annual precipitation amount (150 mm and 75 mm) and frequency (an interval of three days and 15 days) were applied from May 10th to October 4th in each year. Precipitation treatment was conducted by evenly spraying distilled water on the surface of litter bags using a sprayer, and this was conducted in late afternoon to prevent excessive evaporation. The combination of precipitation amount and frequency generated four precipitation treatments (Fig. S3): high amount and high frequency (HAHF), 3 mm of distilled water was supplied every three days (Fig. S3a); high amount and low frequency (HALF), 15 mm of distilled water was supplied every 15 days (Fig. S3a); low amount and high frequency (LAHF), 1.5 mm of distilled water was supplied every three days (Fig. S3b); and low amount and low frequency (LALF), 7.5 mm of distilled water was applied every 15 days (Fig. S3b). Natural precipitation was excluded by covering the experimental plots with a piece of plastic film during rainfall throughout the experimental period. The combination of UV and precipitation treatments resulted in eight experimental groups: Sunlight + HAHF, Sunlight + LAHF, Sunlight + HALF, Sunlight + LALF, UV block + HAHF, UV block + LAHF, UV block + HALF, and UV block + LALF.

The deployment of treatments followed a random split-plot design process. Nine blocks were arranged on flat inter-dune ground, and each block was divided into two main plots. UV block and full sunlight transmission treatments were arranged randomly into each main plot in each block. Each main plot was split into four subplots, and the four precipitation treatments were arranged randomly in each subplot. In total, each treatment had nine replicates, totally 72 subplots were arranged, with an area of