183

The photodegradation effect of plant litter in typical temperate steppe varies by the litter state and age

Xing P[1]; Li F[1]

[1]Key Laboratory of Ecology & Resource Use of the Monoglian Plateau, School of Ecology & Environment, Inner Mongolia University, Hohhot, 010021, China

Key words: Photodegradation; Nutrients turnover; C loss; Litter types

Abstract

We established two field decomposition experiments using *Leymus chinensis* and *Stipa grandis* litter, to quantify the effect of different decomposition drivers (including microbial decomposition, abiotic photodegradation and photoacceleration) on the decomposition of different litter types (surface litter and standing dead) and age (young and old). In experiment I, the presence of photodegradation greatly enhanced the effect of microorganisms. For surface litter, microbial decomposition, abiotic photodegradation and photoacceleration reduced mass 64.4%, 18.9% and 16.7% respectively. For standing dead, microbial decomposition, abiotic photodegradation and photoacceleration reduced mass by 51.6%, 21.5% and 26.9% respectively. Solar radiation affected the decomposition of carbon only; it had no effect on nitrogen. Cellulose was less susceptible to the effect of solar radiation than lignin and hemicellulose. In experiment II, we assessed the effects of prior solar radiation on the subsequent decomposition of plant litter, and found that microbial decomposition and abiotic photodegradation decreased the mass of young litter more than that of old litter, while photoacceleration decreased the mass of young litter less than that of old litter. In conclusion, our results indicated that the impact of abiotic photodegradation tended to decrease over time, and that photoacceleration contributed more to the mass loss than the direct photo-mineralization. Our results suggest that although young and dead standing plant biomass can accelerate decomposition process, which potentially increases the carbon loss of ecosystem and decreases the accumulation of organic carbon; this may indicate a new challenge for grassland sustainability.

Introduction

Traditional models underestimate the decomposition rate in arid environments, and this is largely due to the neglect of photodegradation phenomenon. That has been studied in different ecosystems (King 2012; Wang et al. 2021). However, most of these studies evaluating the effect of solar radiation on decomposition are based on a simple comparison between blocking radiation and allowing radiation to access the litter. Furthermore, it is often difficult to separate the relative contributions of abiotic litter loss and loss due to photofacilitation. Such studies are very limited for assessing the impacts of photodegradation compared with microbial decomposition in different environments and conditions. For example, whether

decomposition positions with different decomposition microenvironment (Lin and King 2014; Jacobson et al. 2015; Wang et al. 2017) will influence the contribution of photodegradation to the decomposition of litter, and whether the contribution of abiotic photodegradation and photoaccelerate on litter degradation changes with time or litter type? These questions require quantitative experiments to answer. In this study, we explore whether decomposition processes differ between different litter types, and how the different types of litter affect the contributions of microbial decomposition, photodegradation and photofacilitation to litter degradation. In addition, we also examined how our treatments influenced litter chemistry, to provide clues as to what compounds might be involved in photodegradation.

Methods

The study was carried out in an experimental grassland at the Grassland Ecosystem Research Station of Inner Mongolia University. The experiment materials were the litter of two dominant plants (*Leymus chinensis* and *Stipa grandis*). We conducted two small experiments that used a two-by-two factorial design and the same decomposition treatments, including two sunlight treatments (sun and shade) and two microbial treatments (sterilization and non-sterilization). The decomposition time both was about one year.

Experiment I: This involved litterbags (5 g litter materials). Half were laid flat on the ground (surface litter); the other half were laid upright and suspended 0.1 m above the ground to simulate the dead standing plant biomass (standing dead). Experiment II: Standing dead materials of *L. chinensis* and *S. grandis* were collected and divided into two parts; half were brought back to lab and stored in refrigerator at a low temperature (young litter), the rest were exposed to sun outside for 7 months (old litter).

Treatment implementation: (1) Sun treatment: 15 cm × 20 cm nylon net bags with a mesh size of 1 mm which passes 90% of UV radiation and photosynthetically active radiation (PAR). (2) Shade treatment: the same nylon net bags covered with two layers of black sunshade net which block 95% of UV radiation and PAR. (3) Sun+sterilization treatment: 12 cm × 17 cm solar-transparent polyethylene ziplock bags (0.08 mm, DengBi, Anhui) which passes 85% of UV radiation and PAR. (4) Shade+sterilization treatment: the same ziplock bags covered with two layers of black sunshade net. For sterilization treatment, before putting into ziplock bags, the air-dry decomposition materials entailed placing in an oven at 121℃ for 20 min (Day et al., 2015). These ziplock bags were changed regularly every two months to ensure their transmission and integrity during the experiment period.

Calculation method: where the X_0 is the initial litter mass, and X_t is the litter mass at a specific time t within the experimental duration. Litter nutrients remaining (carbon, nitrogen, hemicellulose, cellulose and lignin remaining) within a specific time-frame from 0 to t were also computed, where the C_0 and C_t respectively is the litter chemical content of at initial time point (t=0) and sampling time point (t), respectively. The formulae are:

$$Mass\ remaining = X_t/X_0 \times 100\%$$

$$Nutrients\ remaining = C_t/C_0 \times 100\%$$

$$Relative\ contribution\ to\ mass\ change_{microbial\ decomposition/abiotic\ photodegradation} = \frac{Mass\ remaining_{shade+sterilization} - Mass\ remaining_{shade/sun+sterilization}}{Mass\ \ remaining_{shade+sterilization} - \ Mass\ \ remaining_{sun}}$$

$$Relative\ contribution\ to\ mass\ change_{photoaccelerate} = 100 - relative\ contribution_{microbial\ decomposition} - relative\ contribution_{abiotic\ photodegradation}$$

Results

Experiment 1

Litter C loss and the contributions of different decomposition pathways

During 405-day decomposition, mass remaining gradually decreased with time (Fig. 1) and mass remaining under the four treatments were significantly different across from four kinds of decomposition materials. At the end of the experiment 1, the relative contribution of microbial decomposition, abiotic photodegradation and photoaccelerate to cumulative mass loss of *L. chinensis* and *S. grandis* surface litter is 64.4%, 18.9% and 16.7% respectively, and 51.6%, 21.5% and 26.9% respectively for their standing dead.

Litter chemistry

More N remained under the non-sterilization treatment than under the sterilization treatment. N remaining in the litter exposed to sun was usually more than that of litter under shade, while less N remained under the sun+sterilization treatment than under shade+sterilization (Fig. 2a~d). Without sterilization, N remaining in surface litter was higher than that of standing dead without enrichment process. By contrast, for both surface litter and standing dead, C remaining in litter exposed to sun was less than that of litter under shade (Fig. 2e~h).

Sunlight and sterilization treatments both significantly affected the amount of hemicellulose and lignin remaining for both *L. chinensis* and *S. grandis*, but did not significantly affect cellulose remaining (Fig. 2i~n). Only for *L. chinensis* did the litter state significantly effect lignin remaining. Sunlight significantly decreased the amount of hemicellulose and lignin remaining. Hemicellulose and cellulose remaining were slightly lower for non-sterilized surface litter, while the lignin remaining was higher.

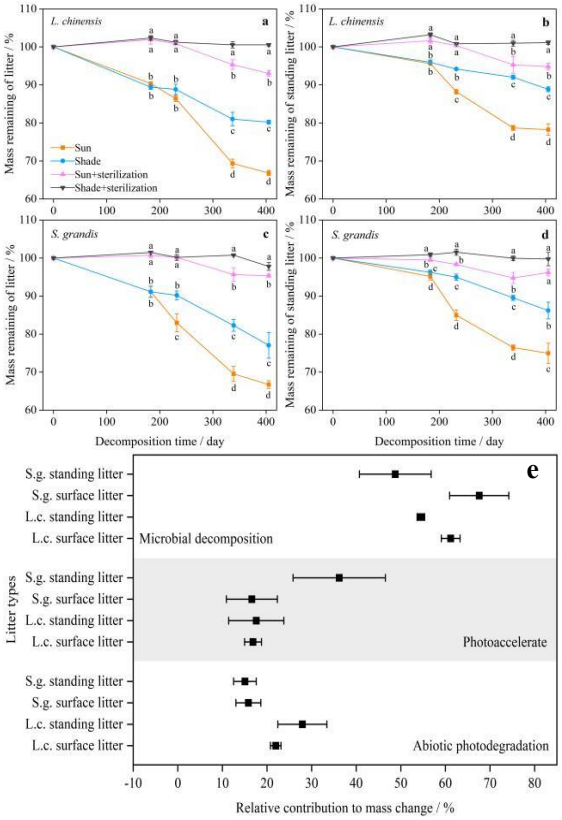

Figure 1 Mass remaining dynamics of litter at different treatment (a~d) and relative contribution of different decomposition pathway to mass change (e) over Experiment 1.

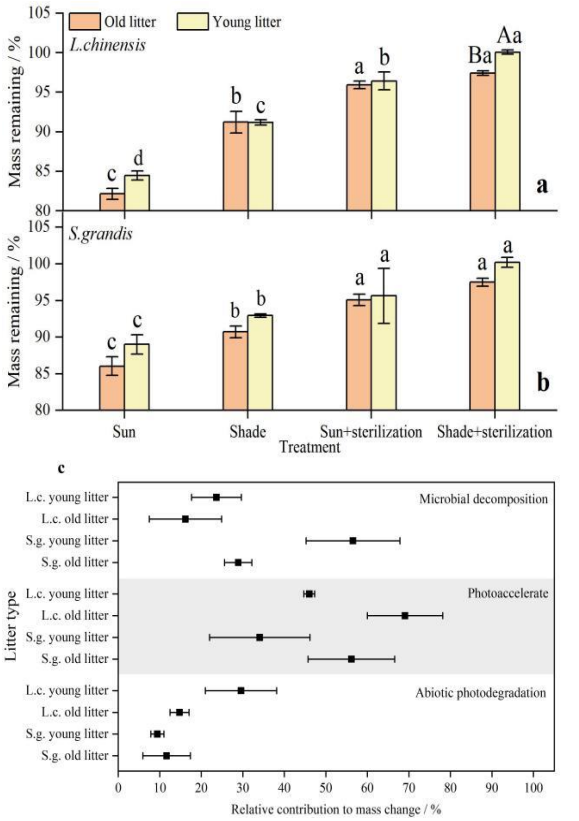

Figure 3 Mass remaining of litter at different treatment (a, b) and relative contribution of different decomposition pathway to mass change (c) over the experiment 2.

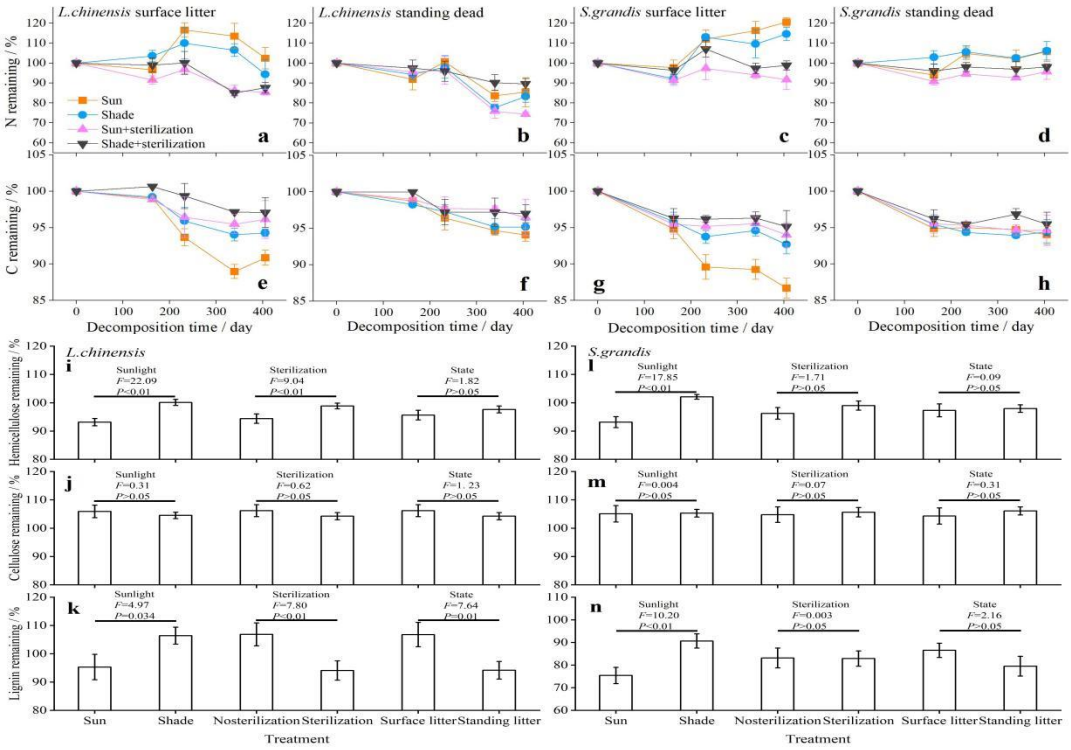

Figure 2 Dynamics of N and C remaining of different litters (*L. chinensis* surface litter (a, e), standing dead (b, f), *S. grandis* surface litter (c, g), standing dead (d, h) under all treatments, and effects of main treatment effect (sun or shade, nonsterilization or sterilization, surface litter or standing dead) on hemicellulose, cellulose and lignin remaining of *L. chinensis* (i, j, k) *and S. grandis* (l, m, n) over the Experiment 1.

Experiment 2

Litter mass remaining and the contributions of different decomposition pathways

The different treatments had significant impacts on both old and young litter. At sun treatment, mass remaining of old litter was lower than that of young litter. Moreover, for young litter, the relative contributions of microbial decomposition, photoacceleration and abiotic photodegradation were 40.1%, 40.0% and 19.5% respectively, while for old litter the relative contributions were 22.5%, 62.6% and 13.2% respectively (Fig. 3).

Discussion

Our results show that solar radiation significantly increased litter decomposition rate. This, solar radiation is a driver of litter decomposition in grassland ecosystem. Solar radiation enhances decomposition by more than 60% on average. However, the promotion effect varies between litter state types. Sunlight increases mass loss of surface litter and standing litter by 56.3% and 88.4% respectively. That means photodegadation promotes decomposition of standing litter more than surface litter. The different drivers of litter decomposition differ between litter state. photoacceleration and abiotic photodegradation have a greater effect on standing litter than on surface litter. Furthermore, there was more N remaining in surface litter, while standing litter has none, which limits microbial mineralization of carbon-based compounds. On the other hand, compared with young litter, old litter decomposed faster, perhaps because of its exposure to sun for 7 months (Angst et al. 2017). That suggests keeping litter standing and this subject to insolation will

lead to faster decomposition when on the soil. Compared with the new litter, the microbial decomposition and abiotic photodegradation of the old litter is less, while photopromotion increases degradation.

Synthesizing two experiments, we conclude that the order of contribution of different decomposition pathway was: microbial decomposition (44.7%) > photoaccelerate (36.6%) > abiotic photodegradation (18.3%). No matter the litter types, microbial decomposition was always the leading pathway in the decomposition process, photoacceleration has a much larger impact photodegradation.

Acknowledgements
We thank Drs Yanan Wang and Yanlong Li for their helps of field work. This work was supported by National Natural Science Foundation of China (Grant No. 32071564 & 3221101980).

References

Day T, René G, Ruhland C (2015) Photodegradation of plant litter in the Sonoran Desert varies by litter type and age. *Soil Biology and Biochemistry* 89, 109-122.

Jacobson K, Diepeningen A, Evans S, Fritts R, Gemmel P, Marsho C, Seely M, Wenndt A, Yang XX, Jacobson P (2015) Non-rainfall moisture activates fungal decomposition of surface litter in the Namib sand sea. *PLoS ONE*, 10, e0126977.

King J, Brandt L, Adair E (2012) Shedding light on plant litter decomposition: advances, implications and new directions in understanding the role of photodegradation. *Biogeochemistry* 111(1-3), 57-81.

Lin Y and King J (2014) Effects of UV Exposure and Litter Position on Decomposition in a California Grassland. *Ecosystems* 17, 158-168.

Wang Q, Pieristè M, Liu C, Kenta T, Robson TM, Kurokawa H 2021. The contribution of photodegradation to litter decomposition in a temperate forest gap and understorey. *New Phytologist* 229, 2625-2636.

Wang J, Liu L, Wang X, Yang S, Zhang B, Li P, Qiao C, Deng M, Liu W (2017). High night-time humidity and dissolved organic carbon content support rapid decomposition of standing litter in a semi-arid landscape. *Functional Ecology* 31, 1659–1668.

Angst S, Cajthaml T, Angst G, Simackova H, Brus J, Frouz J (2017). Retention of dead standing plant biomass (marcescence) increases subsequent litter decomposition in the soil organic layer. *Plant & Soil* 418, 571‑579