Relative Importance of Control Factors for Regulating Litter Decomposition Rate:

Climate, Litter Quality, Decomposer Group, and Soil Abiotic Environment

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Abstract

Plant litter decomposition rate varies hugely across the world [1] and accounts for the majority of territorial organic carbon processing [2]. Factors for regulating the litter decomposition rate and their relative importance are controversial. Here we conducted a national scale transplant experiment to do the following:

1. Investigate the control factors and their relative importance for regulating litter decomposition rates of *P. australis* and *S. alterniflora*.
2. Reveal and explain the latitudinal patterns of litter decomposability of these two species.

Introduction

Litter decomposition is a complex process that consists of physical, chemical, and biological subprocesses that are controlled by both abiotic and biotic factors, including climate, soil, litter quality, and decomposer. This theory of four distinct factors was first postulated by Tenney and Waksman in 1929 [3]. Research has been done to investigate the relationship between these factors and the litter decomposition process. But most research only considered a single factor, which is not comprehensive.

Materials and Methods

Sample Preparations

Sample Preparations The litter samples were collected from nine regions (Figure 1, blue and red marks) for two species along Chinas coastline between August and November 2015, the latitude of which spans from 21.15N to 40.68N. In each region, we set five subsites to be separated more than 1 km for replication, so we got 45 litter samples for each species. All the litter samples were washed and oven-dried at 60°C. Then those litter samples were loaded into litter bags with three different mesh sizes (5 mm, 2 mm, and 0.1 mm), labeled, and weighed. All 45 litter samples' chemical and physical traits were tested, and the detailed trait variables were listed in Table 1.

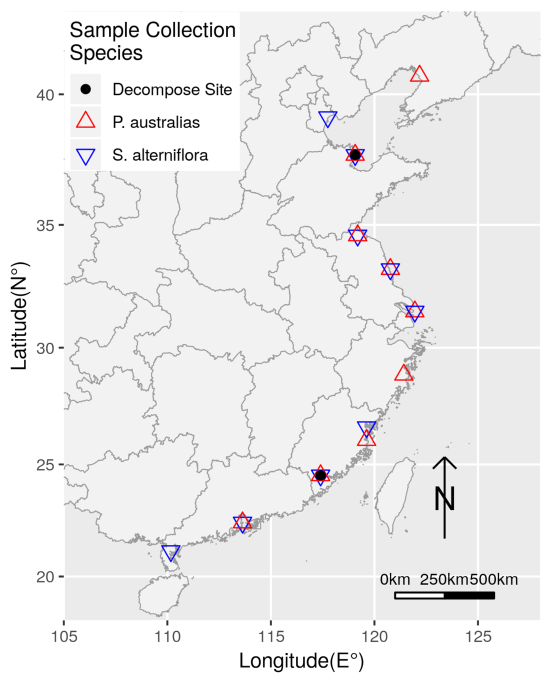


Figure 1: Study sites of this research.

Litter Decomposition Experiment

Transplant experiment was conducted in two national nature reserves in a coastal area in China (Figure 1, black dots), located in Zhangzhou and Dongying, which represent the lower and higher latitudes of the decomposition region. Both sites are located in the estuary and have the natural coverage of *P. australis* and *S. alterniflora*. Litter bags were buried into three subsites in each region for each species in July 2017. Litter bags were harvested three months later (based on pre-experiment) and washed using 0.1 mm sieve, oven-dried at 60°C, and weighed. Soil chemical and physical factors were tested both on site (pH and salinity) and in the lab (TC, TN, AP, SOM).

Table 1: List of variables used in this study

Category		List	Type
Decomposition rate		k	Continuous
Climate		Decompose_site	Dichotomous
Litter	Chemical	C, N, P, K, Ca, Na, Mg, Lignin, Tannin, Cellulose, Hemicellulose, Phenol	Continuous
	Physical	SLA, Toughness, Thickness	Continuous
Soil	Chemical	TC, TN, AP, SOM	Continuous
	Physical	pH, Salinity	Continuous
Decomposer		Mesh_size	Categorical

Data Analysis

The experiment resulted in a total implantation of 1,620 samples, 1,536 of which were collected and mass losses were measured, and 84 missing values were interpolated with the mean values of its treatment groups. Litter decomposition rate constants were calculated based on the commonly used formula: $k = -\frac{ln(M_t/M_0)}{t}$ (M_t: Mass after decomposition, M_0: Mass before decomposition, t: time of decomposition, unit in years). The stoichiometric trait of litter was calculated based on litter chemical traits. To compare the relative decomposability of each species, we also calculated the relative decomposition rates that are normalized within species. Multi-ANOVA and linear regressions were applied to test the relationship between control factors and decomposition rate.

The PCA of litter quality was used along with the results of Multi-ANOVA and linear regressions to select variables for SEM modeling. The latent variable was calculated based on the selected variables of litter quality. We use this latent variable together with the decomposition region (climate), mesh size (decomposer group), and litter decomposition rate constants to construct the SEM. P-values and estimate payloads were calculated. Model judgment is based on model Chi-square, insignificant Chi-square test, RMSEA, and AGFI.

All statistical analyses were conducted in R version 3.4.3 (R Core Team 2017).

Results

Control Factors and Their Relative Importance

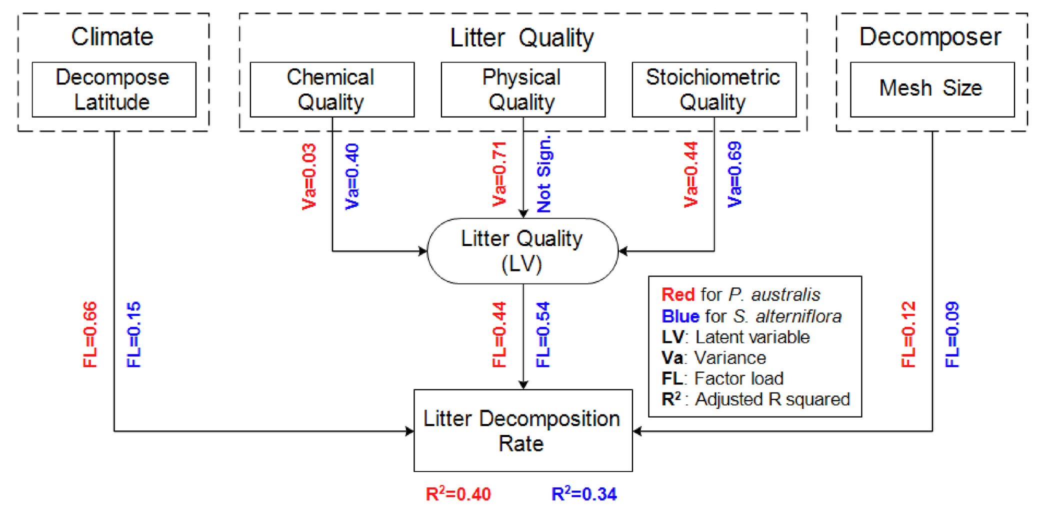
The Multi-ANOVA result (Table 2) shows that the litter quality (origin region), climate (decomposition region), and decomposer group (mesh size) had significant influences on the litter decomposition rate constants of both species. And some interaction effects of these three factors were also significant (OR x DR of both species, DR x MS, and OR x DR x MS of *S. alterniflora*).

The SEM result (Figure 2) shows a distinct difference in relative importance for regulating litter decomposition rate between *P. australis* and *S. alterniflora*. Litter decomposition rate of *P. australis* was majorly regulated by climate (0.66) and litter quality (0.44). Decomposer group (0.12) also affected decomposition rate to some degree. As for *S. alterniflora*, litter quality (0.54) is the dominant control factor; the influences of climate and decomposer were limited.

Table 2: The effects of litter quality (origin region), climate (decompose region), and decomposer group (mesh size) on the litter decomposition rates of two species (ANOVA, type I sum of squres)

	Source	Df	SS	MS	F	Pr
P. australis	Origin Region (OR)	8	183	22.8	41.09	<0.001
	Decompose Region (DR)	1	157	157.4	283.32	<0.001
	Mesh Size (MS)	2	13	6.4	11.44	<0.001
	OR × DR	8	20	2.5	4.5	<0.001
	OR × MS	16	13	0.8	1.43	0.12
	DR × MS	2	0	0.2	0.35	0.70
	OR × DR × MS	16	3	0.2	0.33	0.99
	Residuals	756	420	0.6		
S. alterniflora	Origin Region (OR)	8	332	41.5	90.56	<0.001
	Decompose Region (DR)	1	36	35.6	77.54	<0.001
	Mesh Size (MS)	2	25	12.6	27.52	<0.001
	OR × DR	8	35	4.4	9.66	<0.001
	OR × MS	16	14	0.9	1.98	0.01
	DR × MS	2	7	3.6	7.77	<0.001
	OR × DR × MS	16	12	0.8	1.69	0.04
	Residuals	756	347	0.5		

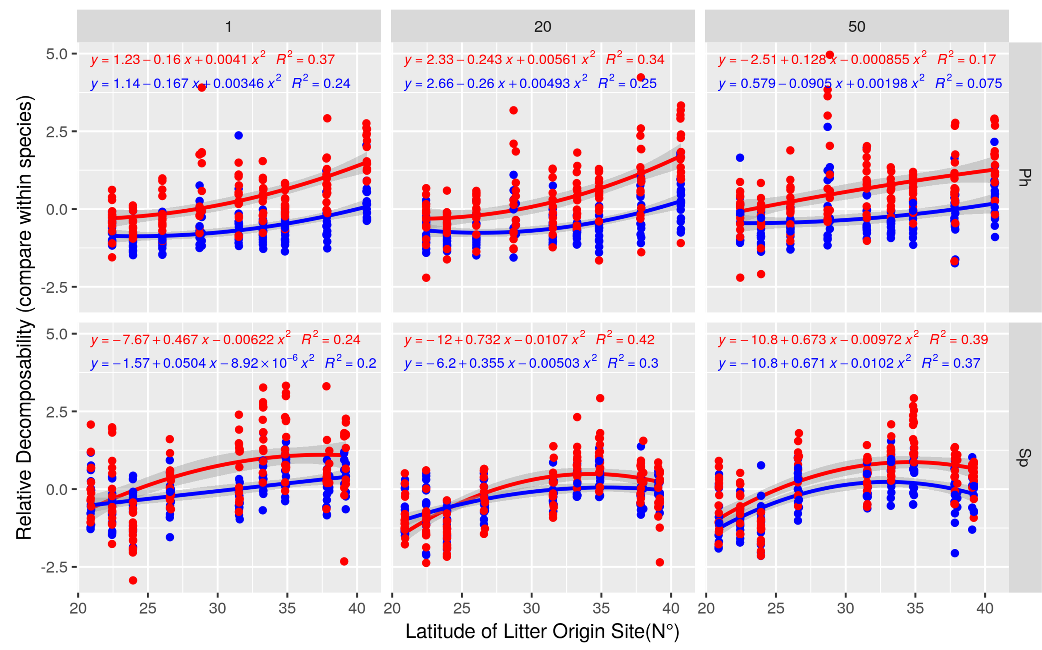
Figure 2: Structural equation models showing the relative importance of control factors for regulating litter decomposition rate.



Latitudinal Pattern of Litter Decomposability

Latitudinal patterns of relative decomposability within species are different between *P. australis* and *S. alterniflora*. For *P. australis*, litter from higher latitude regions always decompose faster than those from lower latitude regions. But for *S. alterniflora*, litters from about 33N have the highest decomposability. This result can be explained with the latitudinal pattern of litter qualities and the relationship between the litter quality and decomposition rate (Appendix).

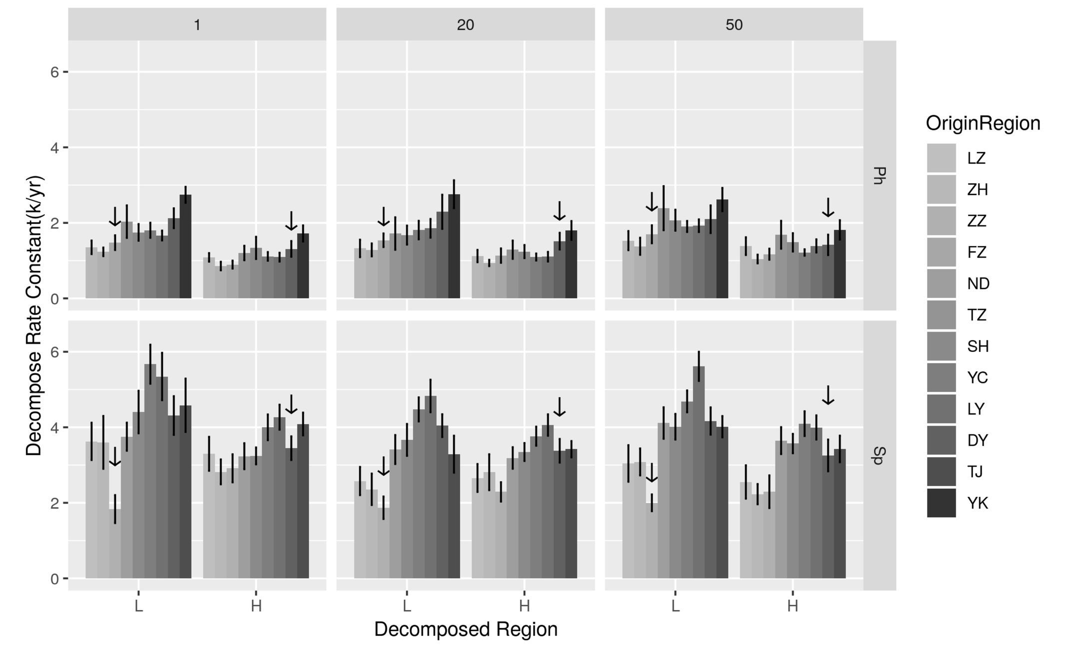
Figure 3: Latitudinal pattern of litter relative decomposibility. Red for samples decomposed in lower latitude, blue for higher ones.



Home Field Disadvantage Effects

Home field disadvantage (HFD) effects were significantly observed in *S. alterniflora* all treatment groups but not in *P. australis* (Figure 4). This samples which decomposed in their original region, were decomposed significantly slower comparing with the latitudinal pattern of litter decomposibility which shows in Figure 3. All the treatment groups of *S. alterniflora* showed the same effect means HFD effects didn't interact with either climate or decomposer group in our research. HFD index were calculated and confirmed the result (Appendix).

Figure 4: Latitudinal pattern of litter decomposibility. ↓ point at the decomposition site of the experiment group.



Conclusions

- Litter decomposition rate of *P. australis* is majorly regulated by climate and litter quality. As for *S. alterniflora*, litter quality is the dominant control factor.
- Latitudinal patterns of relative decomposability within species are different between *P. australis* and *S. alterniflora*. This result can be explained with the latitudinal pattern of litter qualities, which are directly related to decomposition rate.
- HFD effect exists in *S. alterniflora* litter decomposition processes in both higher and lower latitude but are not significant in those of *P. australis*.

References

1.Cornwell & Weedon (2014). Decomposition trajectories of diverse litter types: A model selection analysis. Methods in Ecology and Evolution.
2.US DOE (2008). Climate Placemat: Energy-Climate Nexus, US Department of Energy Office of Science.
3.Tenney & Waksman (1929). Composition of natural organic materials and their decomposition in the soil. Soil Science.

For additional information (Appendix) please scan the QR code: