

Postprint: Early-Stage Litter Decomposition Dynamics in *Loropetalum chinense* Communities at Different Restoration Stages in the Karst Area of the Lijiang River Basin

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Abstract

To investigate litter decomposition in *Loropetalum chinense* communities at different restoration stages in the karst region of the Lijiang River basin, the litterbag method was used to examine early-stage decomposition dynamics. The results demonstrated that after 1 a of decomposition, litter weight loss in *L. chinense* communities followed the order: shrub stage > shrub-tree stage > forest stage. The time required for 50% litter decomposition in the shrub, shrub-tree, and forest stages was 1.28, 1.38, and 1.41 years, respectively, while the time required for 95% decomposition was 5.54, 5.97, and 6.09 years, respectively.

After 1 a of decomposition, nutrient dynamics exhibited the following patterns: C content generally increased in the shrub and shrub-tree stages but decreased in the forest stage; N and cellulose contents increased across all three restoration stages; P content decreased in the shrub and forest stages but increased in the shrub-tree stage; lignin content increased in the shrub stage while decreasing in both the shrub-tree and forest stages.

Correlation analysis revealed that litter decomposition rate in the shrub stage was significantly or highly significantly correlated with C, N, P, C/P, and N/P; decomposition rate in the shrub-tree stage was significantly or highly significantly correlated with N and lignin/N; and decomposition rate in the forest stage was significantly or highly significantly correlated with N, cellulose, C/N, and lignin/N.

Full Text

Preamble

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The Initial Dynamics of Litter Decomposition of *Loropetalum chinense* Communities Among Different Recovery Stages in Karst Areas of the Lijiang River Watershed

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Abstract

To explore litter decomposition in *Loropetalum chinense* communities at different restoration stages in the karst area of the Lijiang River watershed, we used the litterbag method to study the initial dynamics of litter decomposition. The order of litter mass loss in *L. chinense* communities was: shrub stage > shrub-tree stage > tree stage. The predicted time required for 50% and 95% litter decomposition was 1.28 a and 5.54 a for the shrub stage, 1.38 a and 5.97 a for the shrub-tree stage, and 1.41 a and 6.09 a for the tree stage, respectively. Nutrient dynamics showed that organic carbon content generally increased in the shrub and shrub-tree stages but decreased in the tree stage. Nitrogen content showed an overall increase in the shrub and shrub-tree stages, while phosphorus content generally decreased in the shrub and tree stages. Lignin content generally increased in the shrub stage but decreased in the shrub-tree and tree stages. Correlation analysis indicated that litter decomposition rate in the shrub stage was significantly or extremely significantly correlated with organic carbon, nitrogen, phosphorus, C/P, and N/P; in the shrub-tree stage with nitrogen and lignin/N; and in the tree stage with nitrogen, cellulose, C/N, and lignin/N.

Keywords: *Loropetalum chinense* communities; initial nutrient content; Lijiang River watershed karst area; litter decomposition

1. Study Area Overview

The study area is located in Xicun, Guilin City, Guangxi Zhuang Autonomous Region, representing the core section of the Lijiang River watershed in north-eastern Guangxi. The geographic coordinates are 110°36'–111°29' E, 24°15'–26°23' N. The region has a mid-subtropical humid monsoon climate with an

average annual temperature of 18.9°C. The mean temperature is 7.8°C in January and 28°C in July. Annual precipitation ranges from 1490 to 1905 mm, with uneven seasonal distribution and dry winters with little rainfall. The average annual evaporation is 1949.5 mm, and the frost-free period is 300 days. This study examined *Loropetalum chinense* communities at different restoration stages [19], with basic characteristics of sample plots shown in Table 1 .

1. Experimental Design

In fixed sample plots of three restoration stages of *L. chinense* communities, we established 20 m × 20 m quadrats [18]. Within each quadrat, we placed 50 cm × 50 cm nylon mesh collection frames with 1 mm mesh size to collect litter. At the beginning of each month, litter from within the collection frames was gathered. Fresh, undecomposed litter from the three restoration stages was collected monthly, brought back to the laboratory, and oven-dried. This litter was then mixed with that collected in previous months. For each restoration stage, 10 g of mixed litter was accurately weighed and placed into 15 cm × 25 cm nylon mesh bags (1 mm mesh). Each restoration stage had 60 bags, which were randomly placed in the original plots for decomposition starting on the 1st of each month. Every month thereafter, five bags per restoration stage were retrieved. Attached soil and invading roots were carefully removed in the laboratory, and the litter was oven-dried at 65°C and weighed to calculate mass loss and determine substrate quality.

2. Data Processing

The litter remaining rate was calculated as:

$L = (M_t/M_0) \times 100\%$, where M_t is the sample dry weight after decomposition time t , and M_0 is the initial litter weight.

The litter decomposition rate was calculated as:

$D = 100\% - L$, where D is the decomposition rate and L is the remaining rate.

Litter remaining rates were fitted using the modified Olson exponential decay model [22]:

$Y = ae^{-kt}$, where Y is the litter residual rate, t is decomposition time, and k is the annual decomposition coefficient.

Data analysis was performed using Excel 2010, SPSS 19.0, and Sigmaplot 10.0.

1. Litter Decomposition Dynamics

After one year of decomposition, litter remaining rates in the shrub, shrub-tree, and tree stages of *L. chinense* communities were 59.58%, 61.79%, and 62.02%, respectively, with significant differences among stages ($P < 0.05$). Decomposition rates varied significantly across restoration stages, with the annual decomposition coefficient k following the order: shrub stage (0.541) > shrub-tree stage (0.502) > tree stage (0.492). The predicted time for 50% and 95%

decomposition was 1.28 a and 5.54 a for the shrub stage, 1.38 a and 5.97 a for the shrub-tree stage, and 1.41 a and 6.09 a for the tree stage, respectively.

Decomposition rates peaked in July for the shrub and shrub-tree stages, and in August-September for the tree stage. All three restoration stages showed relatively fast decomposition from May to September. The shrub stage had the smallest litter remaining rate, likely due to lower canopy density compared to the tree stage, which had the highest canopy density and thus slower decomposition [17].

2. Initial Litter Nutrient Content

Initial nutrient contents differed significantly among restoration stages, except for cellulose. Organic carbon content was significantly higher in the shrub and tree stages than in the shrub-tree stage ($P < 0.05$). Nitrogen content was significantly higher in the tree stage than in the shrub and shrub-tree stages ($P < 0.05$), while phosphorus content was significantly higher in the shrub and tree stages than in the shrub-tree stage ($P < 0.05$). Lignin content was significantly higher in the tree stage than in the shrub and shrub-tree stages ($P < 0.05$). Initial cellulose content showed no significant differences among stages ($P < 0.05$).

3. Litter Nutrient Release Characteristics

After one year of decomposition, organic carbon content increased in the shrub and shrub-tree stages but decreased in the tree stage. Nitrogen content increased overall in the shrub and shrub-tree stages, with the tree stage showing the highest initial N content and the shrub-tree stage the lowest. Phosphorus content decreased in the shrub and tree stages but increased in the shrub-tree stage. Lignin content increased in the shrub stage but decreased in the shrub-tree and tree stages. Cellulose content generally increased across all stages, with the tree stage showing significantly higher cellulose content than the shrub and shrub-tree stages ($P < 0.05$).

4. Relationship Between Litter Mass Loss and Nutrient Release Dynamics

Correlation analysis between substrate quality and decomposition rate showed that in the shrub stage, decomposition rate was significantly or extremely significantly correlated with organic carbon, nitrogen, phosphorus, C/P, and N/P. In the shrub-tree stage, decomposition rate was significantly or extremely significantly correlated with nitrogen and lignin/N. In the tree stage, decomposition rate was significantly or extremely significantly correlated with nitrogen, cellulose, C/N, and lignin/N (Table 4).

3. Discussion

Litter decomposition releases nutrients that annually meet 69%–87% of forest growth requirements, and decomposition rate largely determines soil nutrient supply capacity and ecosystem productivity [9]. The decomposition coefficient k indicates that faster decomposition occurs with larger k values [22]. In this study, the order of annual decomposition coefficients across the three restoration stages was shrub stage > shrub-tree stage > tree stage, indicating relatively rapid decomposition in the shrub stage.

Substrate quality and stoichiometry affected decomposition rates differently at each stage. Decomposition rate is closely related to N and P contents, with higher N and P promoting faster decomposition [23]. Initial N content increased gradually with forward succession, and decomposition rates at all stages were extremely significantly positively correlated with N, consistent with Song et al. [9]. This may occur because exogenous nitrogen is immobilized by microbes on the litter [25], and increased N content accelerates decomposition [26]. The shrub stage had higher N content both before and during decomposition, which may contribute to its larger k value.

Lignin is a recalcitrant component, while cellulose is more easily decomposed [28]. When lignin content exceeds 25%, it becomes a strong predictor of decomposition [29]. Initial lignin content in all restoration stages was higher than reported in other studies (5%–30%). The shrub stage had the lowest initial lignin content and fastest early decomposition, while the tree stage had the highest lignin content and slowest early decomposition. As decomposition progressed, lignin accumulated, and the tree stage's lignin content became lower than the shrub stage's in later stages, resulting in faster late-stage decomposition in the tree stage, consistent with Li et al. [31]. This confirms that high lignin content limits decomposition.

Cellulose content generally increased across all restoration stages, contrary to Zhang et al.'s [32] findings on *Cinnamomum camphora* and *Toona ciliata*. This may relate to ligninase and cellulase activities [32]. Beyond substrate quality, stoichiometric ratios are important predictors of decomposition rate [33–34]. Lower C/N and C/P ratios generally indicate faster decomposition [24,27,35]. In this study, the shrub stage had relatively high C/N and C/P ratios but faster decomposition rates, possibly because the tree stage had more coriaceous-leaved tree species (e.g., *Ilex bitoritsensis*, *Cinnamomum saxatile*) with more recalcitrant compounds like tannins that hinder decomposition [36]. These factors may explain the tree stage's slower decomposition and smaller k value, possibly related to karst forest characteristics [15]. This suggests that litter decomposition rate decreases with forward succession in *L. chinense* communities.

N/P ratio is a key indicator of decomposition rate [39], decreasing with vegetation restoration succession. In this study, N/P ratios across all stages were below 25 during decomposition, which may contribute to faster decomposition in the shrub stage. Soil environment also significantly affects decomposition.

During the study period, decomposition was relatively fast from May to September, consistent with many studies [40–41]. The winter-spring transition (January–March) had minimal rainfall and lower temperatures, reducing microbial activity and leaching [22], resulting in slower decomposition. The shrub and shrub-tree stages decomposed fastest in July, while the tree stage peaked in August–September, likely due to increased rainfall and temperatures enhancing microbial activity and leaching [22].

Canopy density significantly affects decomposition rates [42]. As *L. chinense* communities restore, canopy density increases [17]. Xu et al. [43] found that decomposition rates in snow-damaged bamboo forests were significantly negatively correlated with canopy density. Higher canopy density creates less favorable microclimatic conditions for decomposition [44–45], with delayed responses to external climate changes [46], possibly explaining why the tree stage’s maximum decomposition rate occurred later. Litter decomposition in *L. chinense* communities at different restoration stages is influenced by multiple factors, and the complex interactions among these factors may involve unconsidered variables such as soil fauna and microorganisms, particularly given this study’s limited duration.

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